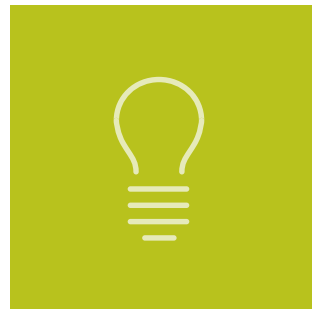


North Carolina

Clean Energy Plan

Transitioning to a 21st Century Electricity System



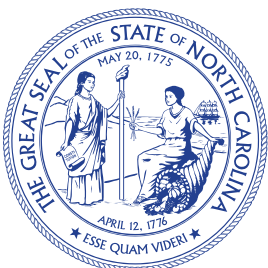
Supporting Document

PART 2

Energy Resources

DRAFT

August 2019



Preface

This is a draft of North Carolina’s Clean Energy Plan (CEP). The public comment period is open from August 16, 2019 through September 9, 2019. Comments may be submitted online at <https://deq.nc.gov/cleanenergyplan>.

The Clean Energy Plan was written by the Department of Environmental Quality as directed by [Executive Order No. 80](#).¹ DEQ was tasked with the creation of a CEP to encourage the use of clean energy resources and technologies and to foster the development of a modern and resilient electricity system. The purpose of the CEP is to outline policy and action recommendations that will accomplish these goals. The CEP is made up of the main document titled *Policy and Action Recommendations* and six supporting documents.



This section presents background information on each electricity generation resource that is currently operating in North Carolina. It was written to enhance the public’s understanding of the various resources currently being used in North Carolina. The historic use of the resource from the year 2000 to the present is presented first. Next, the projected use of that resource in the future out to year 2030 is discussed. It also focuses on the factors that drive the future dispatch of the electricity resource in the state and the potential reasons behind various trends. Future costs for resources are discussed at a high level as needed to understand current trends. Note that this is summary level information and the reader is directed to appropriate references for more detailed explanations.











¹ <https://files.nc.gov/ncdeq/climate-change/EO80--NC-s-Commitment-to-Address-Climate-Change---Transition-to-a-Clean-Energy-Economy.pdf>



PART 2

Energy Resources

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Acronyms

AC	alternating current	DEQ	North Carolina Department of Environmental Quality
ACP	Atlantic Coast Pipeline	DER	distributed energy resource
ADMS	Advanced Distribution Management System	DOA	NC Department of Administration
AEO	Annual Energy Outlook	DOD	US Department of Defense
AEV	all-electric vehicle	DOE	US Department of Energy
AFDC	Alternative Fuel Data Center	eq/kWh	equivalent per kWh
ATB	Annual Technology Baseline	EIA	Energy Information Administration
AWEA	American Wind Energy Association	EPA	Environmental Protection Agency
BEV	battery electric vehicle	EPC	NC Energy Policy Council
BNEF	Bloomberg New Energy Finance	EV	electric vehicle
BNP	Brunswick Nuclear Plant	EVWG	Electric Vehicle Working Group
BOEM	Bureau of Ocean Energy Management	FGD	flue gas desulfurization
Boiler MACT	Boiler Maximum Achievable Control Technology	FHWA	Federal Highway Administration
Boiler GACT	Boiler Generally Achievable Control Technology	FERC	Federal Energy Regulatory Commission
Btu	British thermal unit	GHG	greenhouse gases
BWR	boiling-water reactor	GP	Georgia Power
CAES	compressed air energy storage	GW	gigawatt
CAPEX	Capital Expenditure	GWh	gigawatt-hour
CCR	coal combustion residuals	H ₂ O	water
CCS	carbon capture and sequestration	HAP	hazardous air pollutants
CdTe	Cadmium Telluride	HRSG	heat recovery steam generator
CFR	Code of Federal Regulations	HVAC	heating, ventilation, and air conditioning
CH ₄	methane	IAEA	International Atomic Energy Agency
CHP	combined heat and power	ICE	internal combustion engine
CP&L	Carolina Power and Light	IGCC	integrated gasification combined cycle
CPRE	competitive procurement of renewable energy	IOU	investor owned utility
CO ₂	carbon dioxide	IPP	independent power producer
CO ₂ e	carbon dioxide equivalent	IRP	Integrated Resource Plan
COP	Construction and Operation Plan	ISO	independent system operator
CSA	Clean Smokestacks Act	ITC	investment tax credit
CT	combustion turbine	kWh	kilowatt-hour
DC	direct current	KW	kilowatt
DDU	Deep Direct Use	LBNL	Lawrence Berkeley National Laboratory
DEC	Duke Energy Carolinas	LCOE	levelized cost of energy
DEP	Duke Energy Progress	LDC	local distribution company



NC CLEAN ENERGY PLAN



LDV	light duty vehicle	PM _{2.5}	fine particulate matter
LFG	landfill gas	PNG	Piedmont Natural Gas
Li-ion	lithium ion	PPA	purchase power agreement
LLC	limited liability company	PTC	production tax credit
LMOP	Landfill Methane Outreach Project	PURPA	Public Utility Regulatory Policies Act
LWR	light water reactor	PV	photovoltaic
MIT	Massachusetts Institute of Technology	PWR	pressurized-water reactor
MMBtu	million British thermal units	R&D	Research and Development
MMT	million metric tons	REC	renewable energy credit
MVFC	medium voltage fast charger	REPS	Renewable Energy and Energy Efficiency Portfolio Standard
MW	megawatt	RFF	Request for Feedback
MWh	megawatt-hour	RFP	request for proposal
NCCETC	North Carolina Clean Energy Technology Center at NCSU	RFS	renewable fuel standard
NCDOT	North Carolina Department of Transportation	RINS	renewable identification number system
N.C.G.S.	North Carolina General Statute	RNG	renewable natural gas
NCSEA	North Carolina Sustainable Energy Association	RTI	Research Triangle Institute
NCSU	North Carolina State University	RTO	regional transmission organization
NCUC	North Carolina Utilities Commission	SAP	site assessment plan
NGCC	natural gas combined cycle	SLR	subsequent license renewal
NG CT	natural gas combustion turbine	SMR	small modular reactor
NGPP	natural gas power plant	SO ₂	sulfur dioxide
NC-RETS	NC Renewable Energy Tracking System	SUV	sport utility vehicle
NO _x	nitrogen oxides	T&D	transmission and distribution
NPP	nuclear power plant	TCLP	Toxic Characteristic Leaching Procedure
NPV	net present value	TBtu	trillion British thermal units
NRC	Nuclear Regulatory Commission	TDS	total dissolved solids
NREL	National Renewable Energy Laboratory	TSS	total suspended solids
NRRRF	Neuse River Resource Recovery Facility	TVA	Tennessee Valley Authority
O&M	Operations and Maintenance	UNC	University of North Carolina
OCS	outer continental shelf	USCPC	ultra-supercritical pulverized coal
OSW	offshore wind	USGS	US Geological Survey
PACE	Property Assessed Clean Energy	V	volt
PEV	Plug-in Electric Vehicle	VANC	Virginia and North Carolina
PHEV	Plug-in hybrid electric vehicle	VW	Volkswagen
PJM	Pennsylvania-Jersey-Maryland regional transmission organization	WEA	Wind Energy Area
		WEF	Wind Energy Facility
		WNA	World Nuclear Association
		WTE	waste to energy
		ZEV	zero emissions vehicle



NC CLEAN ENERGY PLAN





1. Coal

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1.1 Coal Introduction

This section presents background information on each electricity generation resource that is currently operating in North Carolina. It was written to enhance the public’s understanding of the various resources currently being used in North Carolina. The historic use of the resource from the year 2000 to the present is addressed first. Next, the projected use of that resource in the future out to year 2030 is discussed. It also focuses on the factors that drive the future dispatch of the electricity resource in the State and the potential reasons behind various trends. Future costs for resources are discussed at a high level as needed to understand current trends. Note that this is summary level information and the reader is directed to appropriate references for more detailed explanations.

One of the factors discussed in this section is the environmental aspects of the resource. Through the stakeholder process, members of the public have expressed concerns over various complex environmental issues and how these issues and impacts will be addressed for a given resource, especially GHGs. This section of the CEP discusses how various environmental rules and issues have influenced the use of a given resource and its potential use in the future. It does not attempt to quantify the impacts of a given resource on public health or the environment. Nor does it attempt to quantify any lifecycle environmental impacts of a resource.

1.1.1 Historical Capacity and Generation in NC

Coal steam power plants have been operating in the United States since the 1882 opening of the first commercial power plant and cogeneration facility in the country, the Edison Illuminating Company’s Pearl Street Station in New York. By the mid-1900’s, coal had become the leading fuel for generating electricity in the US. Coal remained the primary source of power in the US for the next 100 years. In the year 2000, coal steam plants generated about 50 percent of the electric power consumed in the US.

More recently, a number of factors have put significant downward pressure on coal power plants. These factors include;

- The availability of natural gas to provide a more efficient, lower-cost baseload generation resource;
- Declining costs in the renewable energy (RE) industry, particularly in wind and solar;
- The aging of the coal fleet, which has negative impacts on operating performance and costs; and
- Growing concern about environmental risks and future regulations or rules that reduce emissions limits from power plants.

Coal use for power generation began to decline in 2008 and now represents around 30 percent of power generation in the U.S. In 2017, about 1,139 million MWh were generated at coal power plants in the U.S. This is down from 1,998 million MWh during the 2007 peak of coal generation, a drop of 43%.¹

¹ US EIA. (2019). Monthly Energy Review March 2019, Table 7.2b Electricity Net Generation: Electric Power Sector. Retrieved from https://www.eia.gov/totalenergy/data/monthly/pdf/sec7_6.pdf



Capacity

North Carolina had 14 investor-owned utility (IOU) and 4 independent power producer (IPP) coal steam power plants that provided power to the electricity grid in the early 2000’s.² Table 1.1-1 lists the power plants that are currently operating and their owners. The last coal steam boiler to be constructed in North Carolina was Duke Energy Carolina’s (DEC) Cliffside Unit 6, an 850- MW supercritical steam unit that began operation in 2012. In the order approving this new coal generating unit in 2007, the North Carolina Utilities Commission (NCUC) required that DEC retire four older coal units at Cliffside totaling 198 MW, and denied the construction of a second proposed 800 MW unit at the facility³. Figure 1.1-1 Figure 1.1-1: Map of Coal Plants Operating in 2018 shows the location of coal steam plants in North Carolina.

Table 1.1-1: Coal Plants and Ownership

Facility Name	Capacity (MW)	Owner
Belews Creek		Duke Energy Carolinas
Cliffside		Duke Energy Carolinas
GG Allen		Duke Energy Carolinas
Marshall		Duke Energy Carolinas
Asheville		Duke Energy Progress
Roxboro (Units 1-3)		Duke Energy Progress
Roxboro (Unit 4)		Duke Energy Progress, & NC Eastern Municipal Power Agency
Mayo		Duke Energy Progress, & NC Eastern Municipal Power Agency
Edgecombe Genco		Edgecombe Genco, LLC
Roanoke Valley*		Westmoreland Partners LLC

* Plant not operating in 2018

² North Carolina also operated four coal-fired combined heat and power (CHP) plants that provided electricity to the grid in the early 2000’s. Two of these plants converted to fire primarily wood in 2011.

³ NC Utilities Commission (2007). “Order Granting Certificate of Public Convenience and Necessity with Conditions”. Docket E-7 sub 790, 2007.

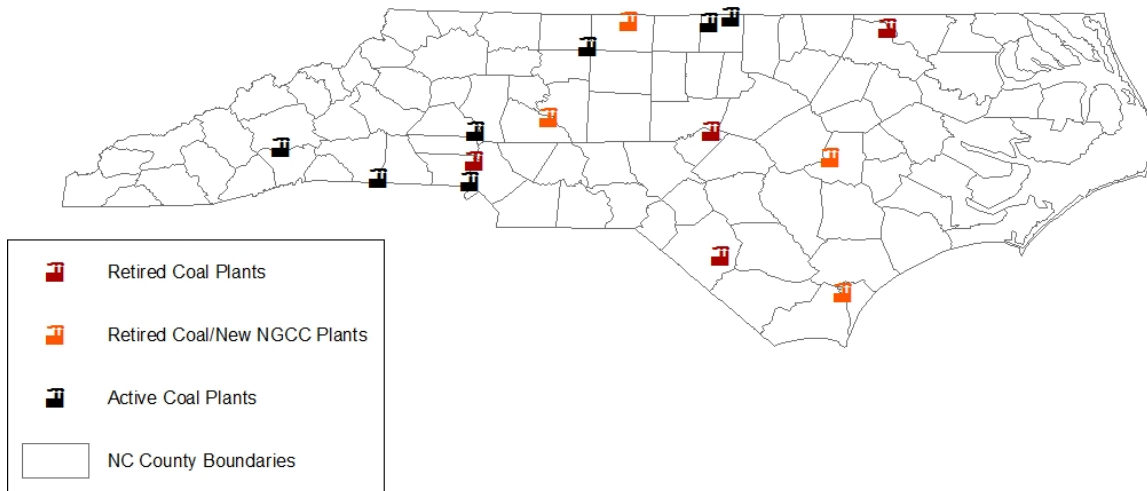


Figure 1.1-1: Map of Coal Plants Operating in 2018

Figure 1.1-2 presents the change in North Carolina’s coal capacity over time.⁴ In 2000, there was 13,296 MW of coal steam power capacity operated by IOU and IPP companies in North Carolina. As noted above, a new 850 MW coal unit was added in 2012 at Cliffside. At that same time, Duke Energy began to retire older, less efficient coal plants. As shown in the figure, Duke Energy retired 2,978 MW of coal capacity by the end of 2018, leaving only 7 plants operating. These coal plants were replaced with natural gas combined cycle (NGCC) plants. In addition, all four IPP coal plants had stopped operating or switched to a different fuel by 2018. In 2018, North Carolina had 10,318 MW of coal capacity operating, a 22 percent drop in coal capacity since 2000.

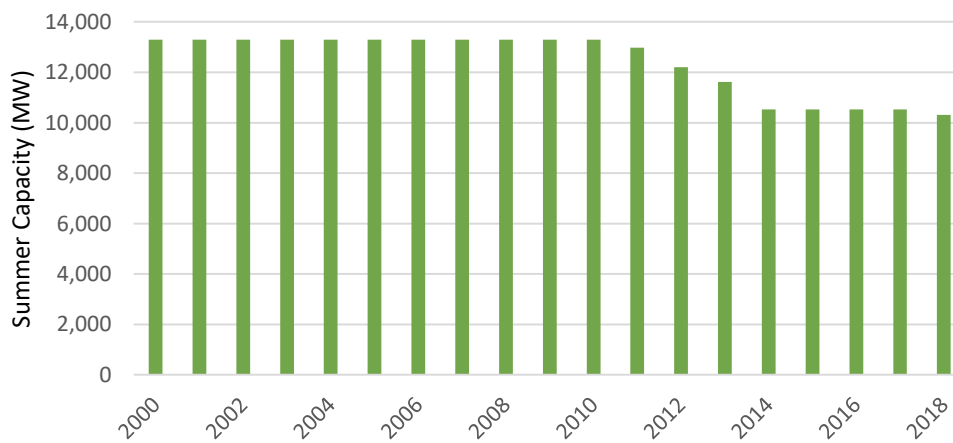


Figure 1.1-2 Historic Coal Steam Power Summer Capacity (MW)

⁴ US EIA. (2018a). Detailed State Data, 1990-2017 Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860). Release Date October 12, 2018. Retrieved from <https://www.eia.gov/electricity/data/state/>



Generation

Figure 1.1-3 presents the electricity generated by IOU and IPP coal steam plants in North Carolina.⁵ Coal generation has decreased significantly, dropping from 76.6 million MWh at its peak in 2007 to 31.4 million MWh in 2018. Coal provided 62% of the generation in the state in early 2000's. Now, coal has dropped to 24% of the generation in the state. This is due to two factors, retirement of coal steam boilers, as discussed above, and decreased operation of the remaining coal power plants.

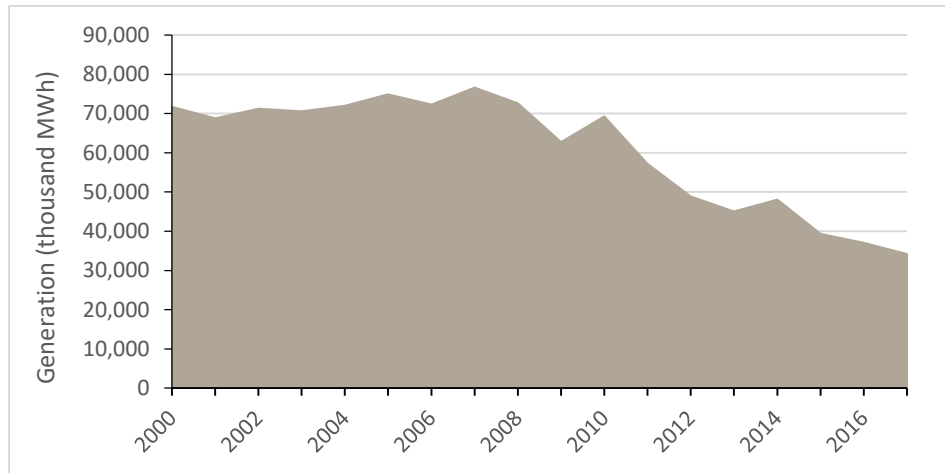


Figure 1.1-3: Historic Coal Steam Power Generation by Year (thousand MWh)

Table 1.1-2 summarizes the current operation of Duke Energy’s coal plants.⁶ A little over half of Duke Energy’s existing capacity is operating as traditional base load units. Of the currently operating coal plants, Duke is operating 3,209 MW of its fleet as “intermediate” units”, at or below 30% annual capacity factors. Approximately 1,679 MW is being operated as peaking units, where the units operate at less than 30% capacity factor and less than 30% of the available hours.⁷

Table 1.1-2: Current Operation of Duke Energy Coal Fleet

Coal Plant Operations	Capacity (MW)	Capacity Factor	Operating Hours Factor
Base	5,430	> 30%	> 50%
Intermediate	3,209	≤ 30%	≤ 50%
Peaking	1,679	≤ 30%	≤ 30%

⁵ US EIA. (2018b). Detailed State Data, 1990-2017 Net Generation by State by Type of Producer by Energy Source. Release Date: October 12, 2018. <https://www.eia.gov/electricity/data/state/>

⁶ US EPA. Air Markets Program Data. Retrieved April 26, 2019 from <https://ampd.epa.gov/ampd/>

⁷ Base load power sources are plants that operate continuously to meet the minimum level of power demand over a period of a day. The power demand above the base load is handled by intermediate and peak power plants, where peak load plants operate only during the highest demand hours of a day.



1.1.2 Planned and Anticipated Capacity and Generation Outlook in NC

Coal is expected to continue to decline as a fuel source for electricity in North Carolina due to both retirement of coal plants and decreased use of coal as a fuel source. Increasing environmental concerns and the availability of less expensive natural gas plants has put significant downward pressure on coal power plants. Starting with Duke Energy’s 2013 IRPs, new electricity generation is planned to be provided by natural gas single and combined cycle plants, rather than coal.

Duke Energy has announced retirements for five coal boiler units at their Asheville and GG Allen plants by 2025. These retirements reduce the coal capacity by 961 MW. Additional retirements are expected as coal plants reach their depreciation life. Figure 1.1-4 gives the remaining coal capacity assuming units retire based on the tax depreciation life as presented in the DEP IRP and DEC IRP for 2018.^{8,9}

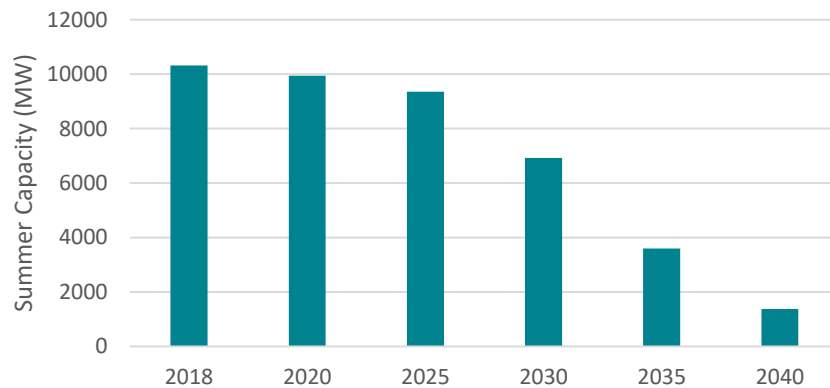


Figure 1.1-4: Projected Coal Steam Power Retirements (MW)

Duke Energy’s 2018 IRPs do not forecast the construction of new coal steam plants in North Carolina. In the IRP, Duke conducted its resource analysis for coal using two different plant types, Ultra-Supercritical Pulverized Coal (USCPC) and Integrated Gasification Combined Cycle (IGCC).¹⁰ Both units were assumed to require carbon capture and sequestration (CCS) making them high cost resources when compared to natural gas combined cycle.

Electricity generation by coal is expected to continue to decrease. The forecast prepared in 2017 for North Carolina’s Greenhouse Gas Inventory shows coal declining to approximately 50% of its 2017 value by 2030.¹¹ However, this does not include several recent developments including;

⁸ Duke Energy Carolinas, LLC. (2018). 2018 Integrated Resource Plan and 2018 REPS Compliance Plan. Retrieved from Docket No. E-100, Sub 157.

⁹ Duke Energy Progress, LLC. (2018). 2018 Integrated Resource Plan and 2018 REPS Compliance Plan. Retrieved from Docket No. E-100, Sub 157.

¹⁰ For more information on types of coal plants see “Critical thinking: Ultra and supercritical technology focus”, Power Engineering International, Paul Breeze, March 23, 2017, Retrieved from <https://www.powerengineeringint.com/articles/print/volume-25/issue-3/features/critical-thinking.html>

¹¹ North Carolina Division of Air Quality. (2019). North Carolina Greenhouse Gas Emissions Inventory. January 2019. Retrieved from <https://deq.nc.gov/energy-climate/climate-change/greenhouse-gas-inventory>



1. Startup of 500 MW Kings Mountain NGCC owned by NTE Energy in 2018
2. Proposed 500 MW Reidsville NGCC owned by NTE Energy for 2022
3. Conversion of coal units at Cliffside, Marshall and Belews Creek to fire both coal and natural gas

Duke Energy is modifying the coal units at Cliffside, Belews Creek and Marshall to allow firing of both coal and natural gas in the boilers.¹² Table 1.1- shows the percent of each fuel and the permit modification status and expected operational date.¹³ Firing natural gas will result in an estimated 5% penalty to the heat rate of the plant (efficiency in converting fuel to electricity) due to lower gas temperatures and higher moisture content of natural gas.¹⁴

Table 1.1-3: Duke Energy Modifications to Fire Coal and Natural Gas in Coal Steam Boilers

Plant	Unit	Permit Limits for Co-Firing	Status	Cost
Cliffside	5	Permitted to fire up to 40% natural gas	Permitted 9/21/2017, Operational late 2019	\$65 million
Cliffside	6	Permitted to fire 100% coal through 100% natural gas		
Belews Creek	1 and 2	No permitted limits on percent of each fuel. (Potential to emit based on 57-43)	Permitted 4/8/2019, Operational in 2020	\$83 million
Marshall	1 and 2	Permit to fire dual fuel is not final at this time (Proposed 90-10)	Permit application submitted. Operational in 2020	\$85 million
Marshall	3 and 4	Permit to fire dual fuel is not final at this time (Proposed 50-50)	Permit application submitted. Operational in 2021	

¹² North Carolina Division of Air Quality. (2017). Permit Review for Cliffside, issued September 21, 2017 and Permit Review for Belews Creek Air, issued April 8, 2019.

¹³ Downey, John. (2018). “Duke Energy wrapping up \$65M gas co-firing project for its Cliffside coal units”. Charlotte Business Journal. November 19, 2018. Retrieved from <https://www.bizjournals.com/charlotte/news/2018/11/19/duke-energy-wrapping-up-65m-gas-co-firing-project.html>

¹⁴ US DOE. (2018). The Electricity Market Module of the National Energy Modeling System: Model Documentation 2018, US Energy Administration, DOE/EIA-M068 (2018). Retrieved from <https://www.eia.gov/outlooks/aeo/assumptions/pdf/electricity.pdf>.



Figure 1.1-5 presents the projected decrease of coal use as estimated by the North Carolina Division of Air Quality due to the modifications at the Cliffside, Marshall and Belews Creek plants to fire both coal and natural gas. The data is presented as heat input and shows that dual fuel firing of coal and natural gas is expected to reduce total coal use in all boilers by approximately 30% from its 2018 value. A similar decrease would happen for generation as well.¹⁵ Co-firing coupled with the new NGCC plants owned by NTE Energy coming on line are expected to decrease coal use in North Carolina well below half its 2018 value.

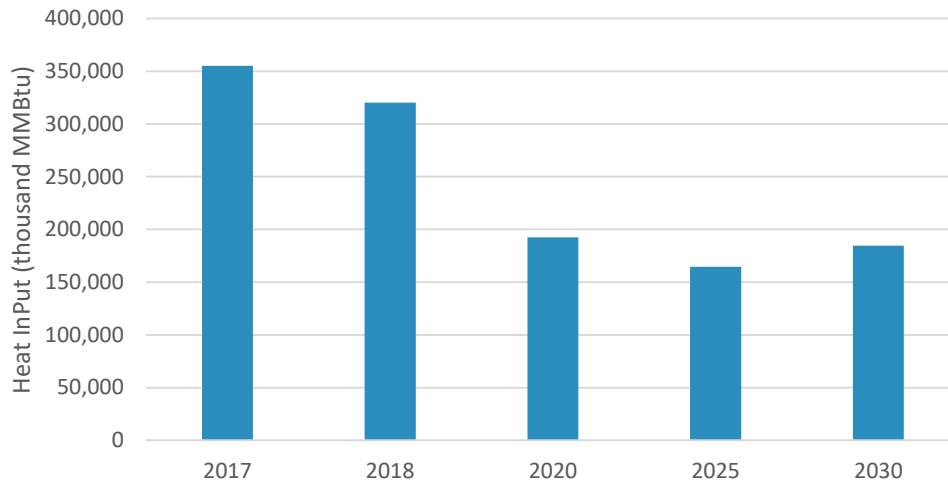


Figure 1.1-5: Projected Decrease in Total Coal Heat Input Assuming Dual Fuel Use in 8 Steam Boilers

1.2. Coal Technology Overview and Application

1.2.1 Technology Description

In a coal steam plant, coal is pulverized onsite into a powder and blown into a furnace where it is combusted. The hot gases flow to a boiler where water circulating through tubes is converted into high pressure steam. The steam pushes a turbine, which in turn drives the shaft of the generator, producing electricity. The steam is then cooled and condensed back into water, which is returned to the boiler to be heated again.

Pulverized coal power plants are broken down into three categories; subcritical pulverized coal plants, [supercritical](#) pulverized coal plants, and USPC plants. The primary difference between the three types of pulverized coal boilers are the operating temperatures and pressures. As the pressures and temperatures increase, so does the operating efficiency. Currently operating coal power plants in the U.S. operated at an average efficiency of 34% in 2017, or at a heat rate of 10,043 Btu/kWh.¹⁶ The maximum operating

¹⁵ Converting between heat input and generation requires the use of the heat rate, which is unknown for the modified plants.

¹⁶ US EIA. (2018). Table 8.2. Average Tested Heat Rates by Prime Mover and Energy Source, 2007 – 2017. Retrieved from https://www.eia.gov/electricity/annual/html/epa_08_02.html



efficiency of subcritical plants are at about 37% efficiency, super critical plants at about 40% and ultra-super critical plants are in the 42-45% range.

1.2.2 Technology Benefits and Limitations

Historically, coal has proved a reliable and cost-effective energy source for electricity generation. Coal has a high heating value compared to natural gas, petroleum and wood. It is the most abundant fossil fuel in the US making its historical price relatively low and stable. It is easily transported and stored onsite. Coal boilers have long operating lives, approximately 40 years.

Traditional coal plants have efficiencies of approximately 37 percent while newer plants have efficiencies of 40 percent and higher. Coal plants can run at 70 to 80 percent capacity factors, meaning they are highly reliable. While newer coal plants are more efficient, NGCC plants operate at higher efficiencies, from 45 percent up to 60 percent.¹⁷

In addition, coal plants take considerable time to ramp up to full capacity, on the order of 24 hours generally. New techniques have accelerated the ramp time to approximately 8 hours, but this puts large thermal and pressure stresses on plant components.¹⁸

1.2.3 Environmental Issues

Combustion of coal for electric power results in significant environmental impacts. These impacts include the following:

- Fly and bottom ash and boiler slag, also called coal combustion residuals
- Air emissions including GHGs, criteria, metals, other hazardous air pollutants
- Wastewater from air pollution control equipment

Each of these issues is briefly discussed. A complete discussion of environmental issues is beyond the scope of this document.

Coal combustion residuals (CCRs) are the byproducts produced from the combustion of coal or the control of combustion air emissions, including fly ash, bottom ash, and other materials that could contain mercury, arsenic, and other toxins. Coal ash is one of the largest types of industrial waste generated in the United States. In 2012, 470 coal-fired electric utilities generated about 110 million tons of coal ash.¹⁹ North Carolina's seven remaining coal power plants generated 3.5 million tons of coal ash in 2017.²⁰ Coal ash is disposed of or used in different ways including storage onsite in surface impoundments, disposal in landfills, and being recycled into products like concrete or wallboard. The effluent from the coal ash impoundments can be discharged under a plant's wastewater discharge permit. See the DEQ

¹⁷ GE. (2019). "Breaking the Power Plant Efficiency Record". Press Release. Retrieved on April 16, 019 from <https://www.ge.com/power/about/insights/articles/2016/04/power-plant-efficiency-record>

¹⁸ National Renewable Energy Laboratory (2012). Power Plant Cycling Costs. April 2012. Retrieved from <https://www.nrel.gov/docs/fy12osti/55433.pdf>

¹⁹ US EPA. Coal Ash (coal Combustion Residuals, or Ccr). <https://www.epa.gov/coalash>

²⁰ US EIA (2017). Form-923, Power Plant Operations Report, Annual Environmental Information, Schedule 8. Part D. Cooling System Information, Monthly Operations, 2017 Final.



website “Introduction to Coal Ash in NC” for more detailed information on environmental impact of coal ash.²¹

In 2013, DEQ filed four lawsuits alleging violations of state law regarding unlawful discharges and groundwater contamination from CCR surface impoundments at all 14 Duke Energy facilities.²² In 2014, an estimated 39,000 tons of coal ash spilled into the Dan River in Eden after a storm water pipe beneath an ash pond at Duke Energy’s Dan River Steam Station ruptured on Feb. 2. The spill caused widespread environmental and economic damage to nearby waterways and properties. These discharges have resulted in numerous enforcement actions by DEQ.²³

Combustion of coal at power plants emits considerably more air pollution than natural gas combustion. Emissions of nitrogen oxides (NO_x) from combustion of coal, the precursor pollutant to ozone, are also much higher than natural gas, around 20 percent. Lastly, coal emits significant amounts of fine particulate matter (PM_{2.5}), sulfur dioxide (SO₂), mercury and other metals. Federal rules limit emissions of the pollutants discussed above, and coal plants have installed air pollution control equipment to comply with the limits. Emissions of carbon dioxide (CO₂) from coal combustion are approximately 40% higher than combustion of natural gas per unit of energy produced. Currently, coal plants are not required to limit emissions of CO₂, however, federal rules have been proposed (See Section 0).

Starting in 2002 with the passing of North Carolina’s Clean Smokestacks Act, coal plants in North Carolina were required to reduce actual emissions of NO_x and SO₂ system wide.²⁴ This contrasts with EPA rules which put a “cap and trade” program in place.²⁵ Most of North Carolina’s coal plants opted to install modern air pollution emissions controls to comply with the state legislation. Since the plants could average emissions across their fleets, the reduction efficiency and costs of controls installed varied from plant to plant. At the time these controls were installed, coal was still the dominant fuel source for power generation.

Coal plants use large amounts of water to cool the steam. According to EIA plant level data, coal plants in North Carolina withdrew approximately 1,173,000 million gallons of water in 2017 for cooling operations.²⁶ This translates into 3,200 million gallons of fresh water per day used to generate electricity in North Carolina. The average intake temperature was 66 degrees Fahrenheit while the average discharge temperature was 76 degrees, 10 degrees higher.

Coal plants generate wastewater in the form of chemical pollutants and thermal pollution. The most significant processes that generate the wastewater are ash handling and flue gas desulfurization (FGD)

²¹ NC DEQ. Introduction to Coal Ash in NC. <https://deq.nc.gov/news/hot-topics/coal-ash-nc/introduction-coal-ash-nc>

²² Ibid.

²³ <https://deq.nc.gov/news/key-issues/coal-ash-nc/coal-ash-archive/coal-ash-enforcement>

²⁴ North Carolina Session Law 2009-390 “Clean Smokestacks Act”, July 2009. Retrieved from <https://deq.nc.gov/about/divisions/air-quality/air-quality-outreach/news/clean-air-legislation/clean-smokestacks-act>

²⁵ Federal Register, Vol. 81, No. 207, Wednesday, October 26, 2016, pp 74504-74650. “Cross-State Air Pollution Rule Update for the 2008 Ozone NAAQS (CSAPR)” Retrieved from <https://www.epa.gov/airmarkets/final-cross-state-air-pollution-rule-update>

²⁶ US EIA (2017). Form-923, Power Plant Operations Report, Annual Environmental Information, Schedule 8. Part D. Cooling System Information, Monthly Operations, 2017 Final.



systems. FGD wastewater generally contains significant levels of metals, total dissolved solids (TDS), total suspended solids (TSS) and nutrients. Other processes generating wastewater include boiler water treatment, coal piles, yard and floor drainage, and other miscellaneous wastes.

There have been several recent changes to wastewater rules for coal plants. In 2014, the NC Division of Water Resources directed Duke Energy to apply for National Pollutant Discharge Elimination System wastewater permit modifications or renewals to address issues at the company's 14 coal-fired electric plants. In 2015, EPA promulgated a final rule that set the first federal limits on the levels of toxic metals in wastewater that can be discharged from power plants.²⁷ On August 11, 2017, the current EPA Administrator signed a letter announcing a decision to conduct a rulemaking to potentially revise the 2015 standards. EPA also finalized a rule postponing the earliest compliance dates for 2015 rule.^{28,29} Discussion of this issue is beyond the scope of this document.

1.2.4 Project Installation and Decommissioning

Each coal steam power plant is a complex, custom-designed system with high capital costs and long lead times. In addition to design complexity, there are numerous technical, environmental, economic, and regulatory issues associated with constructing a coal plant. It requires large amounts of water and fuel; therefore, it must be sited near a freshwater source and rail lines.

The most recent coal boiler unit to be built in North Carolina is the 850 MW Unit 6 at Duke Cliffside Plant, which began operation in 2012. The unit uses an advanced supercritical design and advanced air pollution control systems and took 5 years to build. The effort required more than 2,000 skilled workers onsite, and more than 15 million man-hours.³⁰

Closing a coal plant is a significant and complex process with high costs.³¹ Plants can be retired in place or undergo demolition. Retiring in place is initially cheaper but has ongoing costs while demolition has a higher one-time cost. Costs for decommissioning may include utility separation, asbestos and hazardous material abatement, structural demolition, salvage and scrap recovery, remediation, and restoration of the site to a safe, environmentally sound condition. Other costs include the engineering design project management and public engagement associated with the process. In states that are still regulated, decommissioning costs could be passed through to ratepayers, subject to public service commission approval.

²⁷ Federal Register / Vol. 80, No. 212 / Tuesday, November 3, 2015. pp 67837-67903. Retrieved from <https://www.govinfo.gov/content/pkg/FR-2015-11-03/pdf/2015-25663.pdf>

²⁸ US EPA. Steam Electric Power Generating Effluent Guidelines - 2015 Final Rule. <https://www.epa.gov/eg/steam-electric-power-generating-effluent-guidelines-2015-final-rule#background>

²⁹ NC DEQ. Duke Energy NPDES Wastewater Permitting. <https://deq.nc.gov/about/divisions/water-resources/water-resources-hot-topics/dwr-coal-ash-regulation/duke-energy-npdes-permits-for-facilities-with-coal-ash-ponds/duke-energy-npdes-modifications-renewals>

³⁰ Overton, Thomas. (2013). "Top Plant: Cliffside Steam Station Unit 6, Cliffside, North Carolina", Power Magazine. October 1, 2013. Retrieved from <https://www.powermag.com/cliffside-steam-station-unit-6-cliffside-north-carolina/>

³¹ Malley, Ed. (2016). "Coal Power Plant Post-Retirement Options". Power Magazine. September 1, 2016. Retrieved from <https://www.powermag.com/coal-power-plant-post-retirement-options/?pagenum=1>.



The most significant issue associated with coal plant decommissioning is the removal of CCR from surface impoundments located at the plant. Duke Energy is already scheduled to close eight of the 14 disposal sites in North Carolina. On April 1, 2019 the DEQ ordered Duke Energy to excavate and close coal ash storage ponds at the six coal power plants in the state for which final closure of the CCR impoundments had not been determined. Full excavation is now required of the 11 ash impoundments contained on these six sites. Duke Energy has until December 31, 2019 to decide on a plan to comply with the DEQ decision. A discussion of this issue is beyond the scope of this document. See the DEQ website for more information.³²

1.2.5 Emerging Technology Trends

There are two notable technology improvements to coal-fired power plants that are discussed below. However, the technologies have been available for well over 10 years and still have very limited application.

An integrated gasification combined cycle (IGCC) is a technology that uses a high-pressure gasifier to turn coal into pressurized gas.³³ This process removes pollutants from the coal. The gas is combusted and flows to a gas turbine to produce electricity. In the second cycle, the steam produced by cooling the synthesis gas during gasification is sent to a steam turbine which also generates electricity. IGCC plants are advantageous in comparison to conventional coal power plants due to their high thermal efficiency, low non-carbon GHG emissions, and the capability to use low grade coal. The disadvantages include higher capital and maintenance costs, and the amount of CO₂ released without pre-combustion capture.

Carbon capture and sequestration (CCS) is a technology to reduce the CO₂ emitted from the combustion of coal.³⁴ The CCS process first requires separating the CO₂ from the other gases emitted during combustion. The CO₂ must then be compressed and transported to a storage site. At the storage site, it is injected into geological rock formation that are typically located one to two miles below the earth's surface. These formations have layers of impermeable, non-porous rock that trap the CO₂ and prevent it from migrating upward. Its greatest limitation is that the power plant has to be near an appropriate geologic formation to be cost-effective.

1.3. Future Resource Deployment in NC

1.3.1 Policies and Programs Driving Deployment

The primary policies driving future coal deployment are environmental policies. In July 2019, EPA repealed the carbon rule for existing coal power plants and replaced it with a rule that does not establish specific emissions limits, but rather establishes a “best system of emissions reductions” (BSER) for coal

³² NC DEQ. “Moving Forward with Coal Ash”. <https://deq.nc.gov/news/key-issues/coal-ash-nc/coal-ash-archive/moving-forward-coal-ash>

³³ National Energy Technology Laboratory. “Gasifipedia: 8.3. IGCC Process System Sections”. Retrieved from <https://www.netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/project-examples>

³⁴ Carbon Capture and Storage Association. “What is CCS?”. Retrieved from <http://www.ccsassociation.org/what-is-ccs/>



power plants, and leaves establishing emissions guidelines in the hands of state regulatory agencies.³⁵ Due to this novel approach, it is difficult to understand the impact the rule might have in a given state at this time. EPA is also in the process of proposing modifications to the carbon rule for new coal power plants.³⁶ Lastly, EPA is proposing to determine that it is not “appropriate and necessary” to regulate hazardous air pollutants (HAP) emissions from power plants under Section 112 of the Clean Air Act due to the cost of compliance compared to the health benefits.³⁷ Lastly, the wastewater rule is currently under review by the EPA as discussed above. Should the rules for new and existing coal power plants be modified to increase the allowable emission limits or discharge limits, this evaluation of the planned/anticipated growth of coal power plants may change.

1.3.2 Constraints to Deployment

There are no existing technical or regulatory constraints to coal electricity generation being deployed in North Carolina.

1.4. Grid Integration and Reliability

1.4.1 Grid Integration and Modernization

Since coal power is a traditional resource for electricity generation that can provide power with high reliability and operate at high capacity factors, grid integration of coal is not an issue. More recently, coal is being used to provide peaking and intermediate power to the grid, making it a more flexible electricity resource to support short-term changes in electricity demand.

Grid modernization has the potential to decrease the use of coal power plants to supply electricity since modernization may allow for increased use of lower cost intermittent renewable power such as wind and solar. However, coal plants that can technically transition to providing intermediate and peaking power may still be cost-effective resources post-modernization.

1.4.2 Resiliency

Coal power plants are complex facilities that have considerable safety and emergency procedures and equipment to ensure they can operate during emergencies and severe weather events. Coal is generally stockpiled on site for approximately 2 months to ensure operation during fuel supply disruptions.

On September 29, 2017, US Department of Energy (DOE) proposed the Grid Resiliency Pricing Rule.³⁸ This rule directs the Federal Energy Regulatory Commission (FERC) to mandate that competitive power markets develop and implement market rules to “accurately price” what it refers to as “fuel-secure”

³⁵ Federal Register. Volume 84 No. 130. pp 3250- 32323. July 8, 2019. Retrieved from <https://www.govinfo.gov/content/pkg/FR-2019-07-08/pdf/2019-14396.pdf>

³⁶ USEPA. Proposal: NSPS for GHG Emissions from New, Modified, and Reconstructed EGUs. <https://www.epa.gov/stationary-sources-air-pollution/proposal-nsps-ghg-emissions-new-modified-and-reconstructed-egus>

³⁷ USEPA. Regulatory Actions - Final Mercury and Air Toxics Standards (MATS) for Power Plants. <https://www.epa.gov/mats/regulatory-actions-final-mercury-and-air-toxics-standards-mats-power-plants>

³⁸ Federal Register Vol. 82, No. 194. Tuesday, October 10, 2017. pp 46940- 46948. Retrieved from <https://www.govinfo.gov/content/pkg/FR-2017-10-10/pdf/2017-21396.pdf>.



generation that has “reliability and resiliency attributes.” However, FERC rejected the DOE’s proposed rule by initiating a new proceeding that will examine the resilience of the bulk power system.³⁹

Coal plants in North Carolina, which have CCR surface impoundments, have shown some vulnerability to hurricanes in recent years. During Hurricane Florence in 2018, a cooling pond adjacent to coal ash surface impoundments flooded at the closed Sutton Coal Plant in Wilmington. There was no damage to the coal ash landfill.

1.5. Resource Costs and Benefits

The historic cost for building and operating traditional coal plants generally falls between costs for nuclear plants and NGCC plants. For several years now, the EIA’s Annual Energy Outlook (AEO) has not forecast the construction of new coal plants due to both the higher capital and operating costs compared to NGCC and the cost of complying with anticipated CO₂ environmental regulations for these plants.⁴⁰

Part of a new coal plant’s difficulty in competing with an advanced natural gas plant is the large difference in operating efficiencies, reported as heat rate. AEO 2019 indicates new NGCC plants produce electricity at a rate of 6,000 Btu/kWh while coal plants produce electricity much less efficiently, at a rate of 9,000 Btu/kWh.

In addition, there has been significant retirement of existing coal plants due to higher operating costs compared to gas plants as discussed above. Utilities, including Duke Energy, continue to make investments in existing coal plants to make them more cost effective through modifications to allow operational flexibility and co-firing of natural gas.

Current efforts by the federal government have attempted to decrease the capital and operating costs for existing and new coal plants. These efforts include proposed rollbacks of existing environmental rules and creating monetary incentives for coal power plants as discussed in the previous sections. It is unclear if the sum of these proposed efforts would shift the current economics from favoring both new and existing NGCC plants to coal plants in the future.

1.5.1 Initial Investment Costs

Initial investment costs for new conventional coal power plants have historically fallen between nuclear and NGCC. This trend continues in the 2019 AEO report, which only presents costs for coal plants with CCS. Total overnight cost in 2018 dollars for a coal plant with CCS is on the order of \$5,000 per kW which is on the upper end of the range of costs for coal, nuclear and NGCC (\$6,000 to \$8,000 per kW).⁴¹

³⁹ Docket No. AD18-7-000, FERC 162 FERC 61,012 issued January 8, 2018. Retrieved from <https://www.ferc.gov/CalendarFiles/20180108161614-RM18-1-000.pdf>

⁴⁰ US EIA. (2019). “Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019”. February 1, 2019. Retrieved from https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

⁴¹ US EIA. (2019). “Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2019” January 2019. https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf



Retrofit of existing coal plants to allow for flexible operation of the plants, such as fast ramp-up times, is reported by NREL to be approximately \$10-15 million.⁴² Retrofit costs for co-firing of natural gas at plants in North Carolina have ranged between \$65 million and \$85 million. These costs have been cost-effective retrofits for the plants by allowing them to operate more frequently and/or with lower fuel costs.

1.5.2 Operating and Recurring Costs

Both fixed and variable and operating costs for coal plants with CCS are much higher than NGCC plants. Recent natural gas prices are much lower and more stable than they have been in the past, putting pressure on coal's operating costs, which include significant costs associated with environmental rules, as opposed to NGCC, which is a cleaner burning fuel. Additionally, there are some implications that coal financing may be less attractive given the uncertainty surrounding carbon regulations.

⁴² S. Venkataraman, et al. (2013). "Cost-Benefit Analysis of Flexibility Retrofits for Coal and Gas-Fueled Power Plants". National Renewable Energy Laboratory. NREL/SR-6A20-60862. December 2013. Retrieved from <https://www.nrel.gov/docs/fy14osti/60862.pdf>



2. Natural Gas

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2.1 Natural Gas Introduction

Natural gas is used by the electricity generation sector as a fuel for three primary types of generator systems: 1) natural gas combined cycle systems (NGCC), 2) simple cycle gas combustion turbines (NGCT) and 3) as a replacement fuel for coal in steam boilers. These technologies are discussed further in this section.

Natural gas has been used as a fuel source for electricity generation since the mid-1900s. In 1940, the first 100 MW gas turbine began operating in British Columbia and the first NGCC plant began operating in 1961. Since that time, significant improvements in both generation technologies and fuel availability have grown this sector dramatically. Today's advanced combined cycle natural gas power plants operate with greater flexibility, higher efficiencies, and lower emissions than any other type of fossil fuel plant. In the United States, the development of improved methods to extract natural gas in shale formations through hydraulic fracturing or “fracking” has both lowered the cost of natural gas and made the long-term pricing more stable.¹ As a result, new NGCC power plants are replacing retiring coal-fired units as baseload power plants across the US.

In the year 2000, US natural gas power plants generated only 518 million MWh of electricity.² Today natural gas electricity generation has more than doubled to 1,366 million MWh.³ Natural gas electricity generation will continue to increase in the foreseeable future. In 2018, 18,550 MW of natural gas power plants came online, which is three-fourths of the total capacity added that year.⁴

2.1.1 Historical Capacity and Generation in NC

In the early 2000's, North Carolina had 15 gas plants operated by IOUs with nine of these gas turbine power plants co-located with coal power plants.⁵ There were four gas plants operated by municipalities and cooperatives. Today, NC utilities operate approximately 11,000 MW of natural gas power plants with about an equal split between combined cycle and simple cycle CTs. Combined cycle plants serve as baseload plants, operating more than 5,000 hours annually, while combustion turbines operate as peaking plants, typically operating less than 1,000 hours per year. Table 2-1 presents the ownership and summer capacity for the current fleet of utility scale power plants by plant type.⁶ Figure 2-1 shows the location these plants in North Carolina.

¹ “Shale Gas 101” U.S. DOE, accessed at <https://www.energy.gov/fe/shale-gas-101>.

² Table 7.2B Electricity Net Generation: Electric Power Sector, Monthly Energy Review, US EIA, accessed on May 6, 2019 at <https://www.eia.gov/totalenergy/data/browser/?tbl=T07.02B#/?f=M>

³ Ibid.

⁴ “Natural gas-fired plants dominated 2018 new generating capacity, renewables set to rebound in 2019”, Energize Weekly, EUCI, January 16, 2019, accessed at <https://www.euci.com/natural-gas-fired-plants-dominated-2018-new-generating-capacity-renewables-set-to-rebound-in-2019/>.

⁵ Based on EIA Form 860 data from 2001. Data from 2000 not readily available.

⁶ EIA Detailed State Data, 1990-2017 Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860), <https://www.eia.gov/electricity/data/state/>



Table 2-1: North Carolina's 2018 Natural Gas Power Plant Summer Capacity

Utility Name	NGCT Capacity (MW)	NGCC Capacity (MW)
Duke Energy Carolinas	2,018	1330
Duke Energy Progress	1,936	2568
Southern Power Co	1,200	476.8
Virginia Electric & Power Co		165
Municipal and Cooperative	742	185
Independent Power Producer		486
Total	5,896	5,211

Natural Gas Units in North Carolina

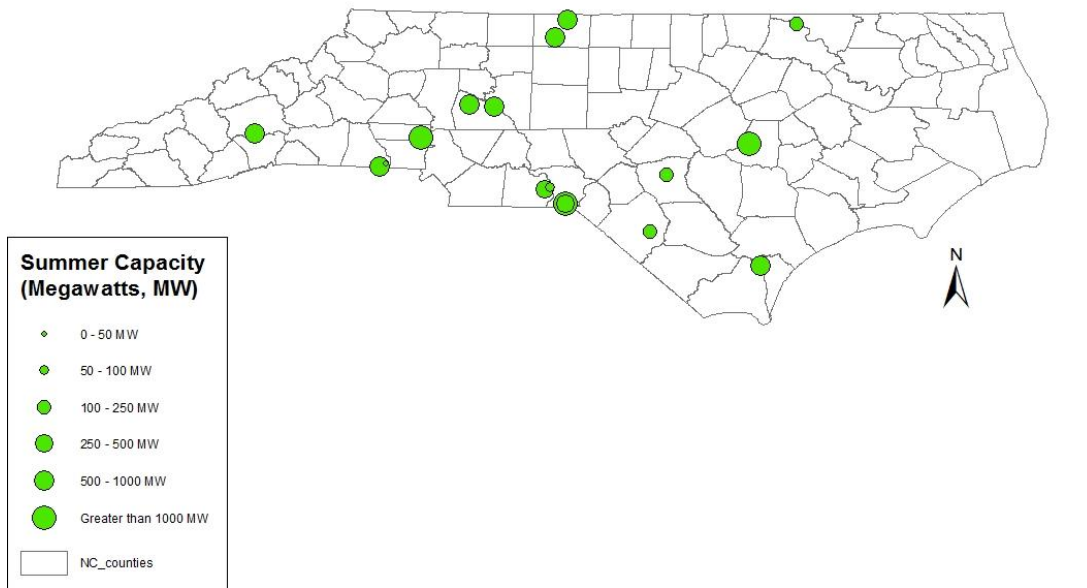


Figure 2-1: Location of Gas Plants in North Carolina Larger than 15 MW



Capacity

Error! Reference source not found. presents the change in NC’s natural gas power plant capacity over time broken out by combined cycle and simple cycle.⁷ In 2000, there were approximately 3,300 MW of natural gas-fired electricity, primarily simple cycle units. Natural gas slowly increased in use until 2011 when Duke Energy began to replace coal plants with NGCC plants. Since 2011, 4,185 MW of NGCC power have come online in NC.

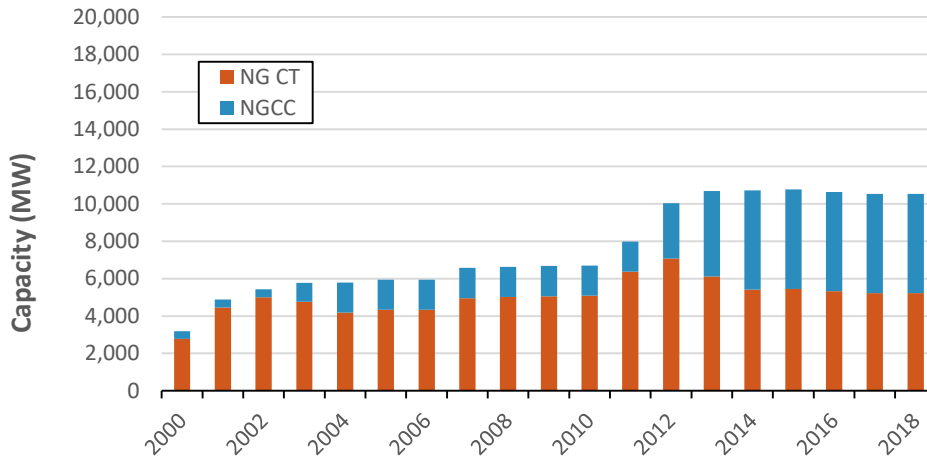


Figure 2-2: Natural Gas Electric Generating Unit Historic Summer Capacity (MW)

Generation

Figure 2-3 presents the historic generation from both simple cycle and combined cycle natural gas plants in North Carolina.⁸ It shows a dramatic increase in generation due to the operation of NGCC plants starting in 2011. In 2010, only 8 million MWh was generated using natural gas and in 2018, almost 44 million MWh was generated, with 80% of that generation provided by NGCC. NGCC power plants are now providing baseload power in NC and operating with capacity factors of 70% or greater. They provided 12% more electricity than coal-fired power plants in 2018.

The figure also demonstrates the efficiency and base load use of the combined cycle design over the simple cycle design. While the operational capacities of the two technologies are close to an equal split in NC, NGCC plants generate far greater amounts of electricity than simple cycle plants.

⁷ EIA Detailed State Data, 1990-2017 Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860), <https://www.eia.gov/electricity/data/state/>

⁸ EIA Detailed State Data, 1990-2017 Net Generation by State by Type of Producer by Energy Source, <https://www.eia.gov/electricity/data/state/>

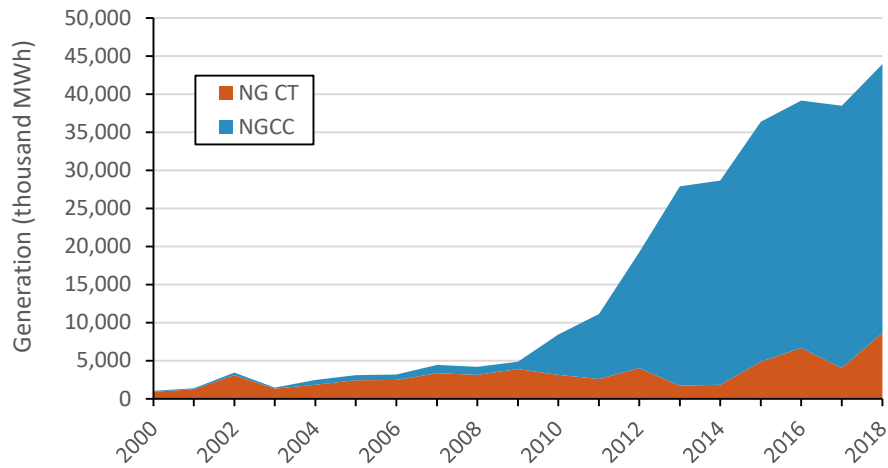


Figure 2-3: Historic Natural Gas Power Generation by Year (thousand MWh)

2.1.2 Planned and Anticipated Capacity and Generation Outlook in NC

Capacity

Figure 2-4 presents the projected growth of natural gas power plants in NC. There are two new NGCC units with a combined summer capacity of 1,072 MW planned to come online between now and 2022.⁹ After that time, the projection relies on the Duke Energy Integrated Resource Plans (IRPs) for capacity additions. The IRPs indicate approximately 4,000 MW of NGCC power will come online between 2024 and 2030 and an additional 1,800 MW of NG CT will be built. Note the IRPs reflect capacity for both the NC and South Carolina territories and do not specify in which state the projected expansions will occur.

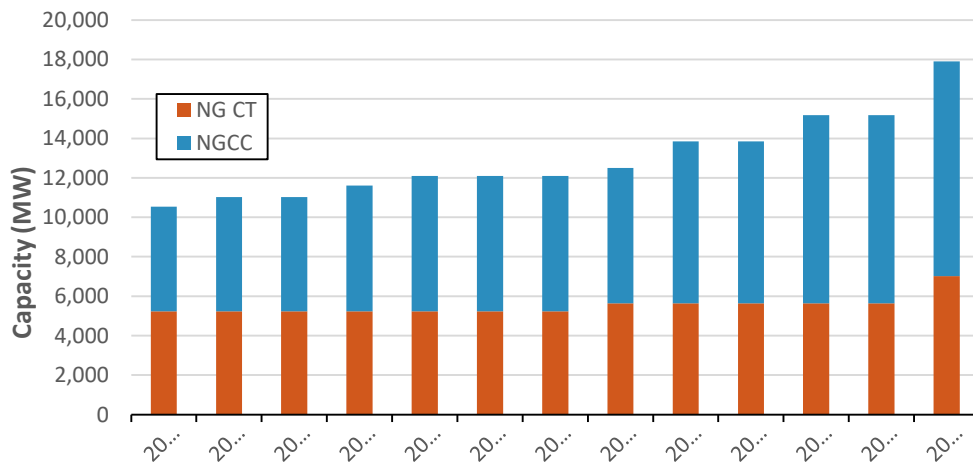


Figure 2-4: Projected Natural Gas Power Summer Capacity Plants from 2018 to 2030

⁹ EIA Detailed State Data, 1990-2017 Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860), <https://www.eia.gov/electricity/data/state/>



Generation

Figure 2-5 presents the projected generation from natural gas power plants in NC out to 2030.¹⁰ It indicates steady growth in generation from natural gas plants, specifically NGCC units, in NC. By 2030, natural gas electricity generation in NC is expected to reach the same value as the peak value for coal in 2007 of 77,000 thousand MWh according to Duke Energy’s current IRPs.¹¹ This forecast does not include the former coal units which have been repowered to co-fire natural gas in conjunction with coal (see Coal Resource for co-fire projection).

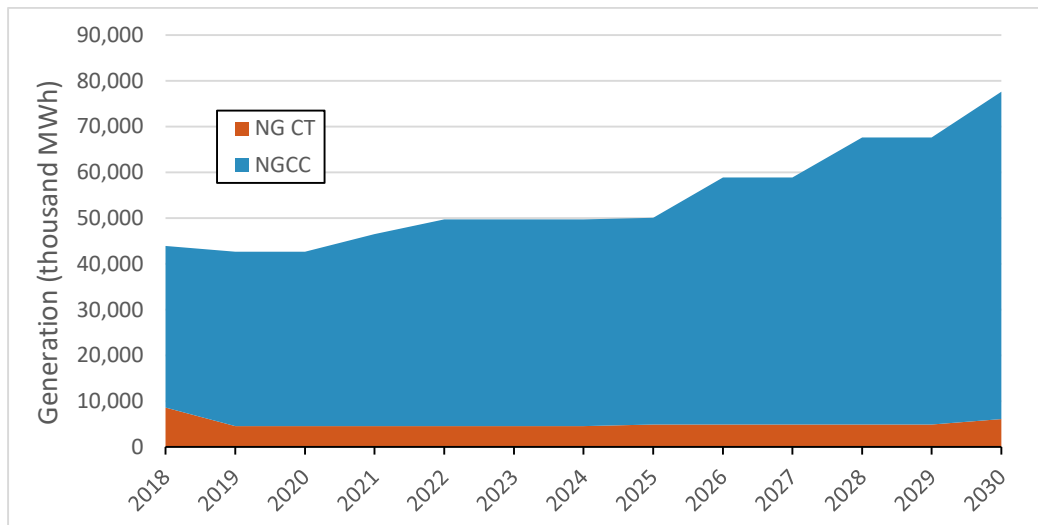


Figure 2-5: Projected Generation from Natural Gas Power Plants from 2018 to 2030

This projection indicates there will be a significant increase in demand due in part to increased electrification of certain sectors such as transportation (electric vehicle charging).

2.2 Natural Gas Technology Overview and Application

2.2.1 Technology Description

A simple cycle combustion turbine (CT) is similar to a jet engine. It mixes gaseous or liquid fuel (generally natural gas and diesel) with compressed air then combusts and expands it. The hot gas flows across the blades of a turbine, turning it. The turbine in a power plant, however, is connected to a mechanical shaft that turns an electric generator which produces electricity. The hot gas exits the turbine and flows up a stack to the atmosphere.

A natural gas combined cycle (NGCC) power plant derives its name from the fact that it has two thermal cycles. The first cycle is the same cycle described above for the CT. The second cycle is a steam turbine-generator cycle referred to as the Heat Recovery Steam Generator (HRSG). It captures the hot gas exiting the gas turbine and sends it to a boiler to produce steam. The steam then flows over a second turbine that turns the shaft of an electric generator, producing electricity. The steam is then condensed back to water

¹⁰ The generation projection was estimated assuming a 75% annual capacity factor for all NGCC and a 10% annual capacity factor for all NG CTs.

¹¹ Assumes all new gas power plants are located in North Carolina.



and recycled. In some HRSG applications, the gas exiting the turbine is heated with a natural gas burner to a slightly higher temperature prior to entering the steam boiler. By combining the gas turbine and steam turbine cycles, the overall net efficiency of the system may be increased by 50%, compared to a simple cycle system.¹²

Natural gas steam boilers operate in the same fashion as coal steam boilers but use natural gas as a primary fuel or co-fire the gas along with coal and/or other fuels. The primary difference is the impact on the heat rate or the efficiency of the plant to generate electricity. Switching from coal to natural gas decreases operating costs, emissions of air pollutants, and waste products.

2.2.2 Technology Benefits and Limitations

As discussed in the introduction to this resource, natural gas power plants have significant advantages over other fossil fuel units. The primary advantage is the higher efficiency of the units. Typical efficiencies of a simple cycle turbine firing gas or oil are around 30 to 35 percent. The most advanced NGCC plant can achieve peak efficiencies of 55 percent, and in 2017, the average heat rate for combined cycle plants in the US was 7,649 Btu/kWh or an equivalent efficiency of 44.6% (EIA). Simple cycle combustion turbines have lower efficiencies than combined cycle plants, averaging 11,746 Btu/kWh or 29% efficient in the US for 2017 (EIA). NGCC plants with advanced designs can achieve peak efficiencies upwards of 60 percent.

An additional benefit is that natural gas power plants provide operational flexibility in regard to the time to reach operational load (ramp time). The ramp time for NGCC units to reach full load is on the order of several hours where coal plants may take up to 24 hours to reach full load. This ability to ramp up quickly is becoming increasingly important as intermittent generation sources, such as solar and wind, are increasingly in use in NC.

Another advantage is their ability to follow changes in electricity demand by rapidly changing their operating load.¹³ As discussed above, the ability to increase and decrease generation quickly is increasingly important in the future where solar and wind resources are intermittent, and the daily demand profiles may become more difficult to manage with increased electrification of the various sectors.

2.2.3 Environmental Issues

Combustion of natural gas emits significantly lower amounts of air pollutants than coal units. Emissions of nitrogen oxides and carbon monoxide from natural gas combustion are only 20% of emissions of coal combustion.¹⁴ Emissions of CO₂ from natural gas combustion are approximately 40% less than coal emissions.¹⁵ Lastly, natural gas combustion emits insignificant amounts of sulfur dioxide, particulate

¹² “U.S. Natural Gas Electricity Efficiency is Always Improving” Jude Clemente, Forbes, Apr 10, 2016, accessed online at <https://www.forbes.com/sites/judeclemente/2016/04/10/u-s-natural-gas-electricity-efficiency-continues-to-improve/#73fb458335a4>

¹³ Amount of fuel use relative to the design maximum fuel use of the power plant

¹⁴ EIA – Natural Gas Issues and Trends 1998,

¹⁵ “How much carbon dioxide is produced when different fuels are burned?”, US EIA, Frequently Asked Questions, June 2018, accessed at <https://www.eia.gov/tools/faqs/faq.php?id=73&t=11>.



matter and metals such as mercury. These low emissions, coupled with higher efficiencies for generating electricity, make natural gas power plants the cleanest burning fossil fuel units.

Despite its low combustion emissions, there are still significant concerns over its use. Natural gas is composed primarily of methane, which is a greenhouse gas (GHG) with a warming potential 25 times greater than carbon dioxide (CO₂).¹⁶ This is a concern in the extraction, process and transmission of natural gas used by the power plant. Significant amounts of methane can escape into the atmosphere during these activities. For 2016, the US EPA estimated methane emissions from these non-combustion activities was approximately 154 million metric tons as CO₂ equivalent emissions.¹⁷ This is 3 times the amount estimated for coal mining. Note that there is considerable debate over the amount of fugitive methane released during these operations.¹⁸ A complete discussion of this issue is beyond the scope of this document.

NGCC plants also use water to generate steam and for cooling. However, they use significantly less water than traditional coal power plants. In 2017, NGCC plants withdrew approximately 237,660 million gallons of water.¹⁹ This is only 20% of the water withdrawn for coal power production, while both generated approximately the same amount of electricity, 34,000 thousand MWh.

2.2.4 Project Installation and Decommissioning

Natural gas power plants are much simpler to build than coal power plants. This is because many of their primary components, such as turbines, can be purchased from manufacturers rather than being built on site to unique design specifications. In addition, they have a smaller footprint than a coal power plant. Lastly, their environmental impact is less, making them easier to permit. However, there are still technical, environmental, economic, and regulatory issues associated with their installation. In addition, they have similar siting issues to coal, including requiring a fresh water source for steam and cooling, and access to an existing natural gas pipeline.

The most recent NGCC plant to be built is the NTE Energy Kings Mountain facility outside of Charlotte, NC. The 500 MW plant was estimated to cost \$450 million and took a little over two years to build and employed 350 workers.²⁰ Southern Company constructed its Cleveland County 720 MW simple cycle gas turbine facility in 2013 at cost of approximately \$330 million dollars.²¹

¹⁶ “Understanding Global Warming Potentials” US EPA, <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>.

¹⁷ *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016*, EPA 430-R-18-003, U.S. Environmental Protection Agency, Washington, D.C., April 2018.

¹⁸ “Estimating U.S. Methane Emissions from the Natural Gas Supply Chain: Approaches, Uncertainties, Current Estimates, and Future Studies”, Garvin Heath, Ethan Warner, Daniel Steinberg, and Adam Brandt, Joint Institute for Strategic Energy Analysis, Stanford University, Technical Report NREL/TP-6A50-62820, August 2015.

¹⁹ US EIA Form-923, Power Plant Operations Report, Annual Environmental Information, Schedule 8. Part D. Cooling System Information, Monthly Operations, 2017 Final.

²⁰ “NTE Energy unveils Kings Mountain power plant, Casey White, Shelby Star, August 29, 2018 accessed at <https://www.shelbystar.com/news/20180829/nte-energy-unveils-kings-mountain-power-plant>.

²¹ “Southern Power starts operations at 720 MW natural gas power plant”, Electric Light & Power/POWERGRID International, December 4, 2012, accessed at <https://www.elp.com/articles/2012/12/southern-power-starts-operations-at-720-mw-natural-gas-power-plant.html>.



Natural gas plants on average have the lowest decommissioning costs.²² As with coal plants, the plant may be either retired and undergo limited remediation and demolition, or be completely dismantled and demolished. Decommissioning gas plants requires dismantling the turbine and generating units, removing fuel storage tanks, and decommissioning gas pipelines, and other equipment at the plant. Since these plants are younger in age, they generally do not have hazardous substances to remove such as asbestos. Natural gas plants have significantly less long-term environmental issues; therefore, more than half the plants are decommissioned and demolished, because the cost is lower than retirement with long-term site security and monitoring.

2.2.5 Emerging Technology Trends

The primary focus of new technologies for natural gas power plants has been increasing the efficiency of the turbines. Improvements in designs and materials allow for higher inlet gas temperatures, which increases the efficiency of the turbine. Advanced NG CT designs can achieve efficiencies of up to 60 percent while advanced NGCC design allow for efficiencies between 60 and 65 percent.²³ In addition, new designs allow for increased flexibility in operating the plants. Lastly, more of the components, such as the HRSG, are being made as modular units and shipped to the site.

Since 2014, the average size of a natural gas-fired combined-cycle power block has increased significantly. The average combined-cycle power block installed between 2002 and 2014 was about 500 MW. After 2014, power block capacity increased, reaching an average of 820 MW in 2017.²⁴ Larger plants typically benefit from economies of scale.

Natural gas plants can also incorporate carbon capture and sequestration that was discussed for coal. The issues are similar to those for coal. The only difference being that natural gas power plants emit less CO₂ than coal plants for the same amount of generation. This technology is not considered cost-effective at this time.²⁵

In 2018, NET Power of Durham, NC began testing a new supercritical gas plant with the goal of producing electricity with near-zero air pollution emissions, including CO₂ capture, at a low cost.²⁶ The plant is a DOE demonstration project located in La Porte, TX. It uses NET Power's Allam Cycle technology, which incorporates a new turbine and combustor developed specifically for the process. Another unique aspect is that CO₂ is the working fluid to drive the combustion turbine. Testing has begun and is expected to continue in 2019.

²² "Decommissioning US Power Plants: Decisions, Costs, and Key Issues", Daniel Raimi, Resources for the Future, October 18, 2017, accessed at <https://www.rff.org/publications/reports/decommissioning-us-power-plants-decisions-costs-and-key-issues/>.

²³ "Efficiency Improvements Mark Advances in Gas Turbines" Darrell Proctor, Power Magazine, January 3, 2018, accessed at <https://www.powermag.com/efficiency-improvements-mark-advances-in-gas-turbines/>.

²⁴ "Power blocks in natural gas-fired combined-cycle plants are getting bigger.", US EIA, Today in Energy, February 12, 2019, accessed at <https://www.eia.com/articles/2012/12/southern-power-starts-operations-at-720-mw-natural-gas-power-plant.html>.

²⁵ US Energy Information Administration (2019) "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019", accessed June 2019. https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf.

²⁶ "Low-cost, emissions-free natural gas power system now operating", Canadian Process Equipment and Control News (CPECN), August 29, 2018, accessed at <https://www.cpecn.com/features/low-cost-emissions-free-natural-gas-power-system-now-operating/>.



2.3 Future Resource Deployment in NC

2.3.1 Policies and Programs Driving Deployment

The Clean Smokestacks Act (CSA), which was passed in 2002, resulted in coal power plants either installing air pollution controls or, if they were no longer cost-effective, opting to retire.²⁷ At the same time, natural gas supply increased substantially due to shale gas development. This made it more cost effective to retire older coal plants and build new NGCC power plants rather than install and operate new coal plants with the required control systems. As discussed in the Coal Resource Section, Duke Energy retired 2,978 MW of coal capacity by the end of 2018. These coal plants were replaced with 4,185 MW of NGCC plants.

A second issue driving deployment of natural gas is the additional pressure placed on coal power due to uncertainty in environmental regulations for coal plants and the requirement to clean up coal combustion residuals in surface impoundments. This increases the uncertainty of future costs for new coal plants and increases the costs for existing and retiring coal plants, making natural gas power plants more attractive. (See Coal Resource Section for more information.)

Lastly, the flexible operation of gas power plants compared to coal plants makes them the ideal choice to support increased amounts of intermittent renewable power, wind and solar. These renewable resources are significantly increasing in use under NC's Renewable Energy and Energy Efficiency Portfolio Standard (REPS) which became effective in 2009 and House Bill 589 Competitive Energy Solutions for NC.^{28, 29} (See Solar Resource Section for more information on these laws.)

2.3.2 Constraints to Deployment

There are no existing technical or regulatory constraints to natural gas electricity generation being deployed in NC.

2.4 Grid Integration and Reliability

2.4.1 Grid Integration and Modernization

Natural gas power is a traditional resource for electricity generation that has many advantages for managing the grid. NGCC units provide baseload power with high reliability. NG CT units are designed specifically to accommodate short-term increases in electricity demand. Therefore, grid integration of these plants is not an issue.

Grid modernization has the potential to increase the use of natural gas simple cycle power plants to supply electricity. It would allow for increased use of low cost intermittent renewable power such as wind and solar. These resources require a back-up resource to provide electricity when they go offline. Since

²⁷ North Carolina Session Law 2009-390 "Clean Smokestacks Act", July 2009, <https://deq.nc.gov/about/divisions/air-quality/air-quality-outreach/news/clean-air-legislation/clean-smokestacks-act>.

²⁸ For more information on the NC REPS, see <http://www.ncuc.commerce.state.nc.us/reps/reps.htm>.

²⁹ House Bill 589, Session Law 2017-192, North Carolina General Assembly, 2017, <https://www.ncleg.net/gascripts/BillLookUp/BillLookUp.pl?Session=2017&BillID=h589&submitButton=Go>.



NG CTs can rapidly start, these units are the primary candidates to supply that back-up power until other technologies, such as energy storage, become available and cost effective.

2.4.2 Resiliency

Natural gas power plants do not provide the same level of fuel security benefits as coal power plants, since they are dependent on the flow of natural gas through pipelines which can be interrupted during extreme events. During recent storm events, including hurricanes Harvey and Irma in 2017, pipelines remained operational, with little or no customer curtailment, and no impacts on end-users. In addition, natural gas serves both power plants and residences. During cold weather events, its use by the non-residential sector may be restricted or curtailed to ensure adequate supplies of natural gas are available to heat homes. However, NGCC power plants are more flexible than coal plants and can be taken offline and brought back up in several hours to secure them during extreme events.

2.5 Resource Costs and Benefits

The cost for building and operating NGCC and NG CT plants generally falls lower than nuclear and coal plants. For several years now, the EIA's Annual Energy Outlook (AEO) has forecast the extensive construction of new NGCC plants in the United States due to this lower capital and operating costs compared to coal and the ability to serve as baseload power.³⁰ Continued improvements in the efficiency and flexibility of these plants also favor them from a cost perspective.

2.5.1 Initial Investment Costs

Total overnight cost in 2018 dollars for a NGCC plant is on the order of \$800 per kW which is at the low end of the range of costs for coal, nuclear and NGCC.³¹ This is due to the use of a cleaner fuel, modular parts, smaller footprint, fewer environmental controls, and less water use. Lastly, NGCC plants emit less CO₂ than coal plants, therefore they are less likely to be regulated for this pollutant in the near future.

A new 560 MW NGCC plant is coming online in 2019 at Duke Energy's existing Asheville plant. This plant is estimated to cost \$893M, which is \$1600 per kW.³²

2.5.2 Operating and Recurring Costs

Both fixed and variable and operating costs for NGCC plants are low compared to coal plants. Recent natural gas prices are much lower and more stable since 2011 than they have been in the past due to the increase in production of shale gas. In addition, there are fewer environmental rules associated with NGCC, which is a clearer burning fuel.

There are plans to build two additional natural gas pipelines to bring shale gas produced in West Virginia to NC. The first pipeline is the Atlantic Coast Pipeline (ACP) which is a joint venture between Dominion

³⁰ "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019", EIA, February 1, 2019, https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf.

³¹ "Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2019" U.S. EIA, January 2019, https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf.

³² "4 things to know about Duke Energy's \$893M natural gas plant, set to open in late 2019", Dillon Davis, Asheville Citizen Times, Oct. 18, 2018, accessed at <https://www.citizen-times.com/story/news/local/2018/10/18/duke-energy-natural-gas-plant-arden-lake-julian-893-m-2019/1660610002/>



Energy, Duke Energy, Piedmont Natural Gas, and Southern Company Gas.³³ It began construction in 2018 and the cost of the project is expected to be over \$6 billion dollars. The second pipeline is the Mountain Valley Southgate Pipeline which filed for approval in November of 2018.³⁴ It is in earlier stages of development. Both plants face opposition from local residents and there are ongoing legal challenges to the projects.

2.5.3 Financing Trends and Options

Traditional financing is used to fund natural gas projects, which includes a combination of private investment firms and banks.

³³ <https://deq.nc.gov/news/key-issues/atlantic-coast-pipeline>

³⁴ <https://deq.nc.gov/news/press-releases/2018/06/21/mountain-valley-pipeline-llc-announces-public-meetings-scheduled>





3. Nuclear

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3.1. Nuclear Resource Introduction

Nuclear power generation is a substantial part of North Carolina’s (NC) existing energy landscape, providing approximately one-third of the electricity consumed in the state. Existing nuclear power plants (NPPs) have supplied a growing share of NC’s reliable, baseload electricity since 1975 when the first reactor was started in the state. This section provides an overview of nuclear technology and NC’s nuclear power plants by generation capacity, location, and historical production. A discussion of NPP’s limitations, environmental footprint, future growth potential, electric grid impacts, costs, and benefits is also included.

3.1.1 Installed Capacity and Generation in NC

The three NPPs operating in NC are wholly owned and operated by Duke Energy [Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP)], the largest regulated utility in the state. A total of five nuclear reactors, or units, operate within these three NPPs with two reactors at Brunswick, one reactor at Harris, and two reactors at McGuire. As shown in Table 3-1 below, the cumulative generation capacity of these three NPPs is 5,118 megawatts (MW).

Total net generation from nuclear was 42,786 megawatt hours (MWh) in 2017, equivalent to 31.4% of NC’s annual electric consumption. As shown in Table 3-1 below, the NPPs owned by DEC and DEP achieved an average capacity factor of 94.4% in 2017.

Table 3-1: North Carolina Nuclear Power Plants, 2017 Capacity and Net Generation ¹

Nuclear Plant Unit and County/Town	Capacity (MW)	Capacity Factor	Owner
Brunswick #1, Brunswick County/Southport	938	91.5%	DEP
Brunswick #2, Brunswick County/Southport	932	93.0%	DEP
Harris #1, Wake County/New Hill	932	95.4%	DEP
McGuire #1, Huntersville/Mecklenburg Co.	1,158	96.9%	DEC
McGuire #2, Huntersville/Mecklenburg Co.	1,158	95.4%	DEC
Total Capacity and Capacity Factor Average	5,118	94.% (avg.)	--
Total Net Generation for NC’s 3 NPPS = 42,786 (000’s of MWh)			

Figure 3-1 below shows the physical locations of the Duke Energy NPP’s: Brunswick is #1 and #2; McGuire is #3 and #4; and Harris is #5.

¹ Nuclear Energy Institute (NEI). *North Carolina and Nuclear Energy*. Retrieved on July 17, 2019 from <https://www.nei.org/CorporateSite/media/filefolder/resources/fact-sheets/state-fact-sheets/North-Carolina-State-Fact-Sheet.pdf>

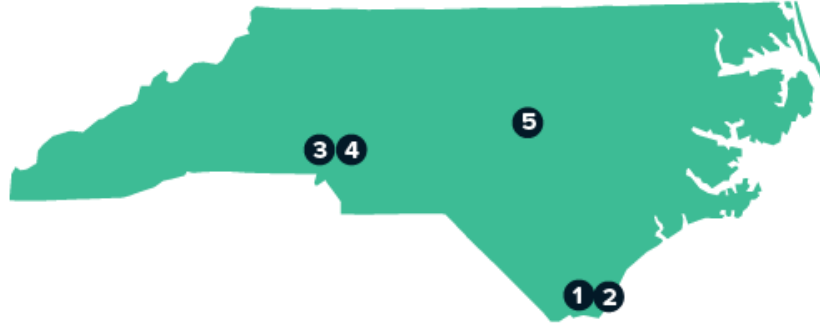


Figure 3-1: Map of North Carolina Nuclear Power Plants from the Nuclear Energy Institute ²

3.1.2 Planned/Anticipated Capacity Growth and Generation Outlook in NC

NC’s first commercial nuclear reactor, at the Brunswick Nuclear Plant (BNP), began operating in 1975 and in 1977 a second reactor became operational. Located near Southport and named after its Brunswick County site, BNP was built by Carolina Power and Light (CP&L), who later merged with Florida Progress to become Progress Energy. In 2012, it merged with Duke Energy to become Duke Energy Progress (DEP). During the 1980s, three more nuclear reactors became operational with two at Duke Energy’s McGuire NPP (Unit #1 in 1981 and Unit #2 in 1983) and another at CP&L/DEP’s Harris NPP in 1986.

In their 2018 NC Integrated Resource Plans (IRPs), DEC and DEP reported that no additional new nuclear generation capacity would be added to their respective systems, with no anticipated NPP retirements over the 15-year planning period. Existing Nuclear Regulatory Commission (NRC) NPP operating licenses allow the units to operate for sixty years, with licenses for NC reactors coming up for renewal starting in 2034. Duke Energy is working with the NRC to evaluate the potential for subsequent license renewals (SLR) of their NPPs to extend the period of operation for an additional twenty years. ³

NC’s three NPPs have been in service from forty-five to thirty-three years, as shown in Table 3-2. All of the NPPs have now been re-licensed for NRC’s current maximum of 60 years. ⁴

Table 3-2: NC NPP Licensing Period

NPP Name	Owner	License Issued	License Expires
BNP #1	DEP	1976	2036
BNP #2	DEP	1974	2034
Harris	DEP	1986	2046
McGuire #1	DEC	1981	2041

² NEI. *Map of U.S. Nuclear Plants*. Retrieved on July 17, 2019 from <https://www.nei.org/resources/map-of-us-nuclear-plants>

³ NC Utilities Commission. *Duke Energy Carolinas, LLC. 2018 Integrated Resource Plan and 2018 REPS Compliance Plan*. Retrieved on July 17, 2019 from <https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=aa9862b5-5e31-4b3f-bb26-c8a12c85c658>

⁴ Nuclear Regulatory Commission (NRC). (2108). *Shearon Harris Nuclear Power Plant*. Retrieved on July 17, 2019 from <https://www.nrc.gov/info-finder/reactors/har1.html>



McGuire #2	DEC	1983	2043
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Since all of NC’s NPPs are licensed until between 2036 and 2046, decommissioning is not yet a pressing issue. The NRC says that decommissioning costs vary, but their cost estimate for a pressurized-water reactor (PWR) is \$290 million and \$370 million for a boiling-water reactor (BWR).⁵ Based on NRC’s cost estimates, the decommissioning cost for NC’s five existing reactors is approximately \$1.53 billion.

3.1.3 Nuclear Technology Definition and Description

The Energy Information Administration (EIA) describes nuclear energy as energy found in the nucleus or core of an atom. Atoms contain three particles: protons, that have a positive electrical charge; electrons, that have a negative electrical charge; and neutrons, that have no electrical charge. The bonds holding the nucleus’s three particles together have enormous energy that can be released when they are broken through nuclear fission. During nuclear fission, a neutron collides with and splits a uranium atom releasing more neutrons and a large amount of heat and radiation energy. When an atom splits, the released neutrons continue colliding with other uranium atoms to create a “nuclear chain reaction” process that repeats itself over and over to produce a desired amount of heat.⁶

The “nuclear chain reaction” and resulting heat that occurs in a NPP reactor is utilized to produce steam.⁷ The resulting steam is then used to turn or rotate a turbine connected to a generator, whose electromagnet’s rotation creates an electric current. Electricity generation in the U.S. (and in NC) primarily comes from power plants that use turbines or similar machines to rotate generators driven by steam.⁸ Most NPPs use uranium (an unstable, naturally-occurring element) as nuclear fuel. Prior to becoming NPP fuel, the uranium undergoes an enrichment process to make it even more unstable and more efficient.⁹

3.2. Nuclear Overview and Application

3.2.1 Technology Benefits & Limitations

Benefits

NPPs provide power continuously throughout the year and are considered as baseload carbon-free generation sources. The only exceptions are for refueling /maintenance outages. According to the World Nuclear Association (WNA), NPPs generate 63% of the United States’ (US) carbon-free electricity, provide the main carbon-free generation source for over half its states, and avoid annual emissions of over 750 million tons of CO₂ as compared to coal. The ninety-eight NPPs in the US have an average capacity factor of over 90%, and have provided reliable electricity by supplying about 20% of the total electricity

⁵ NRC. (2017). *Frequently Asked Questions About Reactor Decommissioning*. Retrieved on July 17, 2019 from <https://www.nrc.gov/waste/decommissioning/faq.html#19>

⁶ Energy Information Administration (EIA). (2018). *Energy Explained*. Retrieved on July 17, 2019 from https://www.eia.gov/energyexplained/index.php?page=nuclear_home

⁷ Nuclear Energy. (2019). *What is Nuclear Energy?*. Retrieved on July 17, 2019 from <https://nuclear-energy.net/what-is-nuclear-energy>

⁸EIA. (2018). *Energy Explained*. Retrieved on July 17, 2019 from https://www.eia.gov/energyexplained/index.php?page=electricity_generating

⁹ Nuclear Energy. (2019). *What is Nuclear Energy?*. Retrieved on July 17, 2019 from <https://nuclear-energy.net/what-is-nuclear-energy>



generated since 2001. The WNA reported that the overall NPP average generation cost per MWh has declined from \$40/MWh in 2012 to \$34/MWh in 2017. The cost decline is most likely related to NPP’s increased operating efficiency, improved maintenance, and reduced length of re-fueling outages. ¹⁰ In its 2018 Levelized Cost of Energy Analysis, Lazard (a financial advisory and asset management company) reports that the marginal cost of existing conventional nuclear generation ranges from \$45/MWh to \$27/MWh. ¹¹

Limitations

Even though NPPs use naturally-occurring uranium as generation fuel, nuclear energy is not considered a renewable source (like solar or wind) because uranium reserves are not unlimited. Because of radiation’s long-life and potential hazard to health, nuclear waste must be properly disposed of or stored. High level waste (fuel assemblies/sealed metal tubes holding ceramic uranium pellets) are initially kept in storage pools at the NPP where it was used for generation for 2-5 years, and then put into steel-reinforced concrete “dry casks” for storage and shipment to a licensed facility, when available. Low-level waste (gloves, tools or machine parts that have been exposed to radioactive materials) is collected and transported to one of four disposal facilities in South Carolina, Washington, Utah or Texas. A permanent high-level waste disposal site at Yucca Mountain, Nevada (NV) has been planned for development by the Department of Energy (DOE) since 1987. If the DOE completes the proposed NV project, upon federal government approval, it would allow for the transport and storage of all U.S. commercial used fuel at the site. Consolidated interim storage sites have been proposed until a disposal site becomes available. ¹²

NPP generation requires an adequate water supply to safely cool heat from the reactor. EIA’s Power Plant Report below (Table 3-3) shows that NC’s NPPs required 1.47 million gallons of water in 2017. The water consumption (that is only shown at the Harris NPP) is most likely attributable to the steam which rises up, through and out of its cooling tower. ¹³

Table 3-3: North Carolina Nuclear Power Plant Usage

Plant Name	Sum of Withdrawal (million gallons)	Sum of Discharge (million gallons)	Sum of Consumption (million gallons)
Brunswick NPP	490,323	490,323	--
Harris NPP	10,719	5,409	5,310
McGuire NPP	971,134	971,104	--
Total	1,472,176	1,466,836	5,310

¹⁰ World Nuclear Association. (2019). *Nuclear Power in the USA*. Retrieved on July 17, 2019 from <http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.aspx>

¹¹ Lazard. (2018). *Levelized Cost Of Energy Analysis-Version 12.0*. Retrieved on July 17, 2019 from <https://www.lazard.com/media/450773/lazards-levelized-cost-of-energy-version-120-vfinal.pdf>

¹² NEI. *What is Nuclear Waste?*. Retrieved on July 17, 2019 from <https://www.nei.org/fundamentals/nuclear-waste>

¹³ EIA. (2017). *Annual Environmental Information, Schedule 8. Part D. Cooling System Information, Monthly Operations, 2017 Final, Sources: Form EIA-923, Power Plant Operations Report*. Retrieved on July 17, 2019 from <https://www.eia.gov/electricity/data/eia923/>



3.2.2 Emerging Technology Trends

Small modular reactors (SMRs) or light water reactors (LWRs), according to the NRC, are those that generate 300 MW or less. SMRs are less capital-intensive than conventional NPPs, which average around 1,000 MW per unit, so financing is easier and construction times are shorter, due to in-factory fabrication. The energy and environmental benefits of SMRs mirror traditional NPPs through greenhouse gas avoidance, grid stability, and capacity factor. The SMR's size offers siting flexibility, too. Over the past several years, the NRC has engaged in varying degrees of pre-application activities with several SMR designers (NuScale Power, BWXT mPower, SMR-106 and Clinch River Nuclear Site). The NRC has issued a site use permit for NuScale Power to build an SMR at the Idaho National Laboratory. It is expected to be completed by 2026.¹⁴

Micro reactors are designed for specialized applications. Their size and mobility offers siting flexibility (including near population centers), remote operation bases off of the electric grid, data center power, disaster relief during energy emergencies such as hurricanes, and other specialized non-electric applications.¹⁵

Non-water advanced reactor technology includes gas reactor technology that incorporates advanced alloy and graphite materials qualification for high temperature gas-cooled systems, scaled integral experiments to support design and licensing, and Tristructural-Isotropic/TRISO-coated particle fuel development and qualification. Fast reactor technology demonstrates the feasibility of advanced systems and component technologies, methods and code validation to support design and licensing, and advanced alloy materials qualification for metal-cooled systems. Molten salt reactor technology investigates fundamental salt properties, models, materials, fuels and technologies for salt-cooled and salt-fueled reactors.¹⁶

To prepare for the advent of the new technologies' possible licensing and deployment, the NRC has developed an advanced non-light water reactor (non-LWR) application review process.¹⁷

3.3. Future Resource Deployment in NC

3.3.1 Policies and Programs Driving Deployment

In the two 2018 IRPs from Duke Energy, it was reported that no new nuclear generation units are planned, with no anticipated nuclear retirements over the IRP planning period. However, DEP's IRP says they plan "capacity uprates", an increase in the peak operating output of a facility, (totaling 56 MW) to

¹⁴ NRC. *Small Nuclear Reactors*. Retrieved on July 17, 2019 from <https://www.nrc.gov/reactors/new-reactors/smr.html>

¹⁵ NRC. (2018). *U.S. Department of Energy Advanced Reactor Research and Development Program for Fast Reactors*. Retrieved on July 17, 2019 from <https://www.nrc.gov/reading-rm/doc-collections/commission/slides/2018/20180424/herczeg-20180424.pdf>

¹⁶ NRC. Ibid. Retrieved on July 17, 2019 from <https://www.nrc.gov/reading-rm/doc-collections/commission/slides/2018/20180424/herczeg-20180424.pdf>

¹⁷ NRC. Ibid. Retrieved on July 17, 2019 from <https://www.nrc.gov/reactors/new-reactors/advanced.html>



the Brunswick and Harris NPPs during 2019 to 2028.¹⁸ DEC had previously begun the process of planning the Lee Nuclear Station power plant in Gaffney, SC. However, the project was halted in 2017 after spending over \$500 million when the project contractor went bankrupt. DEC still holds the NRC-issued Construction and Operating License for a new nuclear reactor should they choose to build another NPP.¹⁹

3.3.2 Constraints to Deployment

NPP capital cost construction per kilowatt (kW) is higher than capital costs for natural gas, solar, and wind. In its 2017 Capital Cost Estimates for Additional Utility Scale Generating Plants Addendum, the EIA estimated an advanced nuclear power plant's capital construction cost to be \$6,384/kW. By comparison, the most expensive natural gas power plant (NGPP) capital cost is estimated at \$1,342/kW, while solar cost is estimated at \$2,644/kW, and onshore wind cost is estimated at \$1,877/kW.²⁰ NPPs take many years to site, license and construct. The DOE estimates the average build time (for an already certified design) is about 7 to 8 years, while some new (not yet certified) designs have the potential to reduce this time primarily through shortened construction times.²¹

In 2010, the DOE estimated that building a new NPP could cost \$6 to \$8 billion (including construction interest).²² More recently, in 2016 Tennessee Valley Authority's (TVA) Watts Bar 2 NPP cost of \$4.7 billion dollars to complete; well over its revised 2007 estimate of \$2.5 billion for the project that began in 1974.²³

Financing NPP construction has become increasingly challenging when compared to less expensive NGPPs. The International Atomic Energy Agency (IAEA) states that the funding and financing of NPPs is "very large." IAEA also says that NPP construction financing can be impacted by cost estimate disparities, high capital costs, construction delays, cost overruns, and inflation.²⁴ The high financing costs of new NPPs has slowed their construction rate dramatically. According to the EIA, the most recent NPP built (in 2016) was TVA's Watts Bar Unit 2 and the next-youngest is their Unit 1 (built in 1996).²⁵ Georgia Power's (GP) Vogtle plant, the only existing current NPP construction project, has seen significant cost escalations and schedule delays. Nevertheless, GP decided in 2017 to continue

¹⁸ NC Utilities Commission. *Duke Energy Progress, LLC. 2018 Integrated Resource Plan and 2018 REPS Compliance Plan*. Retrieved on July 17, 2019 from <https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=25fb3634-54b6-464b-9704-b6fe99cda1a8>

¹⁹ Bizjournals. (2017). *Duke Energy Abandons Plans to Build the Lee Plant*. Retrieved on July 17, 2019 from <https://www.bizjournals.com/charlotte/news/2017/08/25/duke-energy-abandons-plans-to-build-the-lee.html>

²⁰ EIA. (2016) *Capital Cost Estimates for Additional Utility Scale Generating Plants*. Retrieved on July 17, 2019 from <https://www.eia.gov/analysis/studies/powerplants/capitalcost/>

²¹ US Department of Energy (DOE). (2001). *A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010*. Retrieved on July 17, 2019 from <https://www.energy.gov/sites/prod/files/NTDRoadmapVolIII.pdf>

²² DOE. *Status and Outlook for Nuclear Energy In the United States*. Retrieved on July 17, 2019 from https://www.energy.gov/sites/prod/files/Attachment-2-Status_and_Outlook_for_Nuclear_Energy_in_the_US.pdf

²³ Forbes. (2016). *Watts Bar 2, First New US Nuclear Plant Since 1996, Is Now Commercial!*. Retrieved on July 17, 2019 from <https://www.forbes.com/sites/rodadams/2016/10/19/watts-bar-is-now-commercial/#5641949a3680>

²⁴ International Atomic Energy Agency (IAEA). (2008). *Financing of New Nuclear Power Plants*. Retrieved on July 17, 2019 from https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1345_web.pdf

²⁵ EIA. (2019). *How old are U.S. nuclear power plants, and when was the newest one built?*. Retrieved on July 17, 2019 from <https://www.eia.gov/tools/faqs/faq.php?id=228&t=21>



construction and the NPP was then approved by the Georgia Public Service Commission.²⁶ SCANA, a South Carolina utility, stopped building Sumter NPP's two reactors because of cost escalations/schedule delays.²⁷ Because of the large cost overruns SCANA's dire financial condition led to their being acquired by Dominion Energy in January of 2019.²⁸

3.4. Grid Integration and Capacity Factor

3.4.1 Grid Integration

NPP's are considered baseload generation and operate consistently with limited intermittent downtime. Furthermore, NPP's operate in the classical centralized power production methodology. Because of these factors grid integration is less of an issue than with renewable/intermittent resources such as solar which are not baseload and are more decentralized. Also, there are no new NPPs expected to come online, therefore there is no need for integration.

3.4.2 Resiliency Capacity Factor

NPPs operate 24/7 nonstop, year-round (for 18 to 24 months) except for brief periods of re-fueling and maintenance, and are not impacted by extreme hot or cold weather. During hurricanes, NPPs that may be impacted by the event are shut down until the threat is over. As noted in Section 3.2.1 above, NPPs traditionally operate at capacity factors of greater than 90%.

3.4.3 Grid Modernization

As previously stated, traditional NPPs are already adequately integrated into the electric grid. As other generation technologies which have larger impacts on the grid and grid modernization grow, nuclear energy has the potential to enable these technologies. By providing stable baseload generation, NPP's make the integration of variable output renewables and other technologies more feasible. Micro-reactors (very small nuclear reactors) may impact grid operations differently. To address this challenge, the US Department of Defense (DOD) has developed a micro-reactor roadmap since they can operate independently from the electric grid, and supply resilient power and primary power under normal and emergency conditions.²⁹

Starting in the late 1970's, a significant portion of North Carolina's energy needs have been met by its three existing NPPs, and our energy future depends on how this traditional capacity and baseload generation will be replaced. Since NC's existing NPP licenses begin expiring in 2034, the state should start exploring other viable energy options. Going forward, new generating resources should be identified

²⁶ GeorgiaPol. (2017) *Public Service Commission Votes To Continue Vogtle Construction; GA Power To Absorb Substantial Amount Of Cost Overruns*. Retrieved on July 17, 2019 from <https://www.georgiapol.com/2017/12/21/public-service-commission-votes-continue-vogtle-construction-ga-power-absorb-substantial-amount-cost-overruns/>

²⁷ EIA. (2018). *Annual Energy Outlook 2018: Nuclear Power Outlook*. Retrieved on July 17, 2019 from <https://www.eia.gov/outlooks/aeo/npo.php>

²⁸ Dominion Energy. (2019). *Dominion Energy Combines With SCANA Corporation*. Retrieved on July 17, 2019 from <https://news.dominionenergy.com/2019-01-02-Dominion-Energy-Combines-With-SCANA-Corporation>

²⁹ NEI. (2018). *Roadmap for the Deployment of Micro-Reactors for U.S. Department of Defense Domestic Installations*. Retrieved on July 17, 2019 from <https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/Roadmap-micro-reactors-department-defense-201810.pdf>



to replace the NPP's existing capacity and generation even if the NRC extends their licenses (as desired by Duke Energy) for an additional twenty years. It is prudent to now begin looking for a nuclear generation replacement so that we can meet NC's future baseload electric needs.



4. Solar

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4.1 Introduction - Solar Resource and Technology

While not as sunny as southern California, North Carolina has a solar resource comparable to most of the southeast from Texas to Virginia, as seen in Figure 4-1, below.

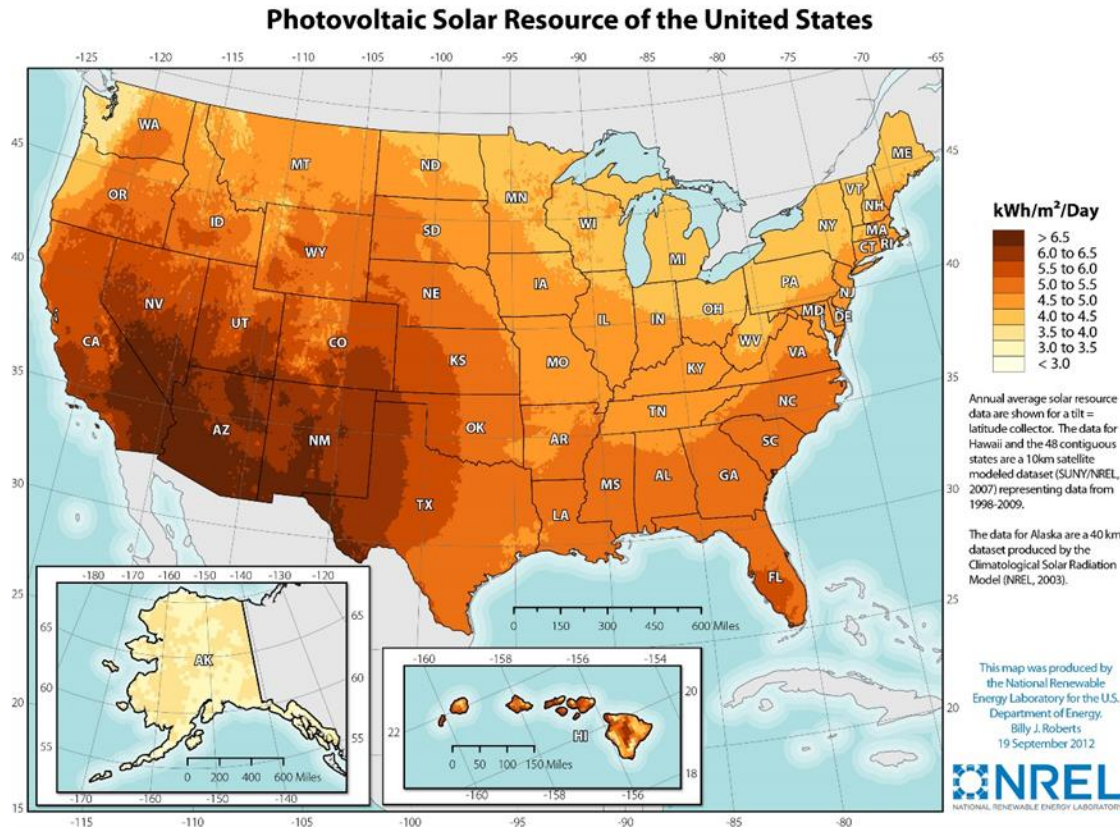


Figure 4-1: Photovoltaic Resource of the United States

Note: North Carolina receives about the same amount of solar radiation, or insolation, as much of the Southeast.

(Source: https://www.nrel.gov/gis/images/eere_pv/national_photovoltaic_2012-01.jpg)

This solar resource has enabled remarkable growth in installed solar capacity over the last 10 years. This growth has been largely utility-scale, ground mount, photovoltaic (PV) systems usually exceeding 1 MW in capacity.

The map below in Figure 4-2, shows that PV projects are widely installed across the state, but with a majority in the eastern NC in the Duke Energy Progress (DEP) utility service territory. Most of the largest installations, shown by largest orange circles (over 50 MW) are in rural areas of the state. Solar developers pay yearly lease payments to land owners as well as property taxes to the county. These payments provide a boost to the local economy.

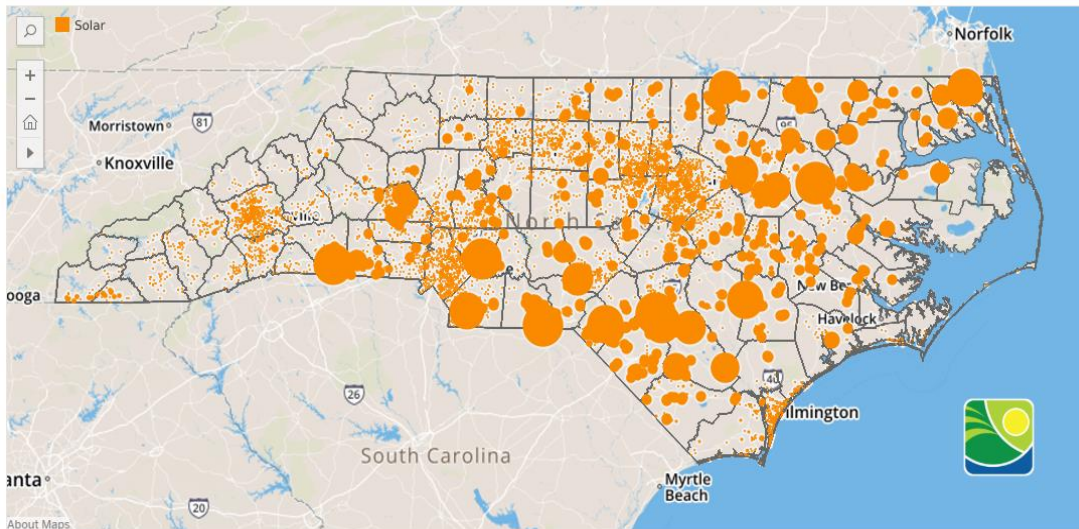


Figure 4-2: Installed Photovoltaic Systems in NC¹

A key policy driver for this growth was the NC Renewable Energy and Energy Efficiency Portfolio Standard (REPS) enacted in 2007 that established NC Investor Owned Utility targets for solar.² NC solar developers and independent power producers have successfully used economies of scale and the Public Utility Regulatory Policies Act of 1978 (PURPA), along with state and federal incentives, to accelerate PV deployment in the state.³ A number of quickly growing solar developers, Duke Energy Solar Investments, and large data centers operated by Facebook, Google, and Apple have been key players investing in NC PV generation. These factors combined with the declining cost of PV have kept the state in the top 5 for solar capacity installed nationally since 2015.⁴ NC HB 589, enacted in 2017, requires Duke Energy to continue solar deployment.⁵ Continuing downward costs for solar pricing and other technology trends like bifacial solar panels and the availability of cheaper energy storage will likely spur further solar growth.

4.1.1 Installation Capacity and Generation in NC

Below in Figure 4-3, is a chart that shows the sharp upward trend in NC PV capacity from 2008 to 2017.⁶ Through the first quarter of 2019, NC PV capacity has risen to about 5,467 MW of solar capacity installed.⁷

¹ NC Sustainable Energy Association, Website accessed April 2019, <http://energync.org/maps/>

² NC Renewable Energy Portfolio Standard, Session Law 2007-397 Senate Bill 3, <https://www.ncleg.net/Sessions/2007/Bills/Senate/PDF/S3v6.pdf>

³ Energy Information Administration, Annual Electric Data Form, 2016

⁴ Solar Shines in NC, PEW Charitable Trust, 2014, <https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2014/10/solar-shines-in-north-carolina>

⁵ NC General Assembly, HB589, Session Law 2017, www.ncleg.net/Sessions/2017/Bills/House/PDF/H589v5.pdf

⁶ NC PV capacity by year, EIA form 923

⁷ Solar Energy Industries Association, accessed July 2019 at <https://www.seia.org/state-solar-policy/north-carolina-solar>

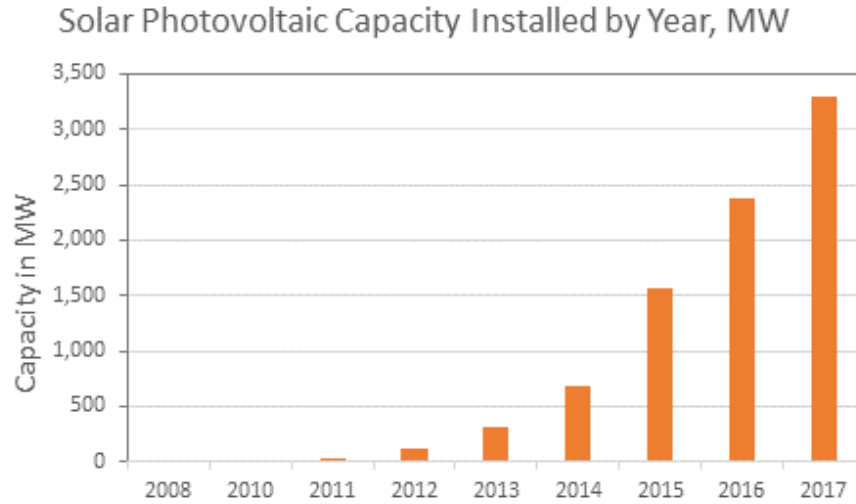


Figure 4-3: NC PV Capacity Installed By Year⁸

Below in Figure 4-4 is a chart showing NC PV generation from 2008 to 2017.⁹ This capacity and generation growth reflects both policy and market forces that have propelled PV installations in NC.

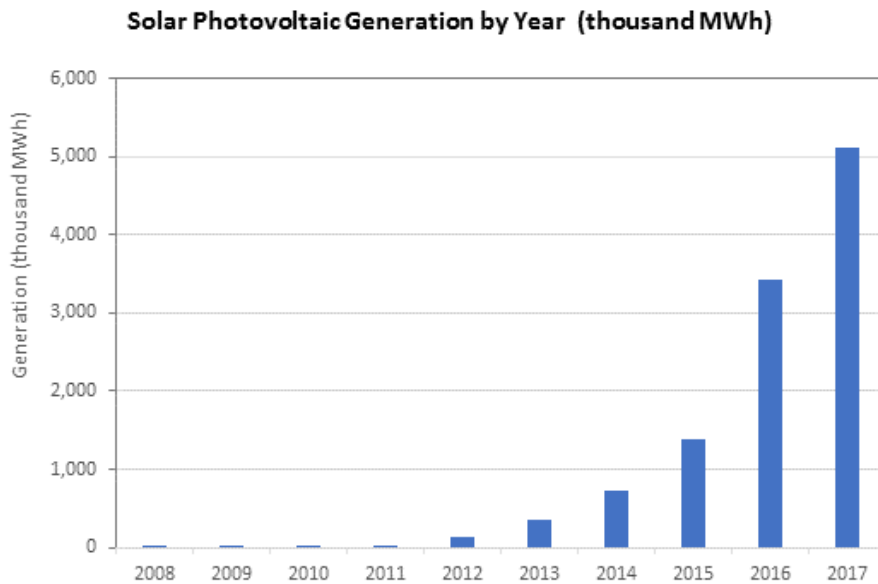


Figure 4-4: NC PV Generation by Year

⁸ NC PV capacity by year, EIA form 923

⁹ NC PV generation per year, EIA form 923



4.1.2 Planned Growth in NC

The chart below (Figure 4-5) shows planned growth in NC for PV. The data comes from the Duke Energy Integrated Resource Plan (IRP) filed in September 2018. These IRP projections include planned PV growth and capacity additions anticipated by Duke Energy as a result of HB 589. The three ranges represented by orange, blue, and grey represent the high, base (central), and low range of PV capacity additions. There is a ramp up in PV capacity additions, then for the years between 2026 until 2033, the growth in capacity flattens out.

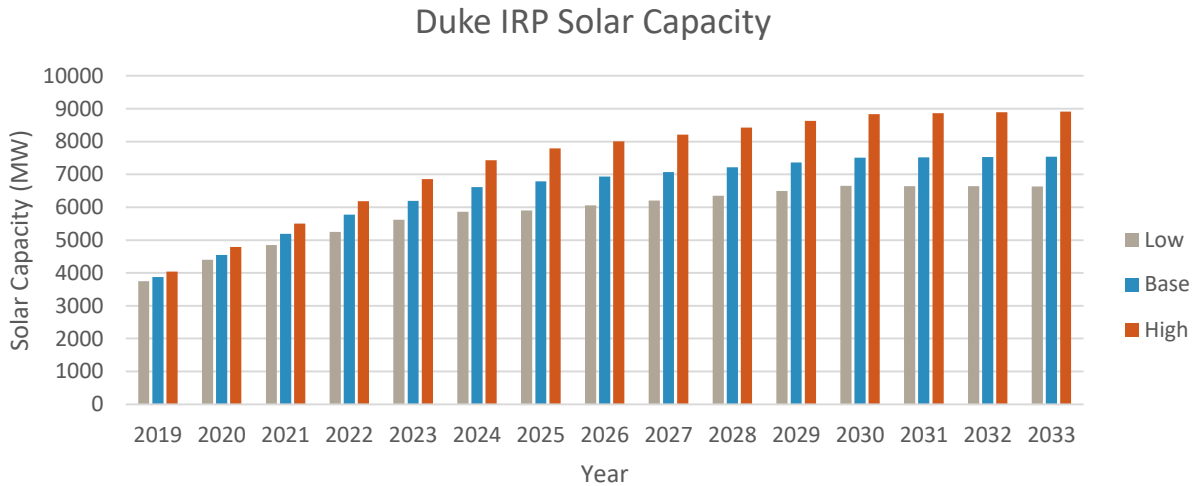


Figure 4-5: NC Planned Solar Capacity from Duke Energy IRP 2018

4.1.3 Technology Description

The solar resource used by the NC electric grid almost exclusively is from the direct conversion of solar insolation to electricity using photovoltaic (PV) panels. PV panels use semi-conductor cells that create a flow of electricity when sunlight photons hit the cells. PV panels are commonly installed either on the ground using a network of metal grids connected to vertical support posts in the ground or on roofs using supports connected to roof members. PV systems have no moving parts and are very durable, continuing to produce power in excess of 25 years with modest reductions in conversion efficiency.¹⁰

The chart below (Figure 4-6) notes DOE goals for PV technology costs nationally, in terms of the levelized cost of energy.¹¹ This chart divides PV into three categories: residential PV is sized between 2 - 20 kW; commercial is between 20 kW – 1 MW; and utility-scale is between 1 – 1,000 MW. Note that the 2020 goal of \$.06 per kWh in utility scale system has already been achieved nationally.¹² If residential and commercial levelized costs for solar continue to go down as the chart shows in 2020, they will be

¹⁰ Photovoltaics Basics from DOE, www.energy.gov/eere/solar/articles/solar-photovoltaic-technology-basics

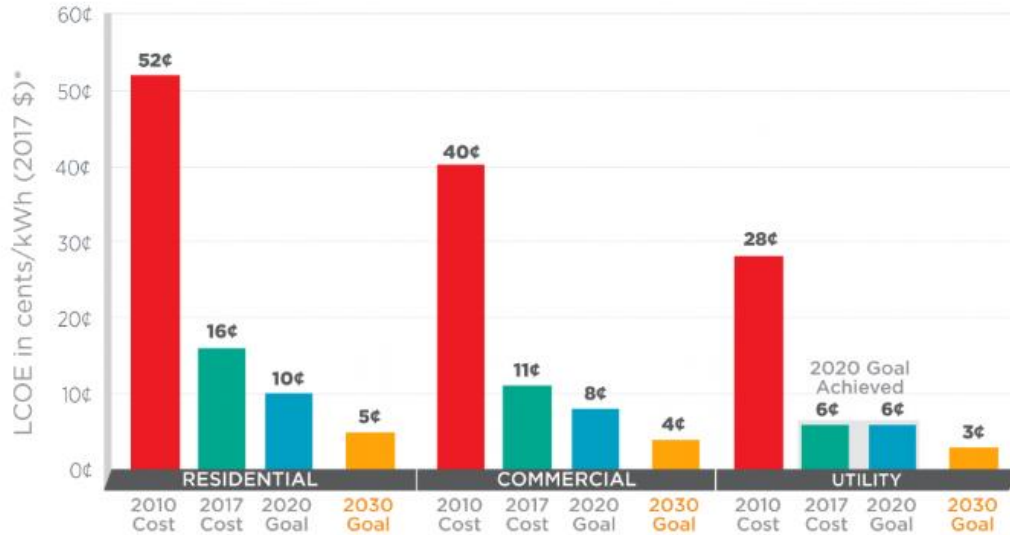
¹¹ From EIA, the levelized cost of energy is the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant. For more information see the EIA website at https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

¹² Photovoltaics,DOE-EERE- Sunshot, 2017, www.energy.gov/eere/solar/photovoltaics



lower than the current NC average residential electricity rate of \$0.11 per kWh and commercial rate of \$0.085 per kWh.¹³

SunShot Progress and Goals



*Levelized cost of electricity (LCOE) progress and targets are calculated based on average U.S. climate and without the ITC or state/local incentives. The residential and commercial goals have been adjusted for inflation from 2010-17.

Figure 4-6: DOE PV Cost Goals and Sunshot Program

A second solar electric class of technologies are concentrating solar power systems. These systems focus solar insolation on receivers using a circulating fluid to absorb the thermal energy. Power tower systems use ground mounted heliostats that focus reflected light on a central receiver. Power tower systems require high insolation values and a high percentage of direct beam insolation annually (lack of cloud cover). Parabolic designs that focus sunlight on a central pipe carrying heat transfer fluid also require high insolation values and very clear skies like power tower systems. Both of these technologies have rarely been installed in NC and are usually found in southwest areas of the country that have a higher quality solar resource.¹⁴

The solar thermal systems generate low- to mid- temperature thermal energy for use by a customer to heat air, hot water or steam for residential or commercial facilities. The market for solar thermal systems in NC has gotten much smaller due to competition from natural gas, which offer more attractive savings.

Other common solar applications include daylighting and passive solar design. Solar daylighting allows sunlight to intentionally and in a controlled fashion to enter buildings through designed window areas that use shading and orientation to limit sunlight that could add extra thermal load to a building. Daylighting can reduce the need for artificial indoor lighting. Passive solar design is typically used in residential

¹³ EIA Electric Power Monthly, Jan 2019,

https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a

¹⁴ Concentrating Solar Power, DOE, www.energy.gov/eere/solar/concentrating-solar-power



buildings and uses sunlight to warm design elements of a building, which reduces conventional thermal heating needs of a building.

4.2 Solar Technology Overview and Application

4.2.1 Technology Benefits and Limitations

Solar energy is widely distributed and only compromised by obstruction from vegetation, buildings or landforms. The resource has a predicted variability due to diurnal and seasonal variation which is well documented, as well as scattering and shading due to atmospheric conditions and cloud cover. The fuel source is free, providing a competitive advantage over conventional energy generation that is subject to fluctuating fuel costs. Technologies to convert solar energy to thermal or electrical energy are scalable and range from the very simple (a black water tank in the sun) to complex (a 500-acre utility-grid connected photovoltaic generation facility). These benefits and the innovations in solar energy conversion have resulted in rapidly growing solar energy adoption, especially in PV technology, which has seen rapid growth in NC as noted earlier. The sections below outline limitations and issues related to solar technology use.

4.2.2 Installation, Siting, Decommissioning and Environmental Issues

Utility-scale, ground mount PV systems are the predominant source of solar-generated electricity supplied to the NC electric grid. These systems are typically installed on relatively flat land, usually in rural or agricultural areas. On average, ground mount systems occupy about 6-8 acres for every 1 MW of capacity, depending on the topography. An NCSU study, *Balancing Agricultural Productivity with Ground-Based Solar Photovoltaic (PV) Development*, looked at land use issues related to these ground mount PV systems.¹⁵ As of December 2016, the study found that these large PV systems occupied 0.2% of NC cropland statewide. Various expansion scenarios are discussed in the study and projections of future land use by PV varied from 0.57% in the year 2030 to up to 8% of NC cropland if ground mount PV supplied 100% of NC current electricity use (an unlikely scenario). As costs for PV continue to fall, solar generation can also come from urban areas like parking lot covers and large building roofs. Less valuable urban land like brownfield reclamation lands or marginal lands surrounding waste water plants, airports, or other open areas can also be used. The use of these urban lands can reduce the reliance on large, ground mount PV projects sited in rural areas using cropland.

Typically, for ground mount PV systems that are fixed tilt, little grading is necessary during construction; but for single axis tracking systems, more site grading must occur. Grading that does occur at sites conserves the topsoil which is returned and distributed to disturbed areas enabling ground cover to get well established. Ground cover helps stabilize the surface and also helps meet the erosion control and sedimentation plan that is reviewed and approved by the NC Department of Environmental Quality.

PV technologies are not known to pose significant risks to adjacent neighbors. Most of the risks occur during construction from traffic into the site and with workers exposed to construction equipment and

¹⁵ Balancing Agricultural Productivity with Ground-Based Solar Photovoltaic (PV) Development, NCSU, Aug 2017, p.6



high voltage. As per the National Electrical Code, solar facilities are surrounded by fencing to prevent surrounding inhabitants from contact with electrical equipment.¹⁶ Potential land impacts of solar are discussed below.

Modern solar installations in NC pose no known risk of leaking or leachate run-off from the panels or component parts because bonded construction of the solar panel forms a complete weatherproof seal. An indication of the durability of solar panels is the typical manufacturer warranty that guarantees performance for 25 years at 80% of original performance capacity.¹⁷ Most solar panels (including both common silicon-based panels and the less common CdTe-based panels) are reported (as far back as 1998) to pass the EPA's Toxic Characteristic Leaching Procedure (TCLP) test, which tests the potential for crushed panels in a landfill to leach hazardous substances into groundwater. Passing this test means that the panels are classified as non-hazardous waste and can be deposited in landfills.¹⁸

Because of the bonded construction discussed above, modern solar installations pose little risk of leaking or leachate from the panels or component parts. Aluminum framed and galvanized structural supports for the module arrays are coated with aluminum oxides to prevent corrosion. Galvanized vertical beams do include zinc, which can pose problems for some crops, especially peanuts. The NC Department of Agriculture and Consumer Services, Agronomic Services Division Laboratory offers soil testing that will reveal the presence and concentrations, if any, of zinc on land near solar facilities. Agricultural liming can limit both additional aluminum and effects zinc may have on crops.¹⁹ For more detailed discussion related to solar facilities, agricultural uses, and health and safety refer to “Balancing Agricultural Productivity with Ground-Based Solar Photovoltaic (PV) Development” and “Health and Safety Impacts of Solar Photovoltaics” two NC State University publications referenced in this section.

4.2.3 Decommissioning and Recycling

PV project developers generally lease land for long-term operation, but these facilities can be removed from a site. This is because it is common practice to drill vertical PV panel supports directly into the ground without using a concrete footer. The other significant underground materials are wiring, which can also be removed, and conduit, which can either be removed or installed at a depth where it would not impact the land if it was returned to farming (usually ~ 3 feet). Electrical inverters at a PV site may be on a small concrete pad but may also be secured using ground anchors attached to a shipping platform that is placed on the ground. A NC model solar ordinance is available for planning and permitting solar developments. This model ordinance also contains decommissioning guidance local governments can use to understand decommissioning options.²⁰

¹⁶ Health and Safety Impacts of Solar Photovoltaics, NCSU & NC Clean Energy Technology Center, May 2017

¹⁷ Health and Safety Impacts of Solar Photovoltaics, NCSU & NC Clean Energy Technology Center, May 2017

¹⁸ NC Clean Energy Technology Center. Health and Safety Impacts of Photovoltaics. May 2017.

https://nccleantech.ncsu.edu/wp-content/uploads/2018/10/Health-and-Safety-Impacts-of-Solar-Photovoltaics-2017_white-paper.pdf. Accessed July 31, 2019.

¹⁹ Balancing Agricultural Productivity with Ground-Based Solar Photovoltaic (PV) Development, NCSU, Aug 2017, p.9-10

²⁰ Template Solar Energy Development Ordinance for NC, NCCETC & NCSEA, 2016.



Deployment trends in NC indicate that in the coming years PV panels will present opportunities and challenges for reuse as well as recycling. Some informal studies indicate that the salvage value of a decommissioned solar facility currently exceeds the cost of decommissioning. Due to durable construction and slowly declining performance, modules may be reconditioned and reused. If recycled for material content, much of the mass in PV panels is glass and aluminum frames. Additionally, inverters and transformers are made of recyclable materials as is wire used on site to connect the arrays of modules to each other and the inverters. As increasing volumes of PV panels enter the recycling marketplace, it is expected that recycling technologies that are more specific to PV panels will be used. Advanced recycling technology allows the recovery of additional high value materials, like the small amounts of silver contained in many panels. Recycling equipment geared toward PV can recover 95% of the semiconductor and over 90% of the glass in a PV panel.²¹ International research has shown that PV manufacturing has resulted in newer PV panels that have less material, this trend will mean less volume to recycle in the future.²²

During the 2019 NC Legislative Session, HB329 was passed.²³ This law requires that DEQ establish a stakeholder process for developing a regulatory program governing end-of-life and decommissioning of PV modules. This stakeholder process will examine issues like determining if renewable energy equipment is hazardous waste, recycling and disposal options, analyzing productive life of equipment, establishing the volume of renewable equipment in the state, and understanding approaches used in other states for end-of-life issues with renewable energy equipment. The NC Environmental Management Commission (EMC) will approve rules developed by DEQ covering the issues outlined in HB329 by January 1, 2022. When rules for this legislation are finalized, there will be implications for project developers that may impact project costs.

4.2.4 Emerging Technology Trends

Along with incremental cost decreases for hardware, there are a number of PV technology trends which could make PV more competitive in the marketplace. Utility-scale PV facilities have used tracking systems for recent projects in NC. Using tracking for residential or commercial PV systems will increase solar conversion efficiencies and allow residential and commercial PV systems to capture more energy in a given space. Another technology gaining a foothold in the marketplace is bifacial panels. Bifacial panels can use light hitting both the front and back of panels, and they are most effective if installed on a reflective or light-colored surface. Bifacial panels gather more energy than traditional panels and they may offer a way to get more power from a confined area, like a roof. Solar combined with storage technology can help the electric grid meet peak generation with renewable generation and can also help customers reduce their peak demand. Solar plus storage can also provide resiliency benefits when the

²¹ Health and Safety Impacts of Solar Photovoltaics, NCSU & NC Clean Energy Technology Center, May 2017, p.9

²² End of Life Management-Solar Photovoltaic Panels, International Energy Agency, 2016

²³ NC General Assembly HB 329, <https://www.ncleg.gov/Sessions/2019/Bills/House/PDF/H329v5.pdf>



electrical grid is down.²⁴ Combining solar with storage technologies addresses the variable nature of solar energy and offers solutions that can replace conventionally fueled generation.

The following sections discussing future solar deployment, grid integration, and costs focus on PV technologies since this technology has had the most impact on NC electric generation grid and is likely to into the future, based on current programs and market trends.

4.3 Future Resource Deployment in NC

Cost trends, technology innovation, and environmental benefits will likely result in increasing PV generation in NC. The sections below discuss the programs and policies that will have a near-term impact on PV deployment in NC.

4.3.1 Policies and Programs Driving Deployment

Enacted in 2007, SB 3 created the NC REPS, an important policy with specific solar deployment targets for the state's investor-owned utilities. Furthermore, the solar programs established in HB 589, *Competitive Energy Solutions for North Carolina*, which was enacted in 2017, will continue to drive solar deployment in the State through 2022. This legislation includes a number of solar programs: a competitive bid program for projects up to 80 MW; a solar rebate program for rooftop or customer-sited solar projects; a large users program for institutions and companies; a third-party leasing program; and a community solar program.²⁵ The act establishes goals for each solar program and, depending on customer participation, competitive bidding, and number of projects in the North Carolina Utilities Interconnection Queue that get interconnected, an additional 6,800 MW of new solar could be installed on the NC electrical grid. The competitive procurement program sets the largest solar installation goal of 2,660 MW. The solar rebate program, which is capped at 20 MW per year, has had strong customer response. In both 2018 and 2019, the rebate program quickly reached the yearly cap early in January. This is an indication of the considerable demand for rooftop solar by utility customers in NC and is also an indication of untapped solar market opportunity.

Another important driver for future deployment is the federal investment tax credit. The federal investment tax credit is currently set at 30% of solar project costs; however, beginning at the end of calendar year 2019, the credit decreases until it reaches 10% in 2022. After 2022, the credit will remain 10% for commercial installations and will expire completely for residential installations, unless it is amended by Congress.²⁶

As previously mentioned, the vast majority of the solar generation in North Carolina occurs at large, utility-scale facilities, in rural areas where land lease costs are lower and more land is available.²⁷ However, there are indications – particularly the quickly exhausted energy rebates provided in HB 589-

²⁴ Newest Technologies in Solar, Energy Sage, <https://news.energysage.com/solar-panel-technology-advances-solar-energy/>

²⁵ NC General Assembly HB 589, <https://www.ncleg.net/Sessions/2017/Bills/House/PDF/H589v6.pdf>

²⁶ Energy Sage, <https://news.energysage.com/congress-extends-the-solar-tax-credit/>

²⁷ NC Solar, Solar Energy Industries Assoc., Q42018, <https://seia.org/state-solar-policy/north-carolina-solar>



that the customer market for rooftop or customer-sited solar at commercial businesses and industries has great potential. When compared to other states, North Carolina has considerably fewer residential rooftop and commercial solar installations; nearly 25% of California’s installations and 50% of New Jersey’s installations are utility-scale projects. Figure 4-7 illustrates the comparatively small amount of residential or commercial solar installations in North Carolina.²⁸

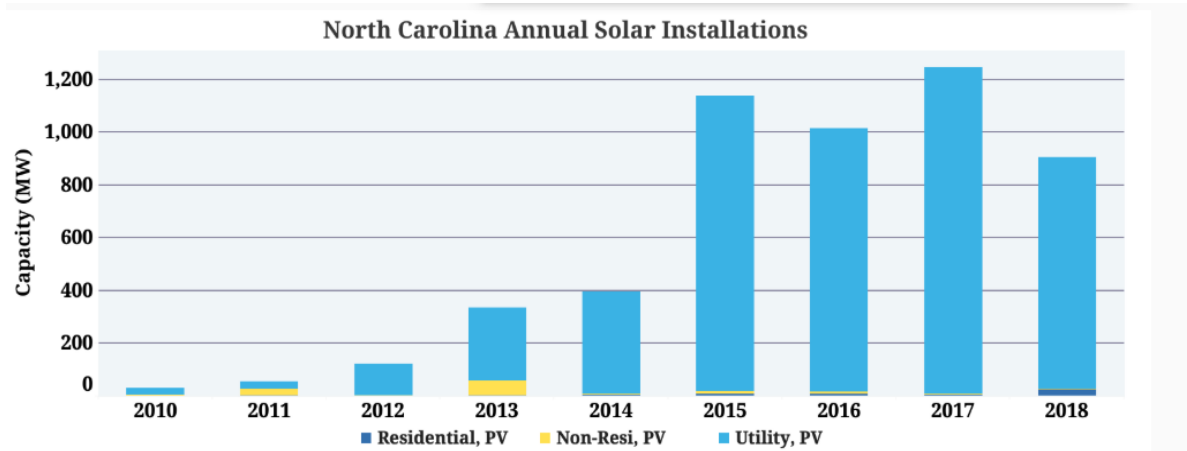


Figure 4-7: NC Annual Solar Installations²⁹

The national data below in Figure 4-8 shows more balanced residential and commercial installations.³⁰ Clearly, the NC solar market at the residential and commercial level is relatively untapped.

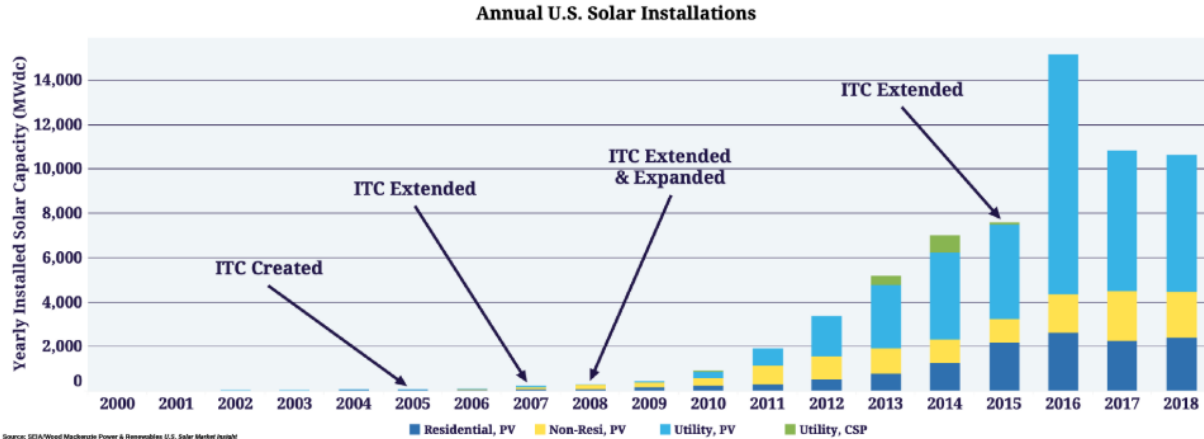


Figure 4-8: Annual U.S. Solar Installations³¹

²⁸ NC Annual Solar Installations, Solar Energy Industries Association, Q4 2018, <https://seia.org/state-solar-policy/north-carolina-solar>

²⁹ Solar Energy Industries Association, accessed June 2019 at <https://www.seia.org/state-solar-policy/north-carolina-solar>

³⁰ Annual U.S. Solar Installations, Solar Energy Industries Association, Q4 2018, <https://www.seia.org/solar-industry-research-data>

³¹ Solar Energy Industries Association, accessed June 2019 at <https://www.seia.org/state-solar-policy/north-carolina-solar>



NC utility-scale solar developers have been able to use economies of scale to quickly build large PV facilities in rural areas. However, commercial and residential PV may have advantages when considering generation and proximity to load. Placing generation adjacent to load may reduce grid infrastructure costs and improve transmission efficiency. Some policies have been identified that have potential to accelerate both residential and commercial solar. Two of these are improved net metering policies and third-party ownership options.³²

HB 589 established a solar leasing program, although only two companies (one of which is Duke Energy) have registered to become solar lessors. NC does not currently allow third-party power purchase agreements (PPAs). While leasing and third-party PPAs offer similar benefits, the federal investment tax credit may not be claimed if the PV system is being leased to a tax-exempt entity. The tax credit may be claimed if a third-party PPA is executed with a tax-exempt entity. Currently, at least 28 states explicitly allow third-party solar PPAs while 7 states explicitly disallow such agreements.³³

Net metering is available in NC, with investor-owned utilities required to provide retail rate crediting for systems up to 1 MW. Municipal utilities and electric cooperatives are not required to offer net metering, so policies, if they exist at all, vary from utility to utility. HB 589 directs Duke Energy to file revised net metering credit rates after a cost-benefit study is completed; these revised rates have not yet been filed yet, but any changes will impact the outlook for behind-the-meter solar in NC. Simplified net metering policies that offer full retail credit for solar generation may encourage customers to install solar at their home or business. In addition, incentives can also be a major market force. There may be no one policy or program that will result in sustained growth of commercial and residential solar markets. It may take incremental action on a number of policy fronts to increase residential and commercial-scale PV.³⁴

4.3.2 Constraints to Deployment

Theoretically, there are few constraints to producing more solar power in NC. Solar technology is both scalable and modular, and the resource itself is spread almost uniformly across the state. Factors limiting the growth of solar energy are likely linked to cost, practical siting and competing land use concerns, and regulatory barriers. A quote from the Balancing Agricultural Productivity with Ground Based Solar PV Development study illustrates solar potential:³⁵

“According to an MIT study, supplying 100% of U.S. electricity demand in 2050 with solar would require use of about 0.4% of the country’s land area; this is only half the amount of land currently used to grow corn for ethanol fuel production, and about the same amount of land as has been disturbed by surface coal mining.”

³² How policies can make or brake solar development in the Southeast, Utility Dive, Dec 2018, <https://www.utilitydive.com/news/how-policies-can-make-or-brake-solar-development-in-the-southeast/544466/>

³³ Database of State Incentives for Renewables and Efficiency, June 2019, https://s3.amazonaws.com/ncsolarcenter-prod/wp-content/uploads/2019/06/DSIRE_3rd-Party-PPA_June_2019.pdf

³⁴ Solar Policy Toolkit, National Conference of State Legislatures, <https://www.seia.org/solar-industry-research-data>

³⁵ Balancing Agricultural Productivity with Ground-Based Solar Photovoltaic (PV) Development, NCSU, Aug 2017, p.6



4.4 Grid Integration and Reliability

4.4.1 Grid Integration

As a variable renewable resource, PV generation at a significantly larger scale (although there is much debate about what constitutes “significant”) will eventually require more advanced grid control to efficiently utilize the higher amounts that will come online in NC. Fortunately, deployment of energy storage technologies and other advanced grid operations and technology improvements can make PV integration easier. Energy storage is more thoroughly discussed in another chapter.

Along with storage deployment, three grid management approaches being used to integrate more renewables include: (i) sub-hourly generation scheduling and faster dispatch; (ii) using expanded balancing areas when additional energy is needed; and (iii) advanced variable generation forecasting. Using five-minute generation scheduling and more frequent dispatch helps grid systems be more efficient, use higher amounts of variable renewable generation like solar, and also reduce reserves needed. Using neighboring balancing areas to the Carolinas grid may help Duke Energy manage its grid with less fluctuation and also help integrate more renewables. Advanced variable generation forecasting is being used by grid operators in the Western Interconnection to improve reliability and schedule generation more efficiently as renewables reach higher penetration rates.³⁶

A National Renewable Energy Laboratory (NREL) operational study looked at ways utility-scale PV can provide important grid functions like frequency control and load following services. The study looked at actual operation of a 20 MW PV facility in Puerto Rico and a 22 MW PV facility in West Texas. Many utility-scale PV facilities already have smart inverters and controls that could enable these PV generators to provide a range of grid services. By operating a PV facility below its rated capacity (possible using current inverter technology), the PV facility can provide additional capacity when needed by the grid – simulating an energy storage device. Of course, a market incentive would be needed for this service as the PV facility owner would lose revenue during these periods of reduced generation. A combination of the new, smart inverters and advanced controls can allow PV facilities to provide grid services including: load following, frequency response, ramping, power quality, spinning reserves, and variability smoothing.³⁷

4.4.2 Resiliency

In 2018, Hurricane Florence provided evidence of how resilient PV installations can be in the aftermath of severe weather events. Many utility-scale PV facilities in eastern NC were undamaged and either produced power during the storm (reduced by cloud cover) or returned to operation after being automatically tripped offline by the grid. Reporting to the NC Energy Policy Council, the NC Sustainable Energy Association had obtained reports from 403 out of a total 431 utility-scale facilities in their database (including Duke-owned PV). Only five sites had damage to equipment and the return to full

³⁶ Operational Changes Are Enhancing System Flexibility, NREL, <https://www.nrel.gov/analysis/insights/2015-04/system-flexibility.html>

³⁷ Advanced Grid-Friendly Controls Demonstration Project for Utility-Scale PV Power Plants, NREL, Jan 2016, <https://www.nrel.gov/docs/fy16osti/65368.pdf>



production was accomplished in under four days at those damaged sites. Utility-scale facilities are typically sited outside flood prone areas and important equipment is usually elevated above the ground, allowing operation even when there is standing water at a site. The PV resource in NC is also widely geographically distributed, which can minimize the impact that severe weather events can have, even those as large as Florence.³⁸ Smaller scale solar (potentially combined with storage) as part of a distributed energy system can also improve resiliency as a backup at critical facilities and as power for remote applications.

4.4.3 Grid Modernization

Grid modernization tools are being used by grid operators to improve the speed and flexibility of electrical grid operations. As distributed energy resources like wind and solar generation, energy storage, demand response, energy efficiency, microgrids, and virtual power plants reach increased penetration, grid modernization is ever more important. Advanced Distribution Management Systems (ADMS) is a term used to describe the integration of various grid functions. These grid functions include: energy analytics like forecasting; outage management; grid supervisory functions like peak power and load allocation; and distributed energy management. Investment in grid modernization has the potential to benefit both grid operations and energy consumers. More efficient grid operation and integration of renewables result in benefits including: improved environmental impacts of power generation, deferred infrastructure and capacity investments, more demand response, more grid flexibility, and improved resiliency.^{39, 40}

4.5 Resource Costs and Benefits

4.5.1 Initial Investment Costs

The National Renewable Energy Laboratory (NREL) conducts research analyzing past, current, and future costs for various energy generation technologies. Below in Figure 4-9 is a national average chart that summarizes this cost information for utility-scale PV that can be found on NREL Annual Technology Baseline webpages. As the chart shows, historical costs of installation, expressed as capital expenditures (CAPEX), decline fairly steeply until 2017. After 2017, CAPEX declines slow, although costs for the mid-cost and low-cost curves continue gradually declining. The high cost case (dashed line) is a conservative case that assumes no improvement beyond 2017, therefore the line for this projection is flat throughout the projection period.

³⁸ NC Energy Policy Council, NCSEA Report on Renewable Energy Assurance, Feb 20, 2019, <https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Energy/Energy%20Policy%20Council/EPC-Combined-Presentations.pdf> - last presentation

³⁹ Distributed Grid Management 101: DERs are reshaping the power grid, ABB, Jan 2019, <https://www.abb-conversations.com/2019/02/distributed-grid-management-101-deres-are-reshaping-the-power-grid/>

⁴⁰ Distributed Grid Management 101: What's Next, ABB, Oct 2018, <https://new.abb.com/us/smartgrids/events-calendar/webinars>

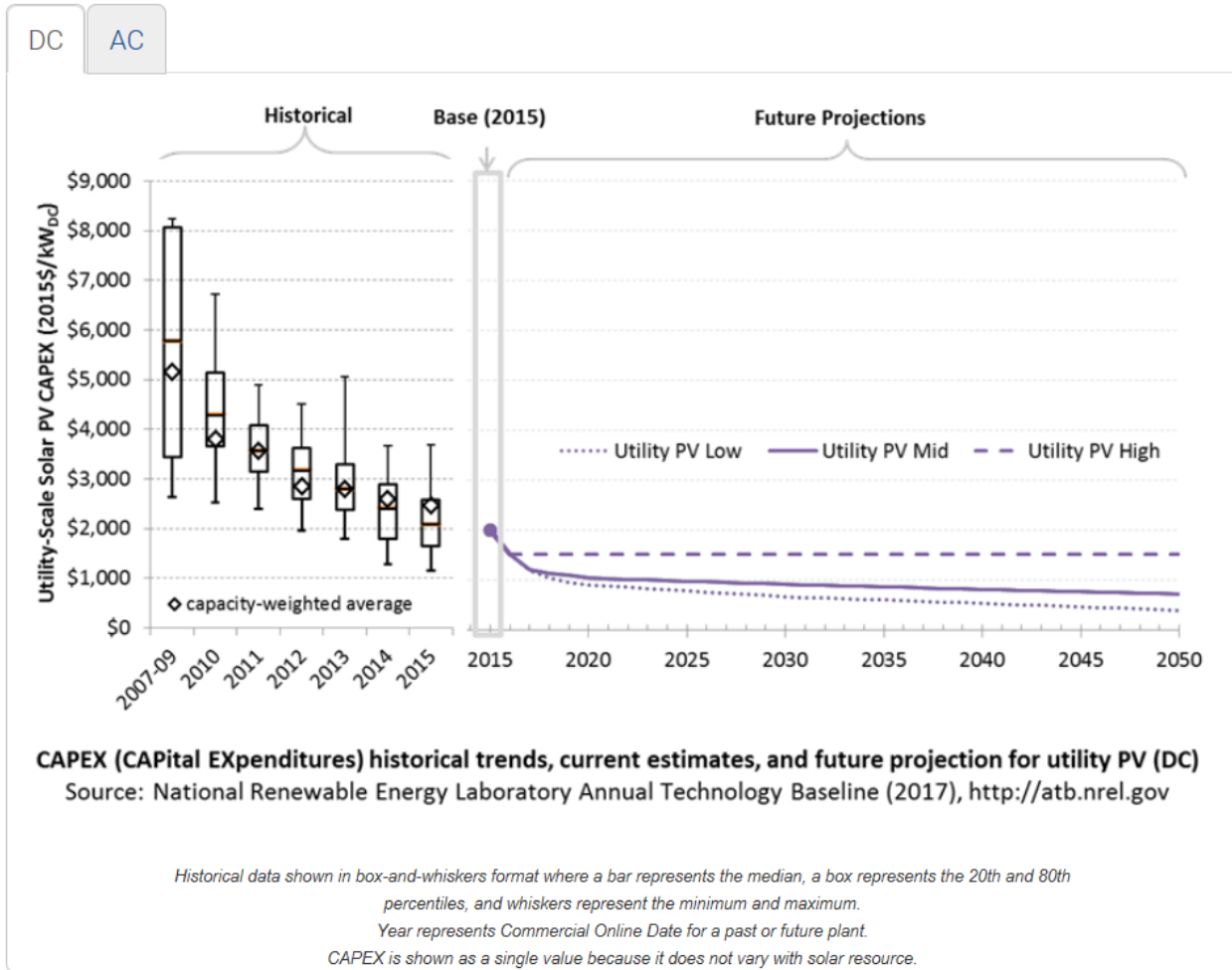


Figure 4-9: Utility-Scale PV Installation Costs (CAPEX) in \$/kW⁴¹

4.5.2 Operating and Recurring Costs

NREL also presents levelized cost of energy (LCOE) projections for utility-scale PV. The NREL levelized cost of energy information incorporates CAPEX (noted above) as well as operation and maintenance costs and capacity factor projections for the contiguous United States. The chart below (Figure 4-10) shows the expected impacts of both market forces and research and development on the levelized cost of utility-scale PV. In the chart, NREL presents both a mid- and low-cost case for comparison and uses a shaded curve with upper and lower boundary cost averages, and a solid line to indicate actual costs for a specific location noted in the chart. The chart shows that PV cost of energy continues to decline through year 2046. There are a number of factors important for continued cost declines. Module efficiency increases and better economies of scale in manufacturing will help. Lowered costs for components like racking and integration of components on modules are another factor.

⁴¹ Annual Technology Baseline-CAPEX, NREL, 2018, <https://atb.nrel.gov/electricity/2018/index.html?t=su>



Improvements in power electronics can also mean better efficiencies and lowered costs. Cost reductions can also come from reduced regulations for siting and interconnection.

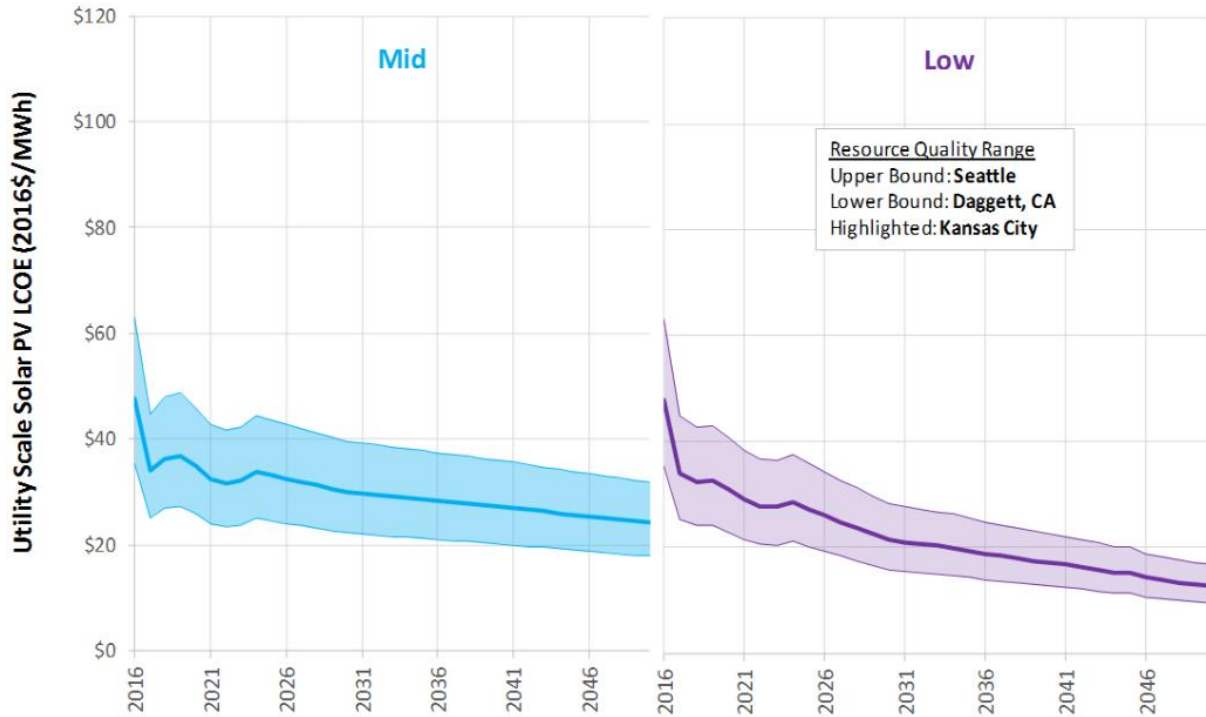


Figure 4-10: Utility-Scale PV LCOE With Market and R&D Financials⁴²

In sum, these cost charts show PV costs are likely to decline which may continue to keep utility-scale PV competitive with conventional generation technologies. It should be noted that this same analysis at the NREL Annual Technology Baseline website shows similar declining cost curves for commercial and residential PV although the commercial and residential curves have higher costs than the utility-scale PV curve.⁴³

4.5.3 Financing Trends and Options

Financing options, such as loans or leases, may help to expand solar access to new people, especially those in lower income or disadvantaged communities. North Carolina does not have any state loan programs for solar, but a variety of loan products are available from private financial institutions. Property Assessed Clean Energy (PACE) financing is another financing option that currently available to commercial entities in NC. PACE financing allows the business to pay for solar or energy efficiency upgrades through an additional property tax assessment.

Another financing option for solar PV is third-party ownership. Solar leasing is authorized in NC up to 1% of peak demand, while third-party power purchase agreements (PPAs) are not permitted in the state. See Page 12 for more information on solar leasing and third-party PPAs in NC. According to Wood

⁴² Annual Technology Baseline-LCOE, NREL, 2018, <https://atb.nrel.gov/electricity/2018/index.html?t=su&s=pr>

⁴³ Annual Technology Baseline-Introduction, NREL, 2018, <https://atb.nrel.gov/electricity/2018/index.html>



Mackenzie (formerly GTM Research), solar loans overtook third-party ownership as the dominant residential solar financing model in 2018.⁴⁴ However, Wood Mackenzie also predicts that third-party ownership will increase to 78% by 2021 for commercial solar PV projects.⁴⁵

Another ownership model for solar PV is community solar, whereby individual customers may purchase or subscribe to a share of a larger solar array. HB 589 required Duke Energy to develop a community solar program and credit subscribing customers at the utility's avoided cost rate. NC does not permit third parties to develop community solar projects. At least 21 states have some type of community solar enabling policy in place, with 17 of these states allowing third parties to develop community solar projects.⁴⁶

⁴⁴ Christian Roselund, PV Magazine USA, Solar loans overtake third-party as dominant residential solar model, July 2018, <https://pv-magazine-usa.com/2018/07/11/solar-loans-overtake-third-party-ownership-as-dominant-residential-solar-model/>

⁴⁵ Michelle Davis, Greentech Media, Commercial Solar May Be 78% Third-Party Owned by 2021, April 2018, <https://www.greentechmedia.com/articles/read/commercial-solar-expected-to-be-78-third-party-owned-by-2021#gs.orou4r>

⁴⁶ NC Clean Energy Technology Center, DSIRE Insight Solar Policy Data Sheet, July 2019.



5. Energy Storage

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5.1 Energy Storage Introduction

Energy storage technologies are a newer power resource, and do not add new generation, but can provide variable energy input, electric grid management services, and can reduce peak demand. Due to cost reductions in battery storage, this technology is emerging as a fully scalable and versatile energy storage technology. Combined with variable, renewable generation technologies like wind and solar energy, energy storage can integrate these variable resources on to the NC electrical grid making renewable generation output smoother and more dispatchable.¹ An indication of the growth in US energy storage deployment is shown in the chart below. Utilities have quickly added energy storage to their operations over the last several years with growth expected to continue.

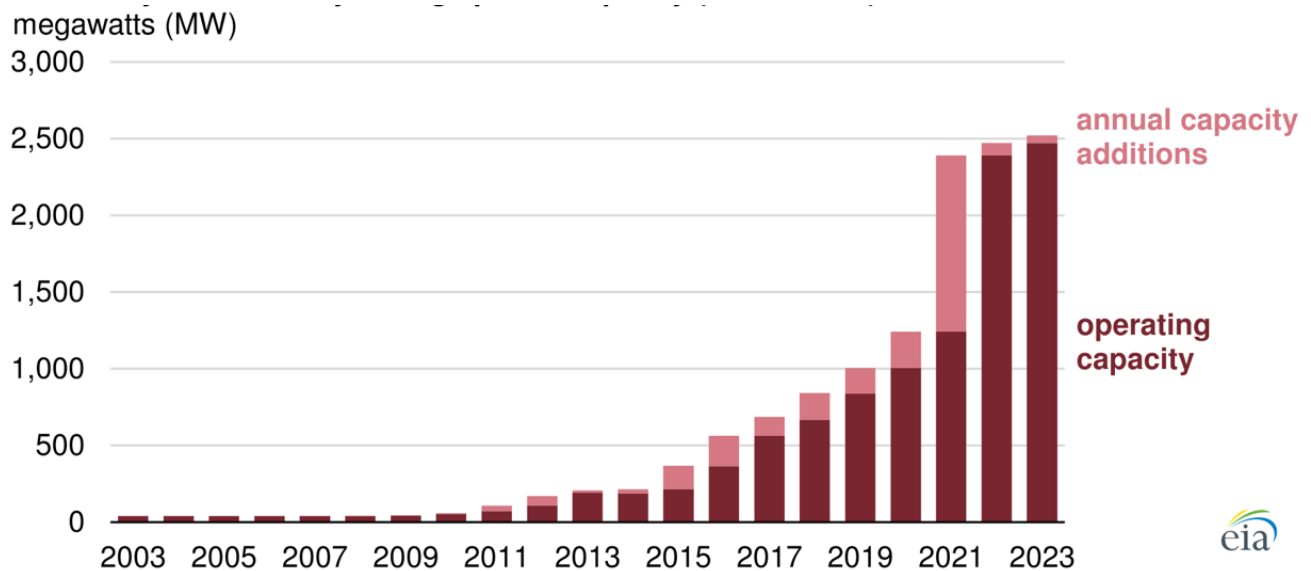


Figure 5-1: U.S. Utility Energy Storage Capacity (EIA, 2019)²

5.1.1 NC Current and Planned Energy Storage

In North Carolina, thermal storage is currently more common than battery storage. There are over 80 chilled water and ice thermal storage projects installed. These projects help a building or facility reduce air conditioning load by using stored ice generated during low-energy cost times to provide cooling during high-energy cost times. Pumped hydro is another storage technology in NC. At the Hiwassee Dam in NC, the Tennessee Valley Authority operates a pumped storage facility using a reversible pump to store water behind a dam. The Hiwassee storage facility has a 124 MW capacity. Large pumped hydro facilities in South Carolina have been used by Duke Energy (the Bad Creek and Jocassee facilities) to help support NC grid balancing. The Bad Creek facility is being expanded and will have higher capacity (going from 1000 MW to 1400 MW) partly to help balance the large solar buildout in NC.

¹ U.S. Department of Energy. *Energy Storage*. Accessed at <https://www.energy.gov/oe/activities/technology-development/energy-storage>.

² U.S. Energy Information Administration. (2019). *U.S. utility-scale battery storage power capacity to grow substantially by 2023*. Accessed on 7/22/19 at <https://www.eia.gov/todayinenergy/detail.php?id=40072>.



Battery storage is a newer technology. Only about 1 MW of battery storage capacity has been installed in NC as of 2018 although several battery projects are planned. A large NC solar developer, Cypress Creek plans 12 MWH of battery storage facilities coupled with solar for Brunswick Electric Membership Corporation. As part of a community solar project, a 500 kW Li-ion battery combined with a 1 MW solar project is planned for Fayetteville Public Works Commission³. Another proposed storage project is a Duke Energy solar PV plus storage project in Hot Springs that was approved by the NC Utilities Commission (NCUC) in May 2019. This solar plus storage project will include 2 MW of solar and a 4 MW battery and is intended to improve electric reliability in the town, which is on a constrained transmission line.⁴

The 2018 Integrated Resource Plans (IRPs) for Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) indicate that a total of 291 MW of battery storage is expected to be installed by 2033 for both DEC and DEP combined.

5.1.2 Technology Description

Energy storage can be defined as “a system used to store electrical, mechanical, chemical, or thermal energy that was once electrical energy, for use in a process that contributes to end-user demand management or grid operation and reliability.”⁵ There are a range of energy storage technologies available. Some of these technologies, like pumped hydro storage, ice, and cooled water storage have been used in NC for years. Others like batteries, super capacitors, compressed air, and flywheels are less common in NC. Batteries, in particular lithium-ion (Li-ion) batteries, have potential for wide-scale deployment because they are modular, have relatively high energy densities, and they are not site-specific like pumped hydro or compressed air systems.

Energy storage technologies have been used by utilities, local governments, businesses, and individuals to control energy use. Thermal storage technologies are typically used in a building or by a network of buildings connected by a district pipe system (commonly called district heating or cooling). Thermal storage can either be used to store and distribute heat or chilled water taking advantage of off-peak energy or using higher efficiency, centrally located thermal or compressor plants. By storing hot water or chilled water/ice, a building operator or network of buildings owned by a local government can reduce peak heating or cooling loads. Hot water tanks used in residential and commercial settings can also function as thermal storage.

There are several electromechanical energy storage technologies. Pumped hydro is a technology that typically uses off-peak electricity to pump water to an uphill reservoir where it can be released to flow

³ North Carolina State University, DeCarolis et al. (2018). *Energy Storage Options for North Carolina*. p.4. Retrieved from <https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf>.

⁴ Utility Dive. (2019). *NC approves Duke's first solar+storage residential microgrid*. Accessed at www.utilitydive.com/news/north-carolina-approves-dukes-first-solarstorage-residential-microgrid/554770/.

⁵ North Carolina State University, DeCarolis et al. (2018). *Energy Storage Options for North Carolina*. p.1. Retrieved from <https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf>.



through generators creating electricity for use when needed, commonly during peak usage times. Another electromechanical technology is compressed air storage. This technology takes advantage of off-peak electricity to compress air which is commonly stored underground. Thermal processes convert this compressed air to lower-cost electricity for use at peak times. Flywheels take advantage of rotational energy used to generate electricity. Flywheels commonly use a rotor spinning at high speeds in a low friction enclosure. Flywheels are typically used for short periods to provide power quality services like frequency regulation.

Battery storage technologies use various electrolyte chemistries to store electrical energy as chemical energy and then release it as electrical energy. Lead acid batteries were the first rechargeable batteries and are commonly used in a range of applications from automotive to grid-scale technologies due to their relative low costs. Lithium-ion (Li-ion) batteries have several advantages over lead acid batteries, including a higher power density and a faster charge rate. For these reasons, Li-ion batteries have been the technology of choice by utilities over the last several years – as noted by their increasing use in grid-scale applications (100% of grid-scale battery applications in the US used lithium chemistry in 2016)⁶. Another factor driving Li-ion deployment is a large drop in pricing. Utility-scale, Li-ion system pricing dropped 29% between 2014-2015 and is expected to drop 36% by 2022.⁷ A Department of Energy (US DOE) Report discussing both utility-scale solar and energy storage notes that utilities in the US have been responsible for 40% of the global deployment of Li-ion storage between 2005-2017.⁸ Flow batteries use a liquid electrolyte held in separate containers, an electric current occurs when the flow battery is connected to a load. Flow batteries are not widely in use like lead acid or Li-ion batteries, due to higher installed costs.

Supercapacitors are devices that use metal plates and an electrolyte to form a conductive interface. Supercapacitors are used in applications requiring many charging/discharging cycles and are notable for fast response times. Supercapacitors are good for short bursts of power but have limited energy capacity. For further, more detailed discussion of energy storage technologies, refer to the *Energy Storage Options for North Carolina* report⁹.

⁶ North Carolina State University, DeCarolis et al. (2018). *Energy Storage Options for North Carolina*. p.18. Retrieved from <https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf>.

⁷ Environmental Defense Fund Blog. (2019). *Energy storage market booms, with more growth to come*. Accessed at <https://www.edf.org/energy/energy-storage>.

⁸ National Renewable Energy Laboratory; Fu, R., Remo, T., Margolis, R. (2018) *U.S. Utility-Scale Photovoltaics Plus-Energy Storage System Costs Benchmark*. Accessed at <https://www.nrel.gov/docs/fy19osti/71714.pdf>.

⁹ North Carolina State University, DeCarolis et al. (2018). *Energy Storage Options for North Carolina*. Chapter 4. Retrieved from <https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf>.



5.2 Energy Storage Technology Overview and Application

5.2.1 Technology Benefits and Limitations

Energy storage services can be categorized in three general areas: 1) end user services, 2) distribution and transmission services, and 3) grid resource adequacy services. End user services occur behind the meter (serving a customer residence, business, or facility) and allow energy storage to help customers control their peak usage and/or adhere to time of use rates. Customers can also use energy storage to provide their own electrical energy when the grid may not be available, increasing the resiliency at a residence, business, or community. In this way, energy storage can reduce customer utility bills and can also help utilities reduce peak demand. Energy storage used for distribution and transmission services can help control voltage fluctuations, reduce peak capacity, defer capacity additions, and help with transmission congestion. And finally, energy storage can effectively address grid resource issues allowing low-cost or clean generation to charge energy storage during low cost times and discharge the stored energy during high cost times reducing peak and shifting energy usage to non-peak times. Energy storage can also prevent solar (or other variable renewable generator) curtailment by absorbing excess peak generation for later use on the system.

The chart below, from the *Energy Storage Options for North Carolina* study, notes different energy storage technologies and shows which energy services are currently economically feasible in NC. Because Li-ion battery prices have exhibited sharp declines recently, the chart also shows Li-ion economics for services Li-ion storage could provide in 2030.

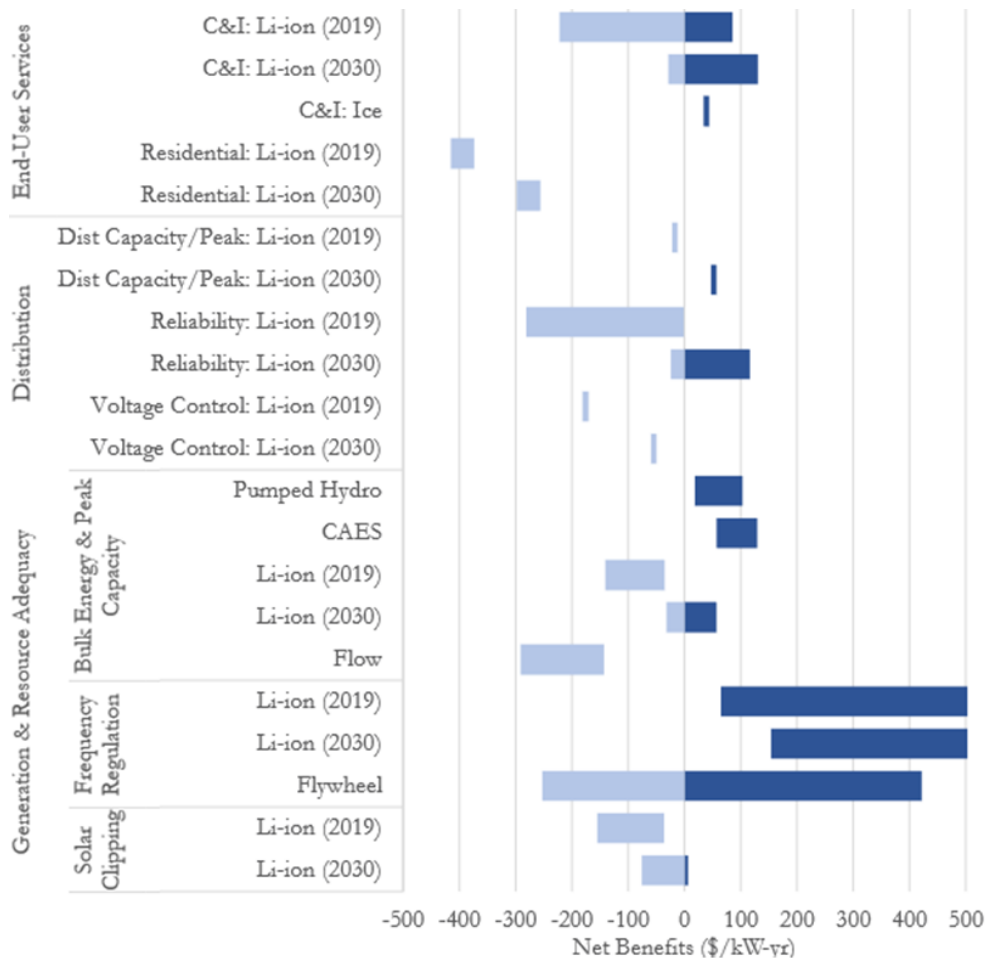


Figure 5-2: Energy Storage Technologies and Services – Net Benefits*

*Range of net benefits (\$/kWyr) for each technology and service category analyzed. Light blue bars represent negative net benefits (i.e., costs exceed benefits), while dark blue bars represent positive net benefits (i.e., benefits exceed costs). Results assuming current Li-ion battery costs in 2019 and projected 2030 costs are presented separately. Note that Li-ion battery benefits for frequency regulation exceed \$500/kWyr but are truncated for readability¹⁰.

Figure 5-2 shows that pumped hydro, compressed air energy storage (CAES), and ice storage are cost effective now. But these technologies are site specific and cannot be deployed or enlarged as easily as battery storage technologies. Flywheels typically are not big enough to provide grid-scale energy storage and their use has been primarily for frequency regulation. Batteries seem to have emerged as the most flexible energy storage technology due to the range of services they can provide, high power density, and variable sizing – everything from tiny watch batteries to the 36 MW Notrees windfarm energy storage project in Texas. Due to their recent steep pricing declines, Li-ion batteries have been the favored

¹⁰ North Carolina State University, DeCarolis et al. (2018). *Energy Storage Options for North Carolina*. p.iii. Retrieved from <https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf>.



technology deployed recently in grid-scale applications. Large companies like Tesla, Panasonic, and Samsung are using Li-ion batteries in electric vehicles (EVs), grid applications, as well as pairing these battery systems with solar or wind facilities.¹¹

5.2.2 Installation and Recycling

The simplest energy storage technologies to install are batteries, due to their high power density, modular deployment options, and small footprint. Residential battery storage can be installed inside or outside on a wall. At a business or institutional facility, battery storage can occupy the same approximate footprint as back-up, fossil fuel generators. At the grid level, battery storage can be installed at a substation or at generation facilities. Pumped hydro is limited to very specific sites, commonly associated with existing reservoirs. No new pumped hydro facilities are noted in the Duke Energy 2018 IRPs.

The other common NC energy storage technology, thermal storage, is usually sited at customer businesses or facilities. Thermal storage does require large tanks or dedicated areas of buildings, making it difficult to add thermal storage to existing buildings. District thermal storage requires advanced planning to site large tanks and design piping and pumps to serve a network of buildings. Thermal storage is typically employed on the customer side of the meter and used to reduce customer peak demand charges.

The recycling industry is just getting started for Li-ion batteries. With the growth of Li-ion batteries used for both EVs and electric grid energy storage, it will be necessary to find sustainable ways to recycle batteries. The US DOE recently opened a Li-ion battery recycling center at the Argonne Laboratories in Illinois. The goal of this recycling center to develop and test profitable ways to recycle Li-ion batteries¹². A recent article in PV Magazine notes that a Finnish company is ramping up a Li-ion battery recycling facility that is using a low CO₂ process to reclaim various important materials like cobalt, lithium, nickel, and manganese and achieving an 80% recycling rate.¹³

5.2.3 Emerging Technology Trends

The use of battery storage by utilities in the US is expected to increase. In addition, deployment of solar plus storage projects is also expected to increase. The use of more storage plus renewable generation projects means that solar or other renewable resources will be more dispatchable and able to provide variable generation services to the electric grid, like conventional generators. Deployment of storage plus renewables projects involves a range of choices depending on the site, market incentives available, storage services desired, and technology selected. A major NC solar developer, Cypress Creek Renewables, is developing a NC project for Brunswick Electric Membership Coop that will pair solar and battery storage at 12 sites. Indications are that this Cypress Creek solar plus storage project will seek to reduce peak electricity costs and provide dispatchable solar power. Another notable project described in

¹¹ North Carolina State University, DeCarolis et al. (2018). *Energy Storage Options for North Carolina*. p.18. Retrieved from <https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf>.

¹² Recycling Today. (2019). *DOE opens lithium-ion battery recycling center*. Accessed at www.recyclingtoday.com/article/doe-argonne-lithium-ion-battery-recycling-research/.

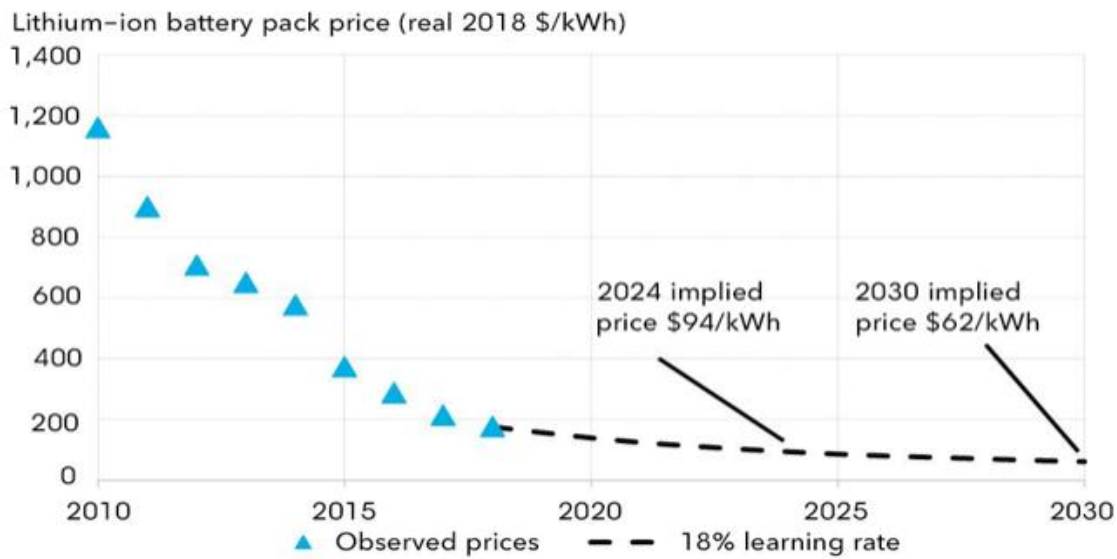
¹³ PV Magazine. (2019). *Innovation boosts lithium-ion battery recycling rate to over 80%*. Accessed at www.pv-magazine.com/2019/03/25/innovation-boosts-lithium-ion-battery-recycling-rate-to-over-80/.



the same article discussing the Cypress Creek project is a Florida solar plus storage facility. The Florida project combines 74.5 MW of solar with 10 MW of batteries. The Florida project will serve Babcock Ranches, designed as a 100% solar community.¹⁴ US DOE research notes that combining a solar and storage project can offer installation cost reductions in terms of reduced land, interconnection, permitting, switchgear, and transformer costs.¹⁵

5.3 Resource Costs

The charts below show cost trends for battery storage. The first one from Bloomberg New Energy Finance, Figure 5-3, shows how costs per kWh for Li-ion batteries (the predominant energy storage technology currently being installed) have come down steeply from 2010. In the future, the price per kWh for Li-ion battery packs is not expected to decrease as rapidly. The second chart from Lazard, Figure 5-4, compares the predominant battery technologies and system cost trends as well as noting factors important in these cost trends. Figure 5-4 also shows a declining cost trend for the selected technologies.



Source: BloombergNEF

Figure 5-3: Li-ion Battery Pack Prices Per kWh¹⁶

¹⁴ PV Magazine. (2019). *Cypress Creek launches solar+storage in North Carolina*. Accessed at <https://pv-magazine-usa.com/2018/03/28/cypress-creek-launching-dc-coupled-solarstorage-in-north-carolina/>.

¹⁵ National Renewable Energy Laboratory, Fu,R, Remo, T., Margolis, R. (2018). *U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark*.

¹⁶ Bloomberg New Energy Finance, Goldie-Scot, L. (2019). *A Behind the Scenes Take on Lithium Battery Prices*. Accessed at <https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/>.



	Capital Cost (\$/kWh)		Average	Technology Trends & Opportunities
Lithium-Ion		CAGR	(8%)	<ul style="list-style-type: none"> Increased variation in magnitude of cost declines going forward Battery OEMs reduce proportion of cobalt to mitigate higher raw material Potential volatility from near-term capacity tightness, followed by multiple new production lines and price-based competition from new entrants Slower cost declines in BOS, EPC and PCS costs, which represent increasing share of total system cost
		5-Year	(28%)	
Flow Battery–Vanadium		CAGR	(11%)	<ul style="list-style-type: none"> Cost declines through increased manufacturing scale and energy densities Long-term contracts with vanadium providers to make costs more predictable Focus on providing plug and play (e.g., turnkey) units to keep EPC costs down
		5-Year	(38%)	
Flow Battery–Zinc Bromide		CAGR	(14%)	<ul style="list-style-type: none"> Cost declines through increased manufacturing scale and increased densities (e.g., thicker zinc plating) Reduced cost through more widely available components (e.g., pumps and valves) Expectations of reductions in EPC and PCS costs
		5-Year	(45%)	
Lead		CAGR	(3%)	<ul style="list-style-type: none"> Limited usability and performance translates into high levelized cost Limited cost improvement expected
		5-Year	(13%)	
Advanced Lead		CAGR	(4%)	<ul style="list-style-type: none"> Greater performance than typical lead-acid options Cost reduction and performance improvements expected to continue OEMs looking to use this class to address larger commercial systems not typically served by lead acid
		5-Year	(17%)	

Figure 5-4: Battery Storage Cost Trends ¹⁷

5.4 Grid Integration and Reliability

An evolving NC energy grid will undoubtedly have more energy storage, likely in the form of batteries. Because batteries can provide a range of grid services and their cost is declining, batteries will probably play a larger role in integrating variable renewable energy (RE) as well as supporting grid services like frequency control and voltage regulation. Duke Energy notes the role batteries can play in the following quote from their 2018 IRP:¹⁸

“Battery storage costs are expected to continue to decline, which may make this resource a viable option for grid support services, including frequency regulation, solar smoothing during periods with high incidences of intermittency, as well as the potential to provide overall energy and capacity value. Energy storage can also provide value to the transmission and distribution (T&D) system by deferring or eliminating traditional upgrades and can be used to improve reliability and power quality to locations on the Company’s distribution system.”

As the quote from the Duke IRP notes, batteries can play a variety of roles integrating variable clean generation sources and supporting the electric grid. Used by themselves, batteries can perform many of the grid functions that conventional generation performs. Used in tandem with renewable generation, batteries can address the variability of generation from RE sources and help with load following requirements. Batteries can also help meet peak demand, and if charged with clean generation, supply clean peak energy.

¹⁷ Lazard. (2019). *Lazard’s Levelized Cost Of Storage Analysis*. Accessed at <https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2018/>.

¹⁸ Duke Energy Carolinas IRP, Sept 2018, p. 33.



5.4.1 Resiliency

Batteries are well suited to support resiliency functions and can be used by themselves, providing a limited amount of power for use when conventional grid access is not available. When paired with a renewable resource like solar, batteries can provide power over multiple days depending on the size and configuration of the priority loads and weather conditions.

In addition, resiliency projects using a microgrid can have a combination of solar and batteries providing power in communities prone to interrupted grid power. An example of this is the Hot Springs, NC project being installed by Duke Energy. This project will have 2 MW of solar and 4 MW of Li-ion battery. The Hot Springs project will provide back-up power to a remote community of 500 residents in the NC mountains.

5.4.2 Grid Modernization

Common elements of grid modernization include: integration of distributed generation; use of digital technology to capture grid conditions and analyze large amounts of data; more efficient use of infrastructure; optimizing use of renewable generation; and increasing integration of electrified transportation. Grid modernization objectives include reduced emissions and cleaner generation, increased resiliency, and greater efficiency and reliability.¹⁹ Battery storage can support grid modernization elements noted above, helping achieve a cleaner, more efficient and reliable grid. The sections above have illustrated how batteries can support increased renewables integration, enhanced resiliency, and support for grid services like voltage control and frequency regulation. Batteries are also easily integrated into digital information and control networks, since the control systems for batteries are digital and batteries can respond quickly to changing grid conditions. It is even possible that the batteries in EVs could be used by the grid when these vehicles are not in use.

Nationally, many states and utilities are engaged in grid modernization. The 2018 50 States of Grid Modernization²⁰ report notes that storage technology deployment is the most common activity being undertaken among a long list of technology deployment, rule-making, and study efforts supporting grid modernization. This is an indication of how states and utilities view the important role energy storage can play in grid modernization.

5.5 Policies and Programs Driving Deployment

NC does not have any programs specifically designed to facilitate energy storage installations. However, there are policy actions underway in NC that have energy storage deployment implications. One recent storage related policy action was the HB 589 directive that an energy storage study be completed by the NC Collaboratory at UNC Chapel Hill.²¹ That study was delivered in December 2018. HB 589 has a

¹⁹ Environmental Defense Fund. (2017). *Grid Modernization*. Accessed at www.edf.org/sites/default/files/GridModReport.pdf.

²⁰ NC Clean Energy Technology Center. (2019). *50 States of Grid Modernization*. Accessed at <https://nccleantech.ncsu.edu/our-work/policy/the-50-states-reports/>.

²¹ NC Session Law 2017-192. *Competitive Energy Solutions for NC House Bill 589*. Accessed at <https://www.ncleg.gov/BillLookup/2017/h589>



number of PV deployment program goals for NC²². In addition, NC Utility Commission dockets dealing with one of HB589 programs, Competitive Procurement of Renewable Energy (CPRE), have topics relevant to energy storage. One docket in particular deals with energy storage protocol that is a part of the CPRE power purchase agreements. In docket hearings, it was noted that electric grid ancillary services, like frequency regulation and voltage control which are particularly suited to batteries, have no transparent market value in NC, making it difficult to monetize the value of these services for a developer considering installing battery storage. Comments by NC Utilities Commission Public Staff regarding the lack of energy storage market transparency in NC is summarized below²³:

First, the Public Staff further states that market participants and Duke generally agree that energy storage can provide many grid benefits, such as frequency regulation, operational reserves, and firm capacity; however, there is no mechanism to pay market participants for these services.

Although price declines will play a role in increasing energy storage in NC, policies may also be necessary to integrate energy storage onto the NC electric grid supporting a timely shift to clean energy. The chart below identifies policy actions being taken to encourage energy storage deployment at the state and federal level. This chart specifically looks at grid level policies identified in the chart as “front of the meter”.

Front-of-the-meter policy and market developments, Q1 2019

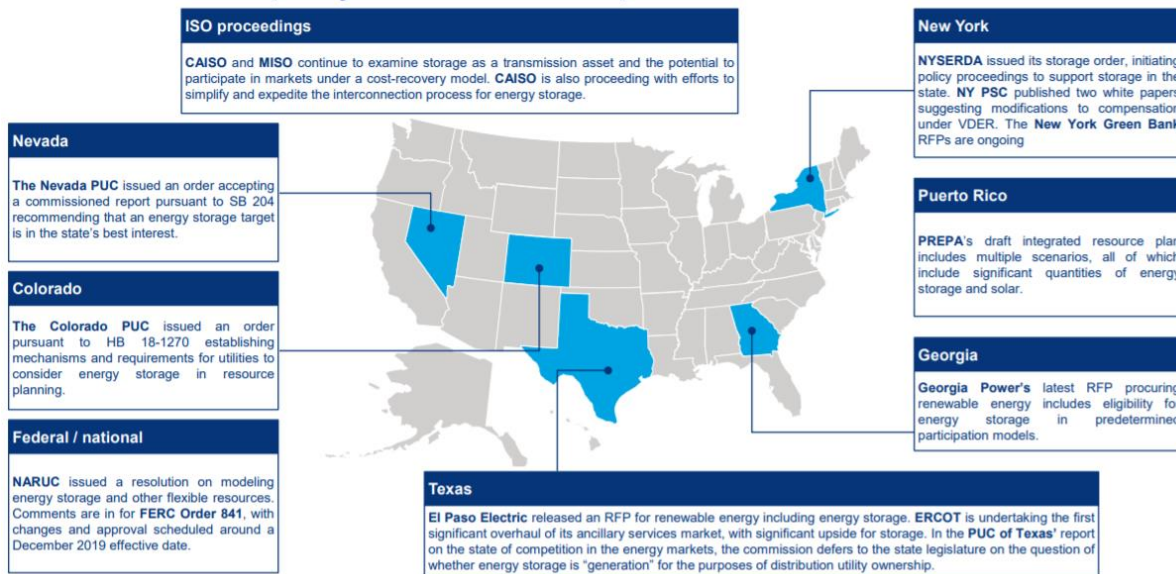


Figure 5-5: 2018 Energy Storage Policy Developments²⁴

²² HB589 is discussed in the Clean Energy Plan section NC Energy Policy Landscape.

²³ NC Utilities Commission. May 1, 2019. Docket E-2 Sub 1159, E-7 Sub 1156 Hearing, p. 14.

²⁴ Energy Storage Association. (2019). *2018 Year in review and Q1 2019 executive summary*. Accessed from Wood-Mackenzie website at <https://www.woodmac.com/research/products/power-and-renewables/us-energy-storage-monitor/>.



At the federal level, Federal Energy Regulatory Commission (FERC) Order 841 (highlighted in the bottom left corner of Figure 5-5 above) encourages regional transmission organizations (RTO) and independent system operators (ISO) to provide markets for energy storage services.²⁵ FERC Order 841 does not apply to Duke Energy as Duke Energy operations in NC are not part of either an RTO or ISO.

During the 2019 NC Legislative Session, HB 329 was passed.²⁶ This law requires that DEQ establish a stakeholder process for developing a regulatory program governing end-of-life and decommissioning of energy storage equipment (and other renewable equipment). This stakeholder process will examine issues like determining if RE equipment is hazardous waste, recycling and disposal options, analyzing productive life of equipment, establishing the volume of renewable equipment in the state, and understanding approaches used in other states for end-of-life issues with RE equipment. The NC Environmental Management Commission (EMC) will approve rules developed by DEQ covering the issues outlined in HB 329 by January 1, 2021. When rules for this legislation are finalized, there will be implications for project developers that may impact project costs.

There are a range of options NC could consider that would facilitate energy storage deployment, including: interconnection policy clarification; defining storage ownership; development of local energy storage codes; and evaluating net metering related to energy storage. Policy options that would further encourage energy storage deployment include: establishing energy storage tariffs and storage standard offers; setting utility procurement goals; and establishing a clean peak standard. For more detailed discussion of NC policy and market options supporting energy storage deployment, refer to *Energy Storage Options for NC*.²⁷

²⁵ GTM Research. (2018). *5 Predictions for Energy Storage Market Going Into 2019*. Accessed at www.greentechmedia.com/articles/read/five-predictions-for-the-global-energy-storage-market-in-2019#gs.5amkhi

²⁶ NC Session Law 2019-132, Renewable Energy Amends. “(II) Require the Environmental Management Commission to Adopt Rules to Establish a Regulatory Program to Govern the Management of End-of-Life Photovoltaic Modules and Energy Storage System Batteries, and Decommissioning of Utility-Scale Solar Projects and Wind Energy Facilities, and Require the Department of Environmental Quality to Establish a Stakeholder Process to Support Development of the Rules.” <https://www.ncleg.gov/Sessions/2019/Bills/House/PDF/H329v5.pdf>.

²⁷ North Carolina State University, DeCarolis et al. (2018). *Energy Storage Options for North Carolina*. Chapter 9. Retrieved from <https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf>.





6. Hydropower

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6.1. Hydropower Introduction

Hydropower has a long history in NC dating back to 1898 when the first storage dam was built in the mountains to the current level of approximately 70 locations across the state¹. Since its first use, hydropower was used in privately-owned distributed generation and utility scale generation scale applications. With this rich history of providing electricity, recreation, irrigation for farming, and jobs to NC, hydropower was the dominant renewable energy (RE) source in the state until 2017¹. New research and development are occurring to improve turbine efficiency and reduce the number of fish kills with turbines, and in the hydrokinetic area to generate electricity in the ocean. In addition, innovative improvements to existing and new facility designs are being implemented to reduce impact to wildlife migration.

6.1.1 Technology Definition and Description

Hydropower can be defined as energy in the form of electricity produced from flowing water through a turbine connected to a generator. Hydropower can be categorized into four broad areas: (1) run-of-river; (2) storage; (3) pumped-storage; and (4) offshore. In NC, storage and pumped storage are the primary categories that hydropower electricity is generated, with very few run-of-river hydropower and no hydrokinetic.

- **Run-of-river hydropower** – Water from a river is diverted to run through a canal or penstock to drive a turbine. Water is normally not stored in this category and can provide electricity continuously as a baseload for a utility company.
- **Storage hydropower** – Water is contained in a reservoir behind a dam and released as needed to drive a turbine located within the dam itself. This is the more conventional and common approach to using water to produce electricity. Electricity can be supplied for the baseload, intermittent load, or for peak loads by the utility company.
- **Pumped-storage hydropower** – Water is pumped from a lower reservoir to a higher reservoir where it can flow by gravity into a turbine to produce electricity similar to storage hydropower. Electricity produced by pumped storage is normally used for peak loads by utility companies.
- **Offshore hydropower/hydrokinetic** – Many technologies fall into this category which harnesses tidal stream or tidal range, or wave power to turn a turbine to generate electricity.

6.1.2 Background and Historical Use in NC

Hydropower, in the category of storage, has been in use in NC since 1898 with the opening of the Idol's Hydroelectric Station in Forsyth County². NC ranks 1st in the South Atlantic region of the country and 11th nationwide in hydroelectric generation in 2018 with 5,001 thousand MWh generated in 2018. From the first hydropower dam until now with approximately 70 currently in use in NC, hydropower was the largest RE in NC until 2017, when it was surpassed by solar power¹. The vast majority of hydropower in NC is located in the western part of the state where rivers and higher elevations are more prevalent, as

¹ U.S. Energy Information Administration (2018). NC Profile Analysis. Retrieve May 2019 from, <https://www.eia.gov/state/analysis.php?sid=NC>

² North Carolina Department of Natural and Cultural Resources. *Hydroelectric Power Introduced 1898*. Retrieve May 2019 from, <https://www.ncdcr.gov/blog/2016/04/20/hydroelectric-power-introduced-1898>



shown in Figure 6-1 below. Electricity generated from hydropower is used for peak-shaving, intermittent, intermediate, or as baseload usage depending on the location in the state.

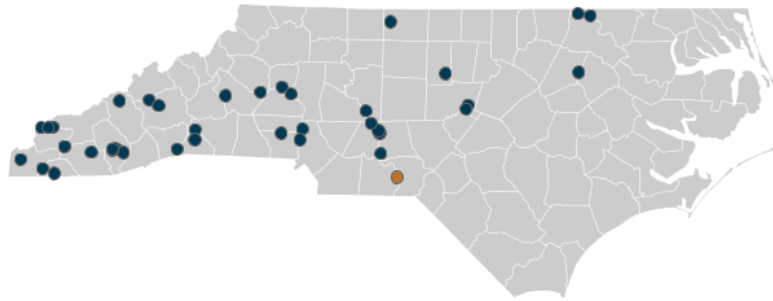


Figure 6-1: NC Hydropower Locations³

6.1.3 Installed and Planned/Anticipated Capacity Growth and Generation Outlook in NC

There are 38 hydropower facilities located in NC totaling 129 MW of generation as shown in Figure 6-1, based on registration with the North Carolina Utilities Commission (NCUC) as renewable energy generating facilities⁴. Of these facilities, two are larger, sized at 16 MW and 31.5 MW with the rest being smaller than 10 MW. DEC owns and operates nine of these facilities, with a combined capacity of 70 MW. Currently, electricity produced from hydropower accounts for 3.7% of the energy generated in NC.

Hydropower Generation by Year

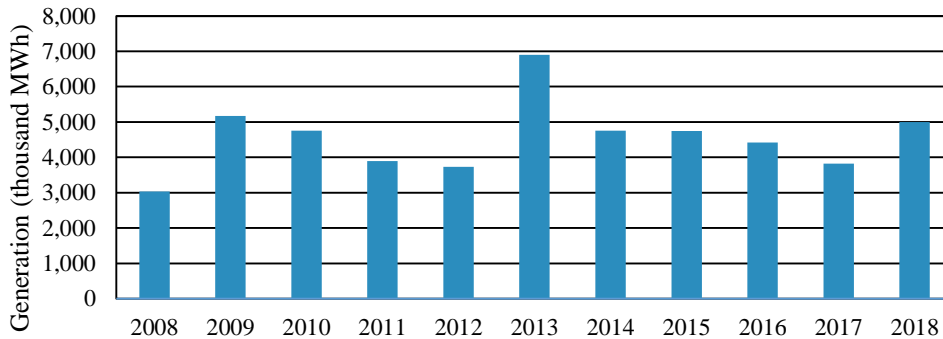


Figure 6-2: Hydropower Generation⁵

³ U.S. Energy Information Administration. (2018). U.S. Energy Information Administration Electricity Data Browser. Retrieve May 2019 from, <https://www.eia.gov/beta/electricity/data/browser/#/topic/1?agg=2.0,1&fuel=00000008&pt=&pm=&sec=vvo&geo=00000004&wd=&ws=&wsn=&wt=&freq=A&datecode=2017&tab=overview&pin=&rse=0&maptype=0%3Cype&ctype=linechart&end=201710&start=200101>

⁴ NC Utilities Commission (2019). *NC Renewable Energy Tracking System*. Retrieve May 2019 from, <https://www.ncrets.org>

⁵ U.S. Energy Information Administration. (2018). U.S. Energy Information Administration Electricity Data Browser. Retrieve May 2019 from, https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2,1,0&fuel=04&geo=fvfvvvvvvvvvo&sec=g&linechart=-ELEC_GEN.N.HYC-DE-99.A~ELEC_GEN.HYC-DC-99.A~ELEC_GEN.HYC-FL-99.A~ELEC_GEN.HYC-GA-99.A~ELEC_GEN.HYC-MD-99.A~ELEC_GEN.HYC-NC-99.A~ELEC_GEN.HYC-SC-99.A~



Figure 6-2 shows the electricity generated from hydropower over the last decade, with the peak occurring in 2013. Growth in the hydro industry in NC is limited and not expected to increase, as solar and distributed generation technologies are becoming more prevalent. DEC is reviewing sites for upgrades and planning a new 4 MW hydro project in NC pending approval from the NCUC. Two additional sites, Mountain Island and Cedar Cliff have been identified with potential upgrades of 6 MW and 2 MW, respectively.⁶ In addition, The US DOE determined that 15 additional sites shown in Table 6-1 are currently not generating power, and have the potential capacity of 105 MWs of electricity⁷. While hydrokinetic energy has the potential to increase growth in this area, no companies have plans currently to deploy turbines offshore to generate electricity.

Table 6-1: Energy Potential at Non-Powered Dams in NC

B. Everett Jordan Dam	Horseshoe Lake Dam
Little River Dam	Tar River Dam
Lock and Dam #1	Lake Hyco Dam
Lock and Dam #2	Moss Lake Dam
William O. Huske Lock & Dam	Bridges Lake Dam
Buckhorn Lake Dam	Lake Mackintosh Dam
H.F. Lee Power Station Cooling Lake Dam	Roxboro Afterbay Dam
Randolph Mill Lake Dam	

6.1.4 Policies and Programs Driving Deployment

NC Session Law 2019-132 (House Bill 329) amended G.S. 62-156(b)3 which allows the producer of electricity to sell power to public utility companies and receive Renewable Energy Credits (RECs). The amendment will allow small hydroelectric producers that have a generating capacity up to 5 MW of energy to be treated similar to energy producers from the swine and poultry waste industry.⁸

6.2. Hydropower Technology Overview and Application

6.2.1 Technology Benefits & Limitations

Hydropower provides many benefits to the surrounding community and to regions downstream of the reservoir location which include: recreation, education, water storage/supply, flood control, irrigation, electrical generation, and flow augmentation. In NC, where droughts and major weather events can cause flooding and inconsistent water supply to communities and farmland, reservoirs created by storage facilities have been helpful to reducing the impact of these occurrences.

⁶ Duke Energy Carolinas, LLC. *2018 Integrated Resource Plan and 2018 REPS Compliance Plan*. Retrieve May 2019 from, <https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=aa9862b5-5e31-4b3f-bb26-c8a12c85c658>

⁷ U.S. Department of Energy Water Power Technologies (2012). *An Assessment of Energy Potential at Non-Powered Dams in the United States*. Retrieve May 2019 from, https://www.energy.gov/sites/prod/files/2013/12/f5/npd_report_0.pdf

⁸ North Carolina General Assembly Session 2019. Retrieve May 2019 from, <https://www.ncleg.gov/Sessions/2019/Bills/House/PDF/H331v2.pdf>



Limitations for the installation of a hydropower facility is proximity to a water supply. In addition, the impact to the ecosystem, including wildlife plays a major part in the type and size of hydropower facility that is installed. Areas that have plants or wildlife, that will be endangered by a change in water flow or chemistry of water would consider a run-of-river hydropower.

6.2.2 Installation, Siting, Decommissioning, and Environmental Issues

Hydropower can have a substantial impact on the environment at the location installed, both upstream and downstream of the site. Impacts occur from the construction, gas emission from the water in the reservoirs, changes to the composition of the water, wildlife impact, low-flow augmentation, and sediment. Construction of a hydropower dam has major impact to the land being altered with equipment brought to level, and/or dig, or the use of explosives to change the landscape. In addition to the land being altered, communities may be impacted, as well as wildlife, depending on the location of the site.

Figure 6-3 displays how the organic material builds up over time and releases methane and carbon dioxide (CO₂) from the reservoir. While this depicts a storage hydro system, CO₂ and methane emissions have also been shown to be emitted with run-of-river systems as well, at a much lower level. Studies have shown an emission range of 0.03 – 0.3 lbs of CO₂ eq/kWh with methane emission unknown at this time.⁹

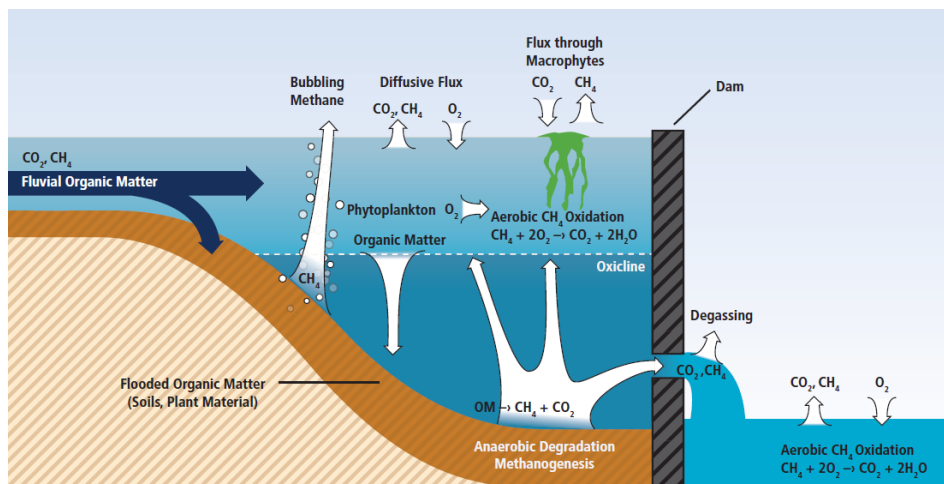


Figure 6-3: Carbon dioxide and methane pathways in a freshwater reservoir

Reservoir dams can alter the water chemistry being held behind the dam and further downstream. Downstream water quality will also be affected, based on how water is released from dam and the quantity that is released. Spillway releases over the top of the dam have a higher concentration of oxygen compared to water near the bottom of the dam. In addition, water near the bottom of the dam will also be colder than water near the surface. The use of a gated tower provides a solution by releasing water from different depths of the reservoir to adjust the oxygen and water temperature flowing downstream.^{2, 10}

⁹ United Nations Intergovernmental Panel on Climate Change. (2011). *Renewable Energy Sources and Climate Change Mitigation*. Retrieve May 2019 from, <https://www.ipcc.ch/report/renewable-energy-sources-and-climate-change-mitigation/>

¹⁰ North Carolina Department of Environmental Quality. *How Do People Affect Instream Flow?* Retrieve May 2019 from, <https://deq.nc.gov/how-do-people-affect-instream-flow>



Storage hydropower plants have impacts on wildlife where migrations can be stopped by the blockage of the normal flow of rivers, and by turbines which can kill or injure fish as they pass through. To assist the migration of wildlife, storage dams are being renovated to allow for wildlife to migrate upstream. In other cases, dams are being removed entirely to allow rivers to flow freely to allowing endangered species to have better migration upstream to spawn and more access to food and shelter.

6.2.3 Emerging Technology Trends

Hydrokinetic technology is the new trend being researched and developed to generate electricity from the flow of water from ocean waves, currents, tides, and from currents in streams and rivers⁶. NC is ideal for deploying this technology and one of only two states on the eastern part of the US that has an ocean current strong enough to generate electricity.¹¹ The Gulf Stream transports 2.5 billion cubic feet of water per second off the coast of Cape Hatteras. It is estimated that if 0.1% of this energy is harnessed, generation capacity of hydrokinetic resource could be 300 GW. The Coastal Studies Institute along with North Carolina State University, North Carolina Agriculture & Technology State University, University of North Carolina Charlotte, and East Carolina University have been testing prototypes off the coast to determine: (1) the best design that can generate the electricity efficiently; (2) which designs are structurally sound to withstand the strong current; and (3) the ideal location to deploy the technology.¹² Turbines are being redesigned to increase the efficiency in existing facilities, while also working to decrease the fish killed passing through the turbines. The amount of fish killed with older turbine designs are not fully known. The currently best-designed turbines average 5-10% kill rate for fish passing through the turbines. The US DOE is sponsoring research and development into more humane turbines that have a 2% or less kill rate.¹³

6.3. Grid Integration and Reliability

6.3.1 Grid Integration

Grid integration of hydropower is similar to utility-scale electric generation facilities. Hydropower can be integrated into small municipal grids and utility-level grids. Storage-based hydropower plants can operate based on demand, and therefore should present fewer integration challenges. Issues with integration occurs with the land topography and difficulty in installing the transmission lines.

6.3.2 Reliability

Benefits to hydropower include the ability to quickly generate electricity without a long timeframe for production startup. The connection of hydropower plants to the grid provides flexibility to utility companies to provide power quickly during peak demands and decrease generation during lower

¹¹ U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. *Marine and Hydrokinetic Resource Assessment and Characterization*. Retrieve May 2019 from, <https://www.energy.gov/eere/water/marine-and-hydrokinetic-resource-assessment-and-characterization>

¹² The North Carolina Renewable Ocean Energy Project. *Investing in North Carolina's Energy* Retrieve May 2019 from, <https://www.coastalstudiesinstitute.org/research/coastal-engineering/renewable-ocean-energy-project-overview/>

¹³ Independent Statistics & Analysis U.S. Energy Information Administration. (2018). *Hydropower generators produce clean electricity, but hydropower does affect the environment*. Retrieve May 2019 from, https://www.eia.gov/energyexplained/index.php?page=hydropower_environment



demands. This eliminates the need for utility companies to have coal, nuclear, natural gas, or other liquid fuel plants on standby to meet possible swings in electricity demand.

6.3.3 Grid Modernization

The integration of hydropower and other renewable resources into the grid can provide consistent energy resources in place of conventional energy sources. The use of solar and wind power can be used during windy or sunny days to offset demand peaks for utility plants, while also providing power to pumps to store water in reservoirs for future peak times when solar and wind are not adequate to meet the demand or during off-peak hours.

6.4. Resource Costs and Benefits

6.4.1 Initial Investment Costs

Construction costs for the building of hydropower plants vary based on the type of plant building and location. The 2018 Hydropower Market Report prepared by the Oak Ridge National Laboratory study of 1 MW to 100 MW size plants showed the construction cost ranged from \$2,000 – \$8,000 per kilowatt on average in 2015.¹⁴

6.4.2 Operating and Recurring Costs

The operation and maintenance costs of hydropower plants is very low compared to other power generation plants, since it does not require the purchase of fuel to generate electricity. Costs are more expensive for small plants versus large plants with the overall average cost of operation and maintenance being 2.5% of the construction cost⁷.

¹⁴ U.S. Department of Energy Water Power Technologies Office. (2018). *2017 Hydropower Market Report*: Retrieve May 2019 from, <https://www.energy.gov/sites/prod/files/2018/04/f51/Hydropower%20Market%20Report.pdf>



7. Bioenergy

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7.1 Bioenergy Introduction

7.1.1 Definition of Bioenergy

Bioenergy is derived from organic sources such as wood, food waste, animal manure, or crop residues. Bioenergy fuels can be solid, such as wood; liquid, such as ethanol; or gaseous, usually methane. In North Carolina, bioenergy production includes fuel sources such as virgin wood, waste wood from wood industries and agriculture, landfill gas, gas from wastewater treatment plants, gas from animal waste management systems, biodiesel, and ethanol.

Examples of the three physical states of bioenergy and their uses in North Carolina are as follows:

- **Woody biomass** is a traditional fuel source used in steam boilers to generate power or process heat by industrial and electric power producers. The wood used is primarily waste wood such as bark, sawdust, wood chips, wood scrap, construction wood waste, and paper mill residues.
- **Liquid biomass**, such as ethanol and biodiesel, are used as transportation fuels. Ethanol is made from the sugars found in grains such as corn. Biodiesel is a fuel made from soy beans, vegetable oils, fats, or greases.
- **Biogas** is produced via anaerobic digestion, is composed mostly of carbon dioxide (CO₂) and methane (CH₄), and is typically collected from municipal solid waste landfills, wastewater treatment plants, and livestock manure management systems. Biogas produced in municipal solid waste landfills, referred to as landfill gas (LFG), is the most common source of biogas in the State.

7.1.2 Production of Bioenergy

Bioenergy is one of the few fuels produced in North Carolina. Most of the bioenergy that is both produced and consumed in North Carolina consists of wood-derived fuel or other biomass that is a byproduct of another process, such as paper plants, lumber mills, and landfills.

Another biomass fuel produced in North Carolina is pelletized wood. In the US, residual wood is used to manufacture 81% of the pellets while roundwood and pulpwood is used to manufacture the remaining 19%.¹ Approximately 96% of the wood pellets manufactured in the South are exported overseas for use in power plants due to higher prices that can be obtained for exported fuel.² The remainder is used for residential heating. Survey data collected by US EIA from the last 2 years indicates that North Carolina wood pellet manufacturing capacity represents approximately 13% of the total US wood pellet production capacity.³ Members of the public have expressed concerns about various environmental aspects of wood pellet production in North Carolina, specifically greenhouse gas (GHG) emissions and forest management. This section is focused on the historical use of bioenergy in the State. Therefore, this section does not address the environmental pros or cons related to manufacturing of wood pellets for export and combustion overseas.

¹ U.S. Energy Information Administration Form EIA-63C, Densified Biomass Fuel Report, December 2018, <https://www.eia.gov/biofuels/biomass/>.

² Ibid.

³ Ibid.



North Carolina has one ethanol plant and three biodiesel plants with a combined annual production capacity of 16 million gallons.⁴ North Carolina imports most of its ethanol, which is blended with motor gasoline and combusted in vehicles.

North Carolina also has facilities which produce biogas. LFG operations produce the majority of biogas in the State, which is primarily used for electricity generation. There are also agricultural/livestock operations across the state that produce varying amounts of biogas, most of which is consumed onsite for electric generation, heating for farm operations, or for delivery into a natural gas pipeline as renewable natural gas.

7.1.3 Consumption of Bioenergy in all Sectors

Figure 7-1 shows the consumption of bioenergy in North Carolina by fuel source type; wood-derived fuel, waste biomass (LFG, poultry litter, etc.), and ethanol.⁵ This data is shown on a heat input basis in trillion British thermal units (TBtu) in order to present the relative contribution of each source.

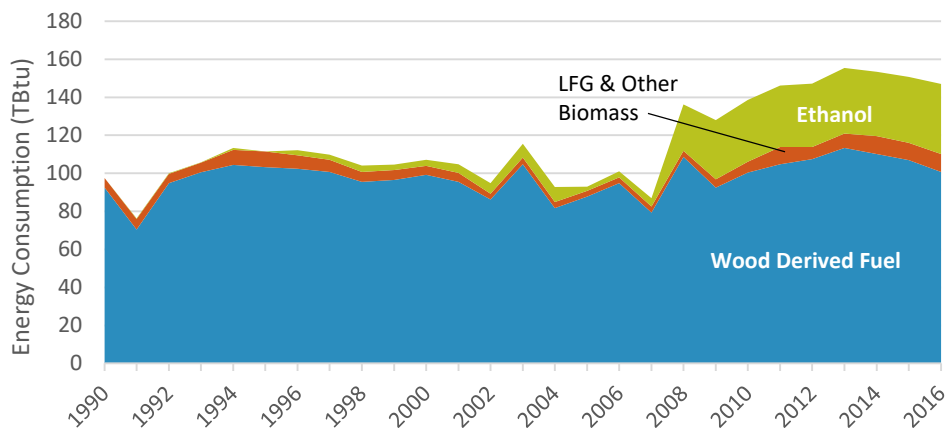


Figure 7-1: Consumption of Biomass Energy by Source (TBtu)

The figure above indicates that wood-derived fuel produced by North Carolina’s wood product industries has been a traditional fuel in North Carolina for well over 20 years. Its use has not increased significantly over that time period with an approximate 15% increase since the early 1990s. While the use of waste biomass as a fuel has increased slightly, it has remained a small percentage of total bioenergy. The use of ethanol for transportation has seen a substantial increase and now represents 24% of the total bioenergy in the State. While this increase in the use of biomass fuels is significant, total bioenergy consumption in North Carolina during 2016 was only 147 TBtu, which is 6% of the total energy consumed in the State (2,554 TBtu).

⁴ US Energy Information Administration , North Carolina State Profile, May 2019, <https://www.eia.gov/state/?sid=NC#tabs-1>

⁵ North Carolina State Energy Data System (SEDS): 1960-2016 (complete), US Energy Information Administration, released June 29, 2018, accessed at <https://www.eia.gov/state/seds/seds-data-complete.php?sid=NC#Consumption>.



Figure 7-2 presents the uses of bioenergy in North Carolina, including direct use by residential, commercial and industrial consumers, use for electricity generation, and use for transportation (fuel ethanol).⁶ Direct use of the bioenergy represented the largest use of bioenergy in the State, approximately 64% in 2016.⁷ Of this 64%, industrial sites represented 78 TBtu (83%) of the energy consumed for direct use. Transportation represents 24% of the bioenergy consumed while electricity generation represents the smallest fraction, 12%.

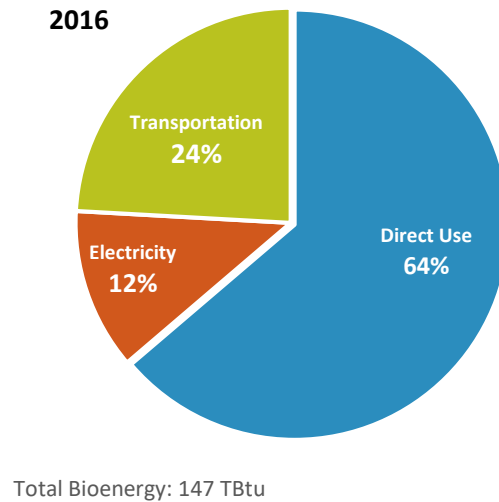


Figure 7-2: Bioenergy in North Carolina by Sector in 2016 (TBtu)

7.1.4 Electric Capacity and Generation in North Carolina Using Bioenergy

This section focuses on the use of biomass for electricity generation. Figure 7-3 shows the location of the 31 bioenergy facilities generating electricity across North Carolina. According to the NCSEA, biomass represents a total generating capacity of 577 MW.⁸ The majority of this capacity is made up of steam boilers owned by industrial facilities, primarily paper companies, and independent power producers. There are also a number of gas turbines and engines firing biogas, including LFG and digester gas. The remainder of the capacity consists of smaller bioenergy resources generating electricity primarily for use onsite.

⁶ Ibid.

⁷ Direct use energy refers to all energy consumed at facilities and residences for space heating, process heating, and to perform work, including electricity generation for use on site.

⁸ NC Sustainable Energy Association, accessed July 2019 at <http://energync.org/maps/>



NC Bioenergy Locations

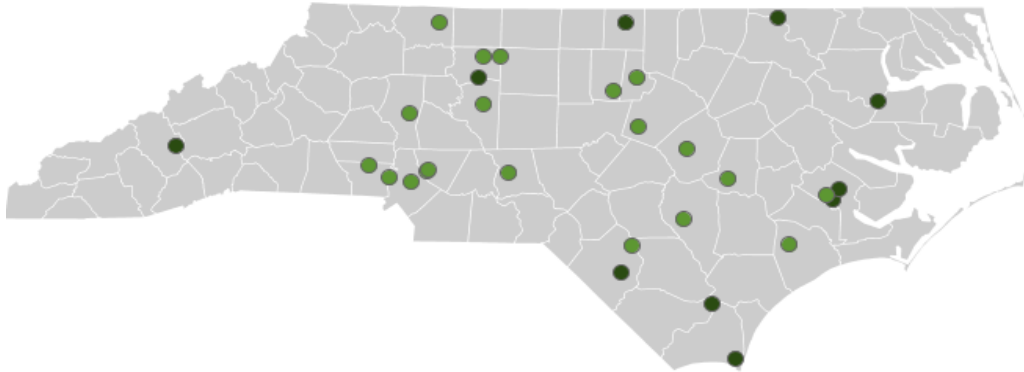


Figure 7-3: Biomass Plants in North Carolina⁹

The U.S. Energy Information Administration (EIA) requires reporting from power plants with nameplate capacities 1 megawatt (MW) or greater. Therefore, the data presented in this section is limited to units greater than this size. Figure 7-4 presents the historical capacity of biomass electricity generation units in the State.¹⁰ The figure indicates an increase in capacity of bioenergy units starting in 2008. This increase was due to implementation of the Renewable Energy and Energy Efficiency Portfolio Standard (REPS), which provided an economic incentive for electricity generation using biomass.¹¹ The capacity additions in the wood-derived fuel sector do not represent new capacity that was built, but rather fuel switching at existing plants firing coal.

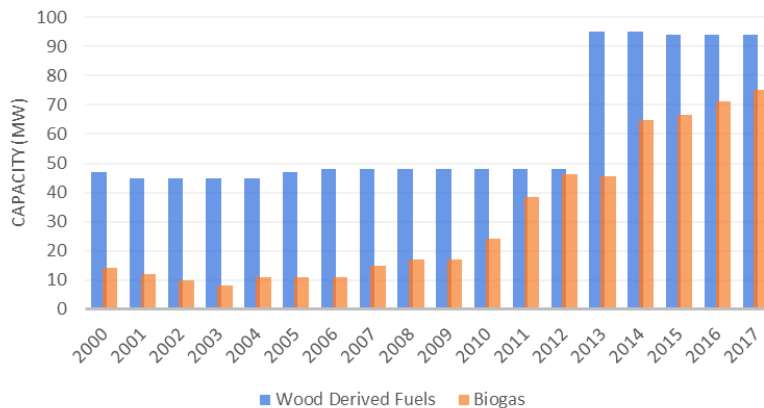


Figure 7-4: North Carolina Landfill Gas (LFG) and Wood Electric Generation Capacity

⁹ US Energy Information Administration, accessed July 30, 2019 at <https://www.eia.gov/electricity/data/browser/#/topic/1?agg=2,0,1&fuel=002o&geo=00000004&sec=g&freq=M&datecode=201812&rtype=s&maptype=0&rse=0&pin=<ype=pin&ctype=map&end=201905&start=200101>

¹⁰ EIA Detailed State Data, 1990-2017 Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860), <https://www.eia.gov/electricity/data/state/>

¹¹ Session Law 2007-397, North Carolina’s Renewable Energy and Energy Efficiency Portfolio Standard (REPS), August 20, 2007, <http://www.ncuc.commerce.state.nc.us/reps/reps.htm>.



Figure 7-5 illustrates the electricity generated by power plants firing both wood derived fuel and LFG and other biomass in North Carolina from 2000 to 2018.¹² Generation from wood derived fuel products has increased by approximately 26% from 2000 levels, with a large increase in 2013 from conversion of a coal facility to woody biomass. Generation from LFG and other biomass has increased substantially, by over 600%. Figure 7-5 also illustrates how implementation of REPS increased generation from biomass resources starting in 2008. Despite this expansion, biomass combustion represents only 2% of North Carolina’s total electricity generation in 2017.¹³

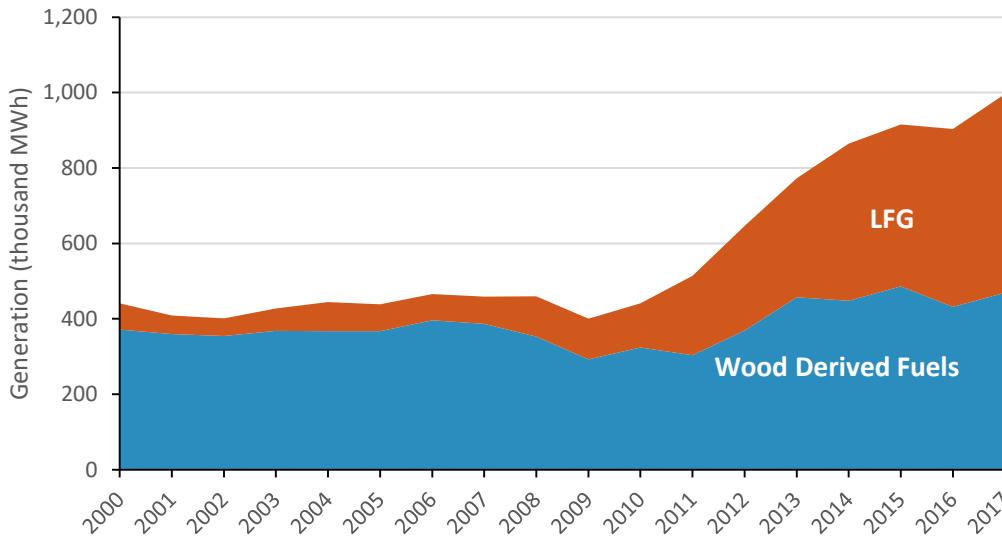


Figure 7-5: North Carolina Annual Electricity Generation from Landfill Gas (LFG) and Wood Products

7.2 Bioenergy Technology Overview and Application

7.2.1 Technology Benefits

Using biomass for energy production has been defined as “renewable energy” in both Federal and State policy, including energy investment tax credits and production tax credits.^{14, 15} Electricity generated from biomass is eligible for Renewable Energy Credits (REC) as part of REPS. According to the North Carolina Renewable Energy Tracking System (NC-RETS), in 2017 20.2% of the State’s RECs were from woody biomass, 5.9% were from LFG, and 3.6% were from animal waste .¹⁶

¹² Energy Information Administration Detailed State Data, 1990-2017 Net Generation by State by Type of Producer by Energy Source, May 2019, <https://www.eia.gov/electricity/data/state/>

¹³ EIA Detailed State Data, 1990 – 2017 Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923), accessed at <https://www.eia.gov/electricity/data/state/>.

¹⁴ Energy Policy Act of 2005, July 2019, <https://www.congress.gov/109/plaws/publ58/PLAW-109publ58.pdf>

¹⁵ Session Law 2007-397, “North Carolina’s Renewable Energy and Energy Efficiency Portfolio Standard (REPS), August 20, 2007, <http://www.ncuc.commerce.state.nc.us/reps/reps.htm>.

¹⁶ North Carolina Renewable Energy Tracking System (NC-RETS), Feb 2019, <https://www.ncrets.org/>



Bioenergy Solids

North Carolina's wood products industries utilize low cost or free waste wood to generate electricity for onsite use. These low-cost fuels provide for less price volatility compared to other traditional fuels. Using the waste biomass for energy production can divert it from landfills and can offset production and consumption of traditional fossil fuels. Finally, since the fuel can be stored for use, biomass electric production is dispatchable and can be scheduled for optimal timing when the resource is most needed.

Liquid Fuels

Biodiesel and pure ethanol are nontoxic and biodegradable. When compared to petroleum-based fuels, the combustion of biodiesel or ethanol-gasoline blends produces less carbon monoxide, sulfur dioxide, and hydrocarbons, as well as fewer air particulates.¹⁷

Biogas

NC ranks third in the country for biogas production potential. Biogas is generated as a result of anaerobic biological processes in sewage treatment plants, landfills, and livestock manure management systems. Between 40% and 60% of the composition of biogas is methane, which has a greenhouse effect 25 times more potent than CO₂. Burning biogas converts the methane to CO₂ which has a lesser global warming impact.¹⁸ Biogas captured from livestock farms, such as swine and dairy livestock operations that employ waste lagoons, prevents those GHG emissions from being released into the atmosphere. Using biogas for heat or electric energy production reduces carbon emissions from natural decomposition and offsets the use of conventional fossil fuels when used as a replacement fuel.¹⁹

7.2.2 Environmental Issues

GHG Emissions from Bioenergy

Greenhouse Gas (GHG) emissions from the combustion of bioenergy in North Carolina was quantified in the North Carolina Greenhouse Gas Inventory (1990-2030) and is presented in Table 2-1.²⁰ GHG emissions from combustion of bioenergy have increased by 44% since 1990 levels due to increased use of these fuels, most notably ethanol and landfill gas. However, the forest carbon flux estimates in the GHG Inventory, also presented in Table 7-1, indicate that carbon is being sequestered in North Carolina. The DEQ recognizes there is uncertainty in these estimates.²¹ Members of the public have raised concerns regarding whether biomass, specifically woody biomass, is carbon neutral. A discussion of the carbon

¹⁷ US Energy Information Administration, Biofuels: Ethanol and Biodiesel, May 2019, https://www.eia.gov/energyexplained/index.php?page=biofuel_ethanol_environment

¹⁸ US Energy Information Administration, Biomass and the Environment, May 2019, https://www.eia.gov/energyexplained/index.php?page=biomass_environment

¹⁹ 2018 North Carolina Energy Policy Council Biennial Report, section C. Bioenergy, page 28

²⁰ North Carolina Greenhouse Gas Inventory (1990-2030), North Carolina Department of Environmental Quality Division of Air Quality, January 2019, accessed at <https://deq.nc.gov/energy-climate/climate-change/greenhouse-gas-inventory>.

²¹ See page 27 of the GHG Inventory for a discussion on uncertainties in estimating the mass of carbon associated with various land use activities.



neutrality of biomass is beyond the scope of this document. For a more complete discussion on GHG emissions from bioenergy and sequestration of carbon in forests and other lands see the North Carolina GHG Inventory, specifically Section 2.9 *Land Use, Land Use Changes and Forestry* and Appendix C *Treatment of CO₂ Emissions from Biomass Combustion*.

Table 7-1: GHG Emissions from the Combustion of Biomass in MMT as CO₂e

GHG Sources and Sinks	1990	2005	2012	2015	2017
Bioenergy Combustion Emissions	8.82	8.62	12.87	13.04	12.73
Forest Carbon Flux	-35.31	-35.17	-38.11	-37.91	-37.77

EPA’s revision to the New Source Performance Standards and Emissions Guidelines for municipal solid waste landfills was finalized August 2016.²² The new rule requires landfills to install and operate landfill gas collection systems, monitor emissions, as well as other provisions. The gas collection systems require either flaring the gas or recovering the gas as energy for direct use or electricity generation. Flaring or collection and use of the gas reduces the global warming potential of the gas emissions, as discussed earlier. In May of 2017, EPA announced the agency was reconsidering the rule; however, it is still a final rule at this time.²³

Bioenergy Solids

Emissions from combustion of wood and wood products includes sulfur dioxides, nitrogen oxides, particulate matter as well as hazardous air pollutants, including hydrogen chloride, formaldehyde, benzene, acrolein, and styrene. Emissions from biomass combustion are temperature-dependent, with lower temperature resulting in incomplete combustion and higher emissions. Emissions of sulfur dioxides, nitrogen oxides, and particulate matter from wood combustion are higher than levels emitted by natural gas combustion. The combustion of biomass solids is subject to various federal and state air pollution regulations which limit emissions of these pollutants, as well as visible emissions and odors. These rules vary based on the size, age, fuel and type of unit. The most recent rules finalized by US EPA are the “Boiler MACT Rule” in 2015 and the “Boiler GACT” rule in 2016, which required fossil fuel and wood steam boilers and process heaters to reduce emissions of hazardous air pollutants by installing control systems and/or meeting several work practice standards.²⁴

²² Federal Register, Vol. 81, No. 167, pp 59332- 59384, August 29, 2016, accessed at <https://www.govinfo.gov/content/pkg/FR-2016-08-29/pdf/2016-17687.pdf>.

²³ For more information of the reconsideration, see <https://www.epa.gov/stationary-sources-air-pollution/municipal-solid-waste-landfills-new-source-performance-standards>.

²⁴ Federal Register, Vol. 80, No. 224, pp 72790 – 72837, November 20, 2015, accessed at <https://www.epa.gov/stationary-sources-air-pollution/industrial-commercial-and-institutional-boilers-and-process-heaters> and Federal Register, Vol. 81, No. 178, pp 63112-63131, Wednesday, September 14, 2016, accessed at <https://www.govinfo.gov/content/pkg/FR-2016-09-14/pdf/2016-21334.pdf>.



Liquid Fuels

Ethanol-gasoline blends have higher emissions from fuel tanks and dispensing equipment than gasoline alone, which contributes to ground-level ozone and smog. Nitrogen oxide emissions from biodiesel combustion may be slightly higher than emissions from burning petroleum-based diesel.²⁵

Biogas

The use of animal waste lagoon systems for biogas operations increases concentrations of phosphorous, nitrates, and ammonia.²⁶ When the lagoons are covered for methane capture, emissions and odors are reduced, but phosphorous and nitrate concentrations increase in the effluent. There are public concerns that odors and other pollution from confinement houses and sprayfields are not adequately addressed by current methane capture technologies.

7.2.3 Installation

Each biomass plant is a unique system with high capital costs. In addition to design complexity, there are technical, environmental, economic, and regulatory considerations associated with constructing power plants. Power generation plants are required to obtain a certificate of convenience from the North Carolina Utilities Commission (NCUC) and necessary environmental permits from the DEQ. Bioenergy power plants rely on proximate availability of reliable, long-term feedstock quantities for operation.

Biogas plant location selection is limited by projected long-term site production potential and piping distances. Typically, piping distances to end-use need to be under 10 miles for project feasibility. Even though many larger LFG sites are required to have gas collection systems, some of these sites don't produce enough methane for electric generation to be economically viable. Animal waste biogas developers in North Carolina look for farms in close proximity to each other in order to keep piping distances as short as possible to aggregate methane gas for injection into natural gas pipelines. Currently, federal and state mandates for biogas in the form of transportation fuel are creating lucrative incentives for biogas, but it is difficult for developers to get it to these markets without adequate access to pipelines of natural gas local distribution companies (LDC). Farms that are not able to aggregate with others use the methane onsite for facility heating and electric generation. Wastewater treatment plants can use the biogas generated on site to heat the anaerobic digester where the gas is produced and create electricity for onsite consumption or sale. When the biogas is used for both electricity and heating the process is called Combined Heat and Power (CHP), and this has been deployed recently at two plants in North Carolina.^{27,28}

²⁵ US Energy Information Administration, Biofuels Explained, May 2019,

https://www.eia.gov/energyexplained/index.php?page=biofuel_ethanol_environment

²⁶ Environmental Defense Fund, Environmental Considerations of Biogas from Swine Farms, May 2018 presentation to NC Energy Policy Council, Dr. Joe Rudek.

²⁷ US DOE CHP Technical Assistance Partnership Project Profile Database, McAlpine Creek Wastewater Management Facility, http://www.chptap.org/Data/projects/McAlpineWWTP-Project_Profile.pdf

²⁸ US DOE CHP Technical Assistance Partnership Project, Installation Database, <https://doe.icfwebservices.com/chpdb/>



7.2.4 Emerging Technology Trends

Liquid Fuels

The liquid biofuels industry continually seeks new feedstocks to produce ethanol or biodiesel more efficiently and is researching new enzymes to enhance production from non-food source cellulosic biomass. New enzymes that help break down complex fibers and aid in the fermentation process are also being evaluated.

Biogas

With the exception of LFG, the biogas industry is still relatively small in scale. Biogas developers work with clusters of farming operations to find better ways to aggregate the biogas in order to reduce costs and add scale to the industry. The biogas industry is also working with natural gas utilities on direct injection of biogas into the natural gas distribution pipelines. Direct injection, called “directed biogas,” qualifies as renewable natural gas. Renewable natural gas (RNG) is a term used to describe biogas that has been upgraded for use in place of fossil natural gas. The first direct injection pilot in NC went into operation in 2018.

7.3 Future Resource Deployment in North Carolina

Bioenergy Solids

According to Duke Energy’s 2018 Integrated Resource Plans (IRP), four (4) biomass projects with a total capacity of 12.9 MW are pending in Duke Energy Carolinas (DEC) territory and one 4.2 MW biomass project is pending in Duke Energy Progress (DEP) territory.^{29, 30} Duke Energy’s 2018 IRP combines biomass and small hydro in its future capacity projections. Using the combined totals from DEC and DEP, the capacity projections peak in 2020 at 406 MW, then steadily declines to 52 MW in 2032. Although individual resource capacities are not noted for biomass or small hydro, the combined reduction indicates that Duke Energy projects little or no future deployment of biomass at scale.

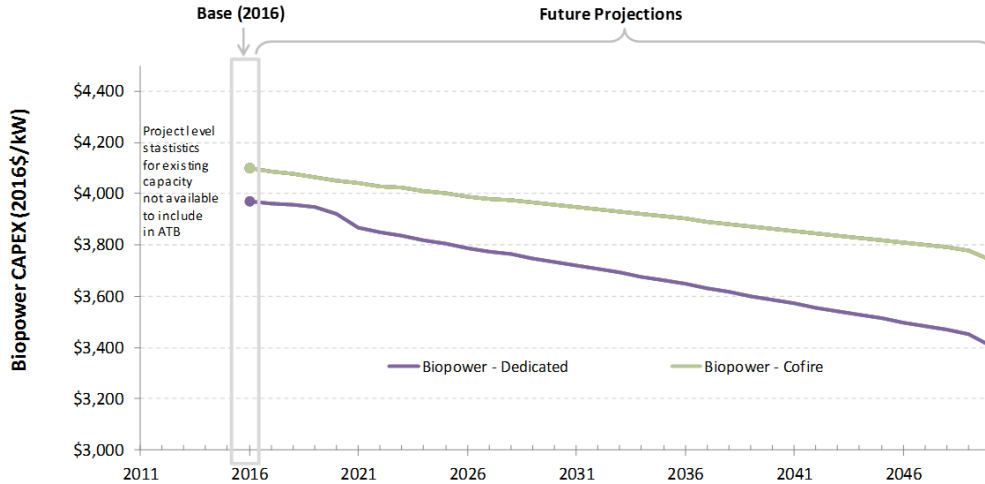
The National Renewable Energy Laboratory (NREL) developed the chart in Figure 7-6 below, which shows national average cost information for dedicated and cofiring utility biomass plants. The chart depicts a projected steady decline in capital installation expenditures through 2050. The projected cost decline is due to expected incremental performance improvements over time.³¹ However, NREL also evaluated the levelized cost of energy (LCOE) projections for biomass plants and projects it to be relatively flat through 2050 due to the low heat content, or low BTU value, of biomass fuels.³² A low BTU value is a difficult economic hurdle for biomass plants to overcome when competing against other higher BTU value, lower cost fuels.

²⁹ Duke Energy Carolinas 2018 IRP, Table I-1: DEC QF Interconnection Queue.

³⁰ Duke Energy Progress 2018 IRP, Table I-1: DEP QF Interconnection Queue.

³¹ Annual Technology Baseline-CAPEX, NREL, 2018, <https://atb.nrel.gov/electricity/2018/index.html?t=cb>

³² Annual Technology Baseline-LCOE, NREL, 2018, <https://atb.nrel.gov/electricity/2018/index.html?t=cb&s=pr>



CAPEX historical trends, current estimates, and future projection for biopower
 Source: National Renewable Energy Laboratory Annual Technology Baseline (2018), <http://atb.nrel.gov>

Figure 7-6: CAPEX Historical Trends, Current Estimates, and Future Projections for Biopower

Source: NREL, Annual Technology Baseline 2018

Liquid Fuels

The EIA’s Annual Energy Outlook 2019 shows national liquid biofuels consumption projections remaining flat from 2020 to 2050.³³ Ethanol and biodiesel production in North Carolina will likely stay stable due to incremental increases in the national renewable fuel standards (RFS) through 2022.

Biogas

Most landfills in North Carolina with economical gas recovery potential are already capturing the gas to use for energy recovery. The EPA Landfill Methane Outreach Program (LMOP) database indicates a small number of landfill sites remain in North Carolina that have potential to utilize LFG for energy.³⁴ Therefore, LFG energy production may be nearing its peak.

In Raleigh, the Neuse River Resource Recovery Facility (NRRRF), the City’s main wastewater treatment facility, is being outfitted with an anaerobic digester which will produce RNG from biosolids. The RNG produced will be injected into the existing natural gas pipeline and used to fuel city buses or sold as a revenue source. The projected project cost is approximately \$150 million. Permitting and construction is scheduled to begin during the summer of 2019.³⁵

A potential area for biogas growth is hog farms in North Carolina. Many farms are expected to cover their swine waste lagoons, collect the methane gas and use it to produce electricity, heat the facilities or sell it

³³ Energy Information Administration, Annual Energy Outlook 2019, chart Energy consumption by fuel, page 27.

³⁴ US EPA Landfill Methane Outreach Program, May 2019 <https://www.epa.gov/lmop/project-and-landfill-data-state>

³⁵ City of Raleigh, NC, July 2019, <https://www.raleighnc.gov/services/content/PubUtilAdmin/Articles/Projects/CIP/NRRRFBioenergyRecoveryProject.html>



as RNG. RTI International is leading an analysis with Duke University and East Carolina University to quantify the biogas opportunities within North Carolina. The analysis will look at effects of biogas use on the climate, environment, societal impacts, and economics and will recommend policy measures for biogas development, including the best uses for biogas (ie. transportation fuel, RNG/pipeline, on-site energy generation, etc.).

7.3.1 Policies & Programs Driving Deployment

As discussed throughout this section, the REPS is one of the main policy drivers for increased use of all types of bioenergy in the State. When the law was written, it was assumed that a large percentage of the generation would be from bioenergy resources. However, this did not happen as expected due to decreases in the cost of solar photovoltaic systems. This law has specific requirements for electricity generation from poultry waste and swine waste in the State, which has directly resulted in development of these wastes as an energy resource and increasing their use. REPS is discussed in detail in the Energy Policy Landscape Section.

Liquid Fuels

The Federal Energy Policy Act of 2005 created the EPA's Renewable Fuel Standard (RFS) program. The RFS program set a target of 36 billion gallons of biofuels by 2022, and now most gasoline sold in the United States is blended with ethanol.³⁶ The RFS program also established incentives, in the form of renewable identification numbers or RINs, with tradable financial value like RECs. Additional incentives for biofuels include production tax credits, low-interest financing, direct grants, and special depreciation. Due to national production targets and RINS incentives, the RFS program has been a driver for the North Carolina production of biodiesel and ethanol.

Bioenergy Solids and Biogas

North Carolina's Renewable Energy and Energy Efficiency Portfolio Standard (REPS) is one of the main policy drivers for increased bioenergy production in the State. Established by Senate Bill 3 in 2007, the REPS law requires investor-owned utilities to source 12.5% of their previous year's State retail electric sales from qualified renewable energy sources, including biomass or biogas by 2021.³⁷ The REPS law also requires electric municipal and cooperative utilities to source 10% of their previous year's North Carolina retail electric sales from qualified renewable energy sources by 2018. A compliance schedule was set out in the law with specific carve outs for solar energy, swine waste and poultry waste, as shown in Table 7-2 below.³⁸

³⁶ US Environmental Protection Agency, May 2019, <https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard>



Table 7-2: North Carolina REPS Compliance Schedule for Investor-Owned Utilities

Year	REPS %	Solar %	Swine Waste %	Poultry Waste (MWh)
2014	3%	0.07%	NA	170,000
2015	6%	0.14%	0.07%	700,000
2016	6%	0.14%	0.07%	900,000
2017	6%	0.14%	0.07%	900,000
2018	10%	0.20%	0.14%	900,000
2019	10%	0.20%	0.14%	900,000
2020	10%	0.20%	0.14%	900,000
2021	12.5%	0.20%	0.20%	900,000

In 2017, the General Assembly passed the Competitive Energy Solutions for North Carolina legislation, or HB 589.³⁹ This law extends development of small power producer operations (less than 2 MW) using swine or poultry waste, landfill gas, manure digester gas, agricultural waste digester gas, sewage digester gas, or sewer sludge digester gas by allowing fixed-term contracts to exceed five years with electric utilities. In addition, HB 589 directs the NCUC to adopt an expedited review process and an interconnection standard for power projects derived from swine and poultry waste.

In June 2018, the NCUC Docket No. G-9, Sub 698 introduced a three-year pilot for directed biogas derived from swine and poultry waste in North Carolina (referred to as “Alternative Gas” in the docket). This order allows Piedmont Natural Gas (PNG) to purchase the alternative gas. The pilot requires PNG to study and report any negative effects on its system or its customers related to the injection of the alternative gas into its distribution pipeline. The opportunities for the directed biogas industry in North Carolina is pending the outcome of this study.⁴⁰

Many businesses and industries have adopted sustainability goals and renewable energy targets, which may increase the future demand for biogas. For example, Smithfield Foods has announced a goal to reduce GHG emissions by 25% by 2025 in its US operations using 2010 as the baseline year. To help achieve this goal, Smithfield has announced plans for swine waste-to-energy and biogas projects across

³⁹ Cite SL for HB 589

⁴⁰ Duke Energy Carolinas NC 2018 Integrated Resource Plan, page 227.



90% of its operations in North Carolina, Utah and Missouri.⁴¹ Most of these projects will result in covered lagoons for biogas production, which curb odors and methane emissions.

7.3.2 Constraints to Deployment

Constraints for biogas systems deployments at wastewater treatment facilities and livestock farms include high capital costs for digester and generation systems, and continued low cost natural gas. Additionally, questions regarding RNG's quality, concerns regarding risk of FERC's oversight encroaching into state activities of LDCs, and difficulty securing a place to inject RNG has impeded the rate at which biogas projects can be developed. These obstacles continue to occur despite the existence of technology, financing and resources to carry out projects, and despite NC being sought after for biogas, particularly biogas derived from agricultural sources. The NCUC has tried to address the cost barriers for swine and poultry biogas by allowing premium prices for REPS carve outs and require NC utilities to generate a small percentage of their renewable portfolio from swine and poultry waste. Utilities have addressed biogas cost issues to meet the REPS requirements by purchasing out-of-state biogas RECs, but this may have dampened demand for in-State biogas resources.⁴² LFG operations are limited by sites with favorable characteristics for economical gas production and recovery.

7.3.3 Grid Integration and Reliability

Biomass and biogas facilities can be considered components of the traditional fleet of electric generating units and are an alternate source to natural gas. Integration is not an issue and dispatchable units can assist in maintaining grid reliability and fuel supply during disaster response and recovery efforts. Biodiesel and ethanol are primarily used as replacement fuels in the transportation sector. Similarly, ethanol blends and biodiesel can be used as supplemental fuels in electric generating engines.

7.3.4 Resiliency

Bioenergy resources can enhance system resiliency by contributing additional available capacity and fuel supply, including onsite fuel storage, during disruption events. Biogas and biofuels can improve the resiliency of communities by providing fuel for backup generators or microgrid operations during a grid-wide outage, and temporarily provide transportation fuels, should traditional fuels be unavailable. Raw forms of biogas can operate electric generators with very little processing of the gas, providing a source of fuel for natural gas powered generators in the case of power outages in rural areas, particularly during flooding or other extreme weather events.

7.3.5 Grid Modernization

Bioenergy electric generation systems are smaller than traditional utility-scale generation facilities and are generally considered distributed energy resources (DER) on the electric grid. Many of these facilities in the State are less than 1 MW in generating capacity and are operated by independent power producers

⁴¹ North Carolina Health News, Smithfield Announces Plans to Cover Hog Lagoons, Produce Renewable Energy, June 2019, <https://www.northcarolinahealthnews.org/2018/10/29/smithfield-announces-plans-to-cover-hog-lagoons-produce-renewable-energy/>

⁴² 2016 North Carolina Jobs Project report, Chapter 3, page 45; <http://americanjobsproject.us/wp-content/uploads/2016/04/NC-Full-report-update-4.13.pdf>;



(IPPs). These DER systems can be coupled with other technologies to build microgrids, which can be disconnected from the larger grid to provide power to a building or series of buildings when necessary. Partnerships could be developed such as the one between South River Electric Membership Cooperative and Butler Farms to demonstrate how biogas DER systems used in microgrids improve community reliability and resiliency during major outage events.⁴³ When combined with Advanced Grid Management Systems and DERs, microgrids can be used to optimize the larger grid for efficiency, emissions reductions, and greater reliability and resiliency. DER optimization may help the utility defer future infrastructure and transmission costs as the grid continues its shift away from central plant generation models.

⁴³ NC Electric Membership Cooperatives, May 2019; <http://www.sremc.com/content/butler-microgrid>



8. Transportation and Electrification

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8.1. Introduction

Transportation is an integral part of NC’s economy and energy future. NC’s transportation sector is used to move goods and people throughout the state. It is the largest end-use energy-consuming sector, and accounts for more than four-fifths of the petroleum consumed in the state.¹ Figure 8-1 shows the energy consumption by end-use sector. The modes of transportation responsible for most of the gasoline and diesel fuel use are light-duty cars, medium and heavy-duty trucks.

The transportation and material moving sector employs over 323,480 people in NC.² According to the most recent Annual Energy Outlook (AEO 2019), passenger travel is projected to increase across all transportation modes and the consumption of transportation fuels grows considerably through the year 2050.³ The report also states that the fuel economy across all vehicle types will increase, particularly all light-duty vehicle types because newer, and more fuel efficient vehicles will enter the market.

North Carolina Energy Consumption by End-Use Sector, 2017

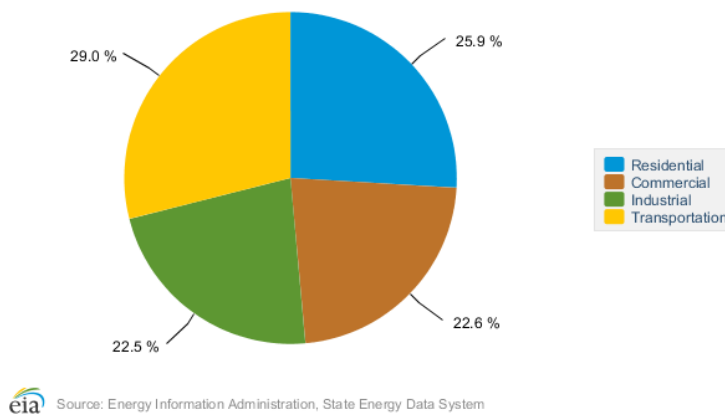


Figure 8-1: North Carolina Energy End Use by Sector

8.1.1 Technology Definition and Description

The advent of electric cars was introduced more than 100 years ago. During the early part of the 19th century, many innovators toyed with the concept of an “electric” car. William Morrison, from Des Moines, Iowa, is credited with creating the first successful electric vehicle (EV) in America.⁴ During the mid-century, electric cars became more visible, and accounted for about a third of all vehicles on the road. Today, there are approximately 1.1 million Zero Emission Vehicles (ZEVs) and Plug-In Hybrid Vehicles

¹ United States Energy Information Administration. (2018) Profile Analysis (North Carolina, Retrieved from <http://www.eia.gov/state/analysis>)

² United States Energy Information Administration. (2018) Profile Analysis (North Carolina, Retrieved from <http://www.eia.gov/state/analysis>)

³ United States Energy Information Administration: www.eia.gov/state/print.php@sid=mc

⁴ <https://www.energy.gov/articles/history-electric-car>



(PHEVs) in the United States, and approximately 7,700 in North Carolina. Electric Vehicles (EVs) utilize electric motors and batteries instead of, or in conjunction with internal combustion engines (ICE). Even though EVs require recharging on a regular basis, they are more efficient than ICE vehicles. Powering the EV with electricity from the grid reduces fuel costs, cuts petroleum consumption, and reduces tailpipe emissions. Transportation vehicles are categorized as one of the following three types of vehicles.

8.1.2 Types of Vehicles

1. **Light-duty vehicles:** (LDVs) include cars, motorcycles, sport utility vehicles (SUVs), and light trucks with a gross vehicle weight rating of 8,500 pounds or less.
2. **Heavy- and medium-duty vehicles:** These vehicles have a gross vehicle weight rating of more than 8,500 pounds. Vehicles in this category are medium-sized trucks (e.g., delivery trucks or mail trucks), dump trucks, school buses, municipal buses, interstate buses, and large trucks. Vehicles of this type are used to move freight or large quantities of passengers.
3. **On-road and Non-road vehicles:** A large variety of vehicles used to transport goods and people, include airplanes, boats and ferries, trains, subways, and trolleys.

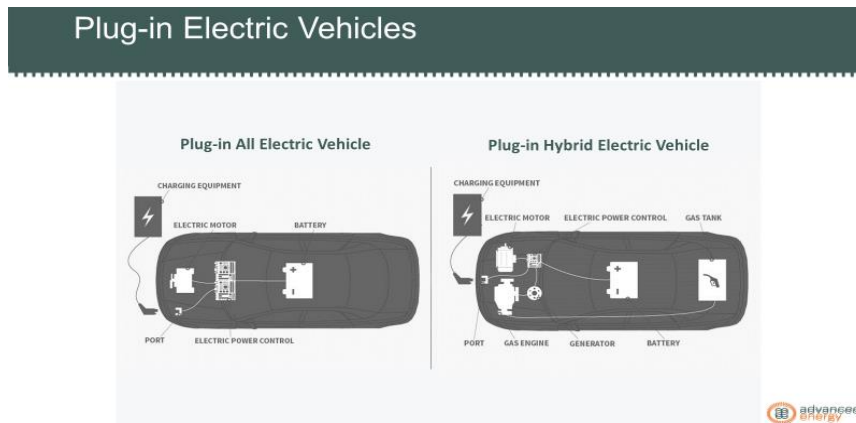


Figure 8-2: Types of Electric Vehicles

There are two basic types of plug-in vehicles, all-electric vehicles (AEVs), more often referred to as ZEV, and plug-in hybrid vehicles (PHEVs), as shown in Figure 8-2 above. ZEVs are powered by one or more electric motors and receive electricity by plugging into the electric grid to charge their batteries. They consume no petroleum-based fuel and produce no tailpipe emissions. ZEVs include Battery Electric Vehicles (BEVs) and hybrid electric vehicles (PHEVs) when in electric mode. The all-electric ranges for ZEVs and PHEVs average between 150 to 250 miles, while a few luxury models have ranges up to 350 miles. PHEVs use batteries to power an electric motor. They are plugged into the electric grid to charge and use a petroleum-based or alternative fuel to power the ICE.

According to Bloomberg New Energy Finance (BNEF), EV sales are projected to increase by as much as 57 percent globally by year 2040.⁵ Figure 8-3 below shows NC EV sales projections from 2019-2040. The data was derived from five different data sources, Auto Alliance, ChargePoint 2018, AEO2019,

⁵ Electric Vehicle Outlook, Bloomberg New Energy Finance, 2018



National Renewable Energy Laboratory (NREL) 2013, and BNEF. The projections for ZEV sales from all scenarios studied shows the projections to be similar up through year 2030. The BNEF predicts the most growth, but the AEO2019 projection is preferred, primarily due to its use of the most recent data.⁶ A portion of the data in the chart is NC specific, while the remaining data is downscaled from national levels.

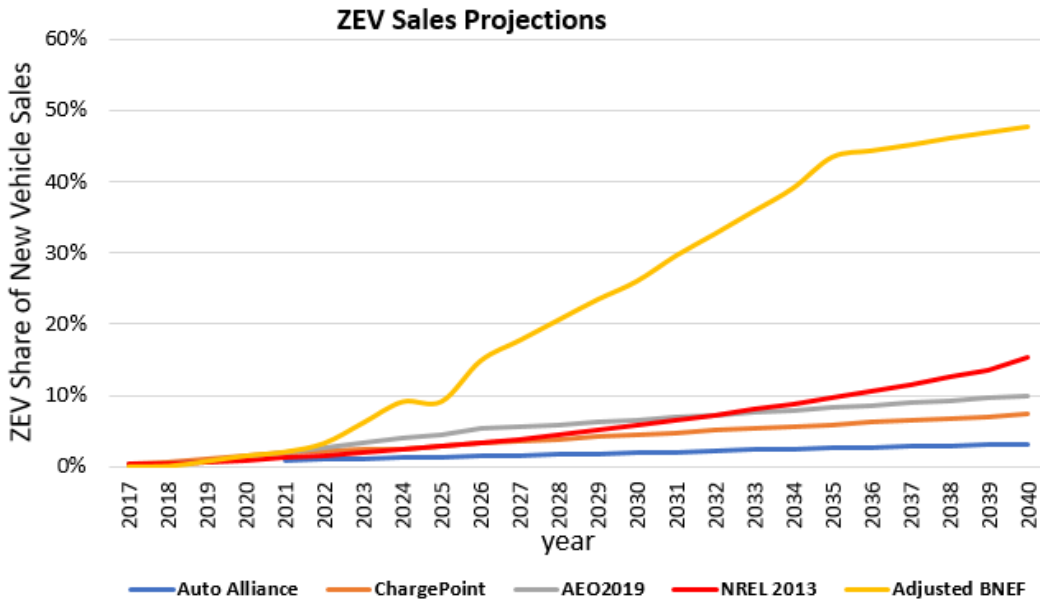


Figure 8-3: Projected North Carolina ZEV sales through 2040

*See Appendix A

8.1.3 NC Electric Vehicle Charging Station Types and Locations

NC's existing demographic and market factors support EV adoption and more EV growth is expected in the future. Figure 8-4 shows that currently, there are approximately 7,700 ZEVs registered in the state.⁷ According the Department of Energy (DOE) Alternative Fuel Data Center (AFDC), there are approximately 592 private/public electric charging stations and 1,375 charging outlets in NC.

Stations designated as "Private - Fleet customers only" allow other entities to charge vehicles through a business-to-business arrangement.⁸

⁶ NC Division of Air Quality, 2019, Analysis of data from <https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/>

⁷ Electric Vehicle Outlook, Bloomberg New Energy Finance, 2018

⁸ <https://afdc.energy.gov/stations/states>

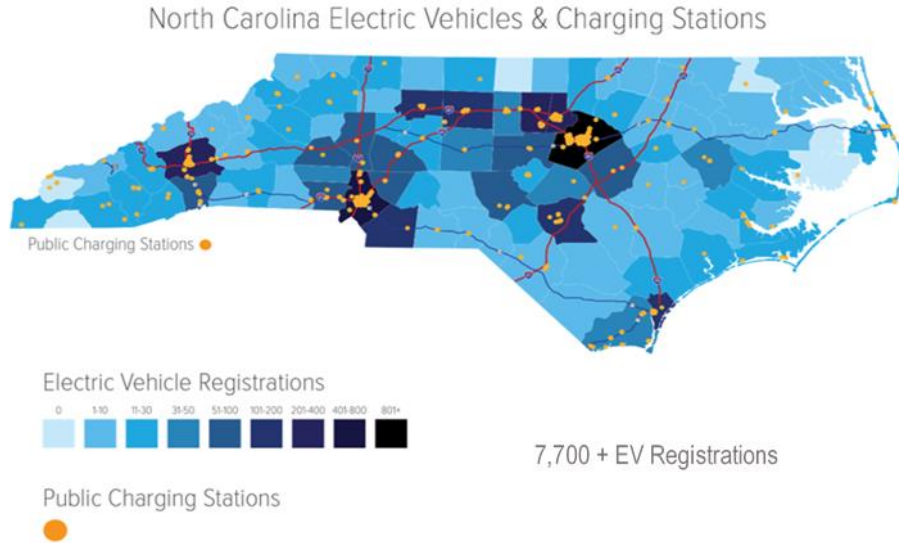


Figure 8-4 North Carolina EV Registrations and Charging Stations

Types of EV Charging Stations

EV charging stations can be located in residential garages, workplaces, schools, hospitals, shopping centers, town centers, bus and fleet depots, interstate stops, or any location where proper electrical power is available.

Charging equipment for EVs is classified by the rate at which the batteries are charged. Charging times vary based on how depleted the vehicle battery is, how much energy it holds, the type of battery, the type of charging equipment, and the vehicle onboard charge rate. The charging time can range from less than 20 minutes to 20 hours or more, depending on the above factors and the charging systems that follow below.⁹

1. Level 1 equipment provides charging through a 120 volt (V) alternating current (AC) connection. Most plug-in EVs are equipped with an AC Level 1 cord set, so that no additional charging connector is required. One hour of Level 1 charging can provide approximately 2 to 5 miles of travel range.
2. Level 2 equipment offers charging through a 240V (typical in residential applications) or 208V (typical in commercial applications) electrical service. One hour of Level 2 charging will provide approximately 10 to 20 miles of travel range.
3. Level 3 Direct current (DC) fast charging equipment, or DC Level 3 (typically 208V/480V AC three-phase service), enables rapid charging along heavy traffic corridors at installed charging stations. How fast depends on both the power delivered by the charging station and the acceptance rate of the battery, though a range of 60-80 miles of range per 20 minutes charging is common. As vehicle manufacturers and charging manufacturers continue to develop this technology, it is likely that charge times will become even faster, as both the power delivered by the charger and the power accepted by the battery in the vehicle increase.

⁹ U.S. Department of Energy, "Vehicle Charging," <https://www.energy.gov/eere/electricvehicles/vehicle-charging>



8.2. Transportation Electrification Technology Overview and Application

8.2.1 Technology Benefits and Limitations

1. *Utility Customer Benefits:*

MJ Bradley and Associates conducted a study for Duke Energy to estimate the costs and benefits of increased adoption of EVs. The study estimated the financial benefits to NC electric utility customers for the utilization during low load hours, and for EV increased utility revenues resulting from EV charging. The analysis assumes that by 2030, all ZEVs will have 200-mile range per charge, and all PHEVs will have 50-mile all-electric range.¹⁰ The study analyzes two scenarios: a moderate or “business as usual” scenario and a more aggressive high-adoption scenario. The difference in adoption rates between the two scenarios is shown in Figure 8-5. It should be noted that the adoption numbers in Executive Order 80 (EO 80) and the scenarios modeled by MJ Bradley are not the same. Under the moderate “business as usual” scenario under MJ Bradley, there is an assumption that there will be 469,000 plug-in EVs (both plug-in hybrids and all-electric vehicles) on the road by 2030. EO 80 calls for 80,000 ZEVs (all-electric vehicles) by 2025.

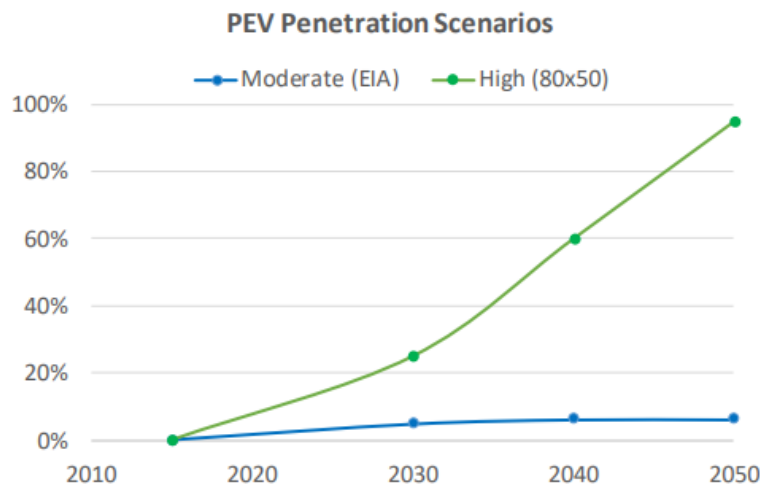


Figure 8-5: PEV Penetration Scenarios¹¹

The study determined that under the “moderate” or business as usual scenario, the estimated annual benefits from fuel and maintenance costs will be approximately \$843 per year, as compared to costs of owning ICE vehicles. In addition, since EVs have no exhaust systems and do not require oil changes, both emissions and maintenance costs are reduced. Under the same “moderate” scenario, greenhouse gas (GHG) emissions are projected to be reduced by up to 17.4 million tons in 2050.¹⁰

¹⁰MJ Bradley and Associates <https://mjbradley.com/sites/default/files/NC%20PEV%20CB%20Analysis%20FINAL.pdf>

¹¹ MJ Bradley and Associates <https://mjbradley.com/sites/default/files/NC%20PEV%20CB%20Analysis%20FINAL.pdf>



Figure 8-6 below shows MJ Bradley’s estimate of the Net Present Value (NPV) of projected annual “net revenue” that utilities could realize from additional electricity sales for EV charging under a baseline charging scenario. The analysis is based on 2016 average electricity use of 12,746 kWh per household in NC.¹²

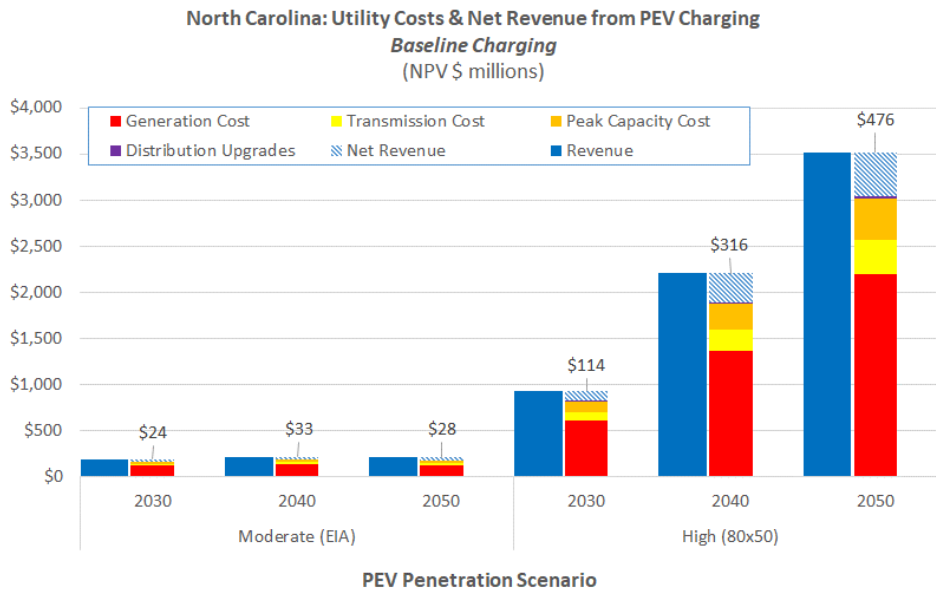


Figure 8-6: EV Baseline Charging Projections¹³

Under the Moderate EV penetration scenario, the NPV of net annual NC revenue is projected to total \$24 million in 2030 and \$28 million in 2050. Under the High EV scenario, the net annual revenue is projected to be \$114 million in 2030, and approximately \$476 million in 2050.⁹

Managed charging is also known as smart charging, which allows a utility or third party to remotely control vehicle charging by turning it up, down, or even off to better correspond to the needs of the grid. Figure 8-7 below shows the NPV for managed charging scenarios. The NPV of net annual revenue for the moderate EV penetration scenario is projected to be \$43 million in 2030 and \$49 million in 2050. The high EV scenario shows a managed charging annual utility net revenue of \$213 million in 2030 and \$681 million in 2050. This analysis estimates that when compared to baseline charging, managed charging will increase the annual utility NPV per EV by \$42 in 2030, and \$20 to \$31 per EV in 2050.⁹

¹² MJ Bradley and Associates <https://mjbradley.com/sites/default/files/NC%20PEV%20CB%20Analysis%20FINAL.pdf>

¹³ MJ Bradley and Associates <https://mjbradley.com/sites/default/files/NC%20PEV%20CB%20Analysis%20FINAL.pdf>

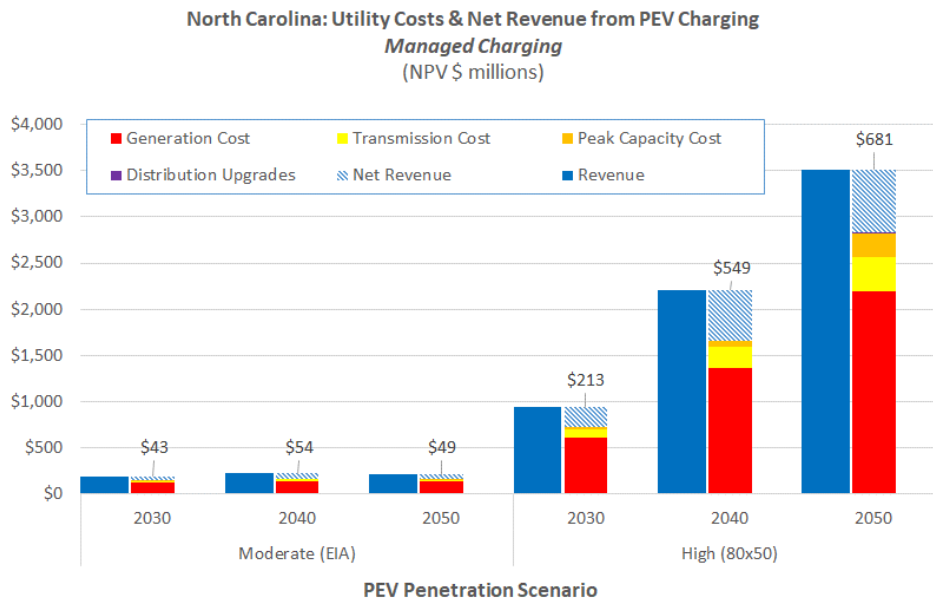


Figure 8-7: EV Managed Charging Projections

2. Driver Benefits:

The primary consumer or driver benefits through cost savings from reductions in fuel usage and vehicle maintenance requirements. When compared with a typical ICE vehicle, an EV owner could realize a potential fuel savings of \$700-\$1,100 per year based on the 2018 average cost of gasoline at \$2.74 per gallon, and an average of 12,000 vehicle miles traveled annually.¹⁴ In addition, since EVs have no exhaust systems, and fewer moving parts, and do not require oil changes, maintenance costs are reduced. Figure 8-8 is a custom survey conducted by DOE that shows the most important factors for EV drivers is the cost savings.

3. Environmental Benefits:

Air emissions from EVs and PHEVs are dependent on the electricity source and have significant emissions reduction benefits when compared to ICE vehicles. EVs produce zero tailpipe emissions, and PHEVs produce no tailpipe emissions when in all-electric mode. The average ICE vehicle produces 414 grams of GHG emissions per mile, whereas the average EV produces 376 grams of GHG emissions per mile.¹⁵ Today an EV or PHEV using an average mix of US power generation sources, (coal, natural gas, nuclear and renewables) causes roughly 3800 pounds of GHG emissions per year, which is less than the national average of 4300 pounds per year.¹⁶ The energy supplied through power sources vary from fossil fuels to renewable sources. NC’s electric grid is cleaner than most states. As the state diversifies towards a cleaner generation fleet, the net impacts from the EV sector will be reduced further.

¹⁴ MJ Bradley and Associates <https://mjbradley.com/sites/default/files/NC%20PEV%20CB%20Analysis%20FINAL.pdf>

¹⁵ Argonne National Laboratory GREET model, WTW Calculator

¹⁶ U.S. DOE Alternative Fuels Data Center, “Electric Vehicle Emissions”

https://afdc.energy.gov/vehicles/electric_emissions.html



Benefits of Driving Electric - Owner

Electric vehicles provide:

- Cost savings
- High performance
- Healthier communities
- Energy independence

ANNUAL FUEL COST SAVINGS				
Miles per Year	Avg. Miles per Day	Gasoline Cost per Year	Electric Cost per Year	Annual Savings
10,000	27	\$617	\$333	\$283
12,000	33	\$1,100	\$400	\$700
15,000	41	\$1,375	\$500	\$875
20,000	55	\$1,833	\$667	\$1,167
25,000	68	\$2,292	\$833	\$1,458

Assumptions: Cost per Gallon Gasoline: \$2.75, Cost per kWh: \$0.10
 Source: afdc.energy.gov



Most Important Electric Vehicle Factors



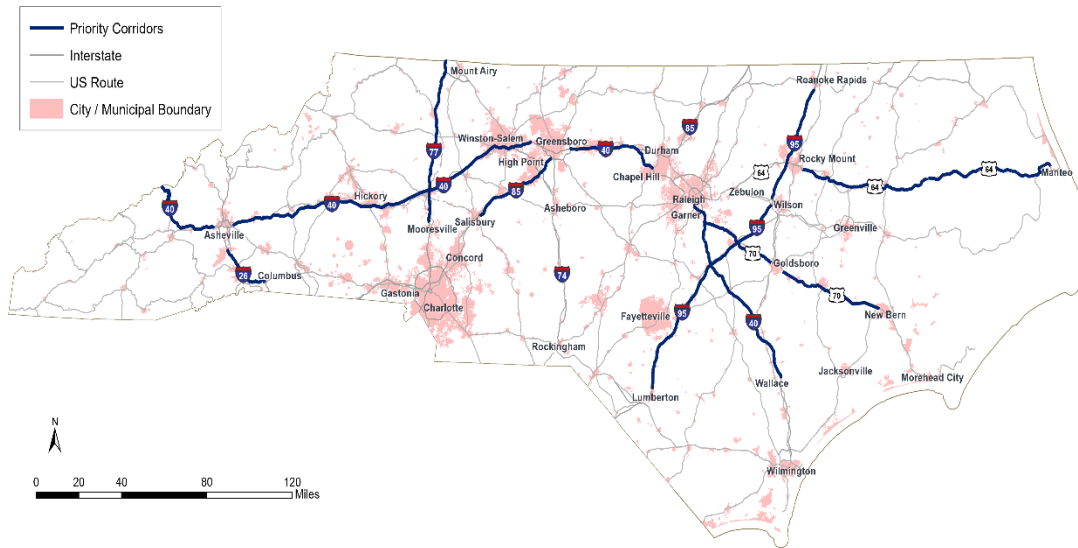
Figure 8-8: Benefits of Driving Electric

The lack of sufficient EV charging infrastructure can be a barrier to adoption, compounding “range anxiety” and hesitations about driving an EV. In NC, the most critical issue is the lack of DC fast charging stations. Figure 8-9 is a map of the Federal Highway Administration’s (FHWA) Designated EV Recharging Corridors in NC.¹⁷ NC has an existing network of charging infrastructure which is primarily Level 2. Most of the charging stations are located in city centers and along certain major highways, but there are long stretches of highway corridors that have little or no EV infrastructure. The general public uses Level 2 or DC fast charging. In addition to the infrastructure costs associated with EV charging, there are other factors to be considered such as zoning regulations, parking ordinances, and environmental concerns.

The NC Department of Transportation, (NCDOT) in coordination with the Department of Environmental Quality (DEQ), is to develop a ZEV Plan to achieve the ZEV registration goal established by the EO 80. NCDOT’s plan is divided into three phases. The first phase is to prioritize ZEVs when purchasing or leasing new vehicles and to prioritize low emission alternatives when ZEV use is not feasible. Phase 2 tasks will include coordinating with local transit agencies and reviewing funding options for NCDOT to buy ZEVs. The third phase requires NCDOT to finalize efforts establishing alternative fuel corridors that support ZEVs.¹⁸

¹⁷ NC DOT priority Corridor Map. www.ncdot.gov

¹⁸ NC Dept. of Transportation www.dot.gov



Map Created By
NCDOT Transportation Planning Division

Figure 8-9: NC DOT Volkswagen Phase 1 Priority Corridor Map

8.2.2 Emerging Technology Trends

In 2018, researchers at NC State University (NCSU) FREEDM Engineering Research Center built an EV fast charger that is about 10 times smaller and more efficient than existing systems. Since it is 60 % more efficient during charging, the charging process takes less time. NCSU is now building a version that is capable of both charging vehicles more quickly and charging multiple vehicles at the same time.

The new technology, a medium voltage fast charger (MVFC), performs the work of both the transformer and the fast charger. The MVFC uses electric power directly from a medium-voltage utility line to convert the energy into a charging process. This new approach offers four times more power from the same charging system footprint and at the same time reduces the charging station installation costs.¹⁹

Durham NC based CREE Semiconductor has a division called Wolfspeed that is a global leader in silicon carbide (SiC) semiconductor power handling devices. SiC technology offers performance characteristics that are superior to conventional silicon semiconductors. SiC technology offers higher performance, lighter weight, smaller size, higher efficiencies, and lower temperatures, all of which are valuable features for on-board chargers, inverters, and other power-handling equipment commonly found in both EVs and EV charging stations. It is SiC technology that gives the FREEDM Center’s MVFC charger much of its superior performance. As SiC technology is increasingly used in EVs and EV charging systems, efficiencies will increase, weights will drop, ranges will improve, and charge times will decrease.

According to BNEF, by 2040, up to 50% of new car sales are projected to be EVs.²⁰ This EV growth will require revolutionary technologies like MVFC and SiC to meet charging demands.

¹⁹<https://www.freedm.ncsu.edu/projects/y10-modular-mv-fast-charger>

²⁰ Bloomberg New Energy Finance *Electric Vehicle Outlook 2019*. <http://www.bloomberg.com>



8.2.3 Other Electric Vehicle Initiatives

The NC Plug-In Electric Vehicle Taskforce, (NC PHEV) was launched in 2011 through a collaboration of partners that included government, industry, electric utilities, non-profits, and other stakeholders to create the state's first PHEV readiness plan called the NC PHEV Roadmap. In 2016, the NC Sustainable Energy Association (NCSEA) convened the Electric Vehicle Working Group (EVWG). The EVWG's goal is to help establish state policy and regulatory framework as it relates to transportation electrification in the state.

8.3. Future Resource Deployment in NC

8.3.1 Policies and Programs Driving Deployment

In October 2018, Governor Roy Cooper signed Executive Order 80 (EO 80) requiring a Zero Emissions Vehicle (ZEV) Plan to achieve the goal of having 80,000 NC registered ZEVs by 2025. EO 80 directs cabinet agencies to prioritize ZEVs when purchasing or leasing new vehicles and to utilize ZEVs when possible for agency-related business travel. The Department of Administration (DOA) is instructed to develop a Motor Fleet ZEV Plan that identifies the types of trips for which an EV is feasible, recommend infrastructure necessary to support EV use, and develop options and strategies to increase the purchase and usage of EVs. DOA must also account for each agency's EV miles driven by vehicle type.

As part of the Volkswagen (VW) Mitigation Settlement, NC was awarded \$92 million in 2018. Fifteen percent of the funds will be used to expand the state's EV infrastructure. The NC Division of Air Quality (NC DAQ) has released two RFPs for projects that achieve significant reductions in emissions. The first phase will provide more than \$27 million in funding for a Diesel and Bus program, and a DC Fast Charge program. Under the Diesel and Bus Program, \$24.5 million will be available, and 40 % of these funds will be allocated for school bus replacement. The DC Fast Charge program will allocate \$3.4 million to EV charging infrastructure installations.²¹

During the 2019-2020 legislative session, NC Session Law 2019-132 (House Bill 329) was passed to exempt EV charging stations from regulation as public utilities. This law amends G.S. 62-3(23) to exclude a person who uses an EV charging station to resell electricity to the public for compensation from being treated as a public utility as long as the following apply: 1) The reseller has procured the electricity from an electric power supplier that is authorized to engage in the retail sale of electricity within the territory in which the EV charging service is provided; 2) All resales are exclusively for the charging of plug-in EVs; 3) The charging station is immobile; and 4) Utility service to an EV charging station shall be provided subject to the electric power supplier's terms and conditions.²²

²¹ NC Division of Air Quality. www.ncdeq.gov

²² North Carolina General Assembly Session 2019. Retrieve July 2019 from, <https://www.ncleg.gov/EnactedLegislation/SessionLaws/PDF/2019-2020/SL2019-132.pdf>



8.3.2 Constraints to Deployment

1. Upfront Purchase Costs of Vehicles

New EVs are still more expensive than similar ICE vehicles. For example, the Chevrolet Cruze and Chevrolet Bolt are similar-sized passenger vehicles. The 2019 Chevrolet Cruze starts at \$20,495, whereas the 2019 Chevrolet Bolt starts at \$37,495 without state or federal incentives.²³ This upfront cost difference is a major barrier for many consumers.

2. Availability of vehicles for sale in NC

Because there is greater demand in states with more incentives, not all vehicle models are available for sale everywhere in the US. According to EVadoption.com, there are 31 models available for sale in NC versus 42 in California and Oregon.²⁴ However, according to the experience of staff at the NC Clean Energy Technology Center, even those 31 models of plug-in vehicles may be difficult to come by. A dealer might be able to order them but will not have them available on the lot for a consumer to examine.

3. Ability of government agencies to use “total cost of ownership” when making procurement decisions

Government agencies in NC have separate capital and operating budgets for vehicles. Fuel savings from the use of EVs cannot be used towards the capital budget to help an agency defray the higher upfront cost of EVs.

4. Concerns of motorists

Even as EVs continue to grow in popularity, motorists have concerns about purchasing due to: range anxiety; fear of public charging station availability; battery life; the time required to charge the battery; and ability to have the vehicle serviced. These concerns may be because of the consumer’s lack of understanding and education about charging availability.

8.3.3 Initial Investment Costs

The initial upfront cost for the installation of an EV charging station can vary depending upon its location and the owner’s preference of equipment. As seen in Figure 8-10, level 1 (the least expensive option) requires a 120V outlet. Level 2 requires 240V or 208V power service and a dedicated circuit of 20 to 80 amps. The DC fast charging equipment (the most expensive option), requires 3 phase power and is usually installed through an EV charging station network. The increased costs for DC charging are based on the equipment used, and installation expenses that may require an electrician to install a 480V transformer. Table 3-1 shows equipment costs; the installation costs can vary greatly depending on whether trenching is necessary and also based on whether the electrical infrastructure needs to be upgraded.

²³www.chevrolet.com

²⁴ EVadoption, “Factors Contributing to EV Sales Market Share By US State,” <https://evadoption.com/factors-contributing-to-ev-sales-market-share-by-us-state/>



Figure 8-10: Infrastructure Charging Station Costs²⁵

8.4. Grid Integration and Reliability

8.4.1 Grid Integration

In April 2019, Duke Energy Carolinas (DEC) filed a proposal with the North Carolina Utilities Commission (NCUC) for an Electric Transportation Program. If approved, the \$76 million program would offer residential charging, public charging, fleet EV charging, EV school bus charging, and EV transit bus charging. The residential charging and fleet charging components would offer a \$1,000 and \$2,500 rebate respectively to qualifying stations.²⁶

8.4.2 Grid Modernization

In February 2018, the Energy Policy Council (EPC) heard several presentations on EVs, including necessary infrastructure improvements, and projected EV penetration in the State. According to Lang Reynolds (Duke Energy), growth in electricity demand from EVs is not currently expected to require any incremental generation capacity.²⁷ Lower penetration rates will not impact the grid but as it grows, it is projected that by year 2030 new capacity or generation may be needed.

8.5. Resource Costs and Benefits

Today’s EVs are more expensive when compared to a similar sized ICE vehicle. Because of increased technological advances, mass production of batteries, and available tax credits, the purchase cost of EVs is declining. The cost for the most economically feasible EVs ranges from \$32,000 to \$45,000 before tax credits are applied. Together, these factors are making EV purchases more cost effective.

Twenty-one states now have enacted legislation to collect additional fees from EV owners. This action increases the cost of owning an EV. The NC Department of Revenue collects gasoline taxes for funding

²⁵ Advanced Energy, 2019 www.advancedenergy.org

²⁶ <https://www.wfae.org/post/duke-energy-proposes-76-million-program-electric-vehicles-and-chargers>

²⁷ Energy Policy Council. (2018, February 21). *Energy Policy Council Meeting, February 21*. Retrieved from <https://deq.nc.gov/about/divisions/energy-mineral-land-resources/energy-policy-council/epc-meetings>



transportation projects. Since EVs do not use gasoline, NC collects a \$130 registration fee annually on all EVs to recoup the lost gas tax revenue.²⁸ A study by the North Carolina Clean Energy Technology Center estimated that the lost gas tax revenue per electric vehicle was less than \$130 per year.²⁹ The NC General Assembly introduced Senate Bill 446 (SB 446) in the 2019-2020 legislative session, which calls for increasing the fee on EVs from \$130 to \$275 over the next three years, but no further legislative action was taken regarding the bill.³⁰

²⁸ DOE. [www.https://afdc.energy.gov/laws/state](https://afdc.energy.gov/laws/state)

²⁹ Brutz, H. and Carr, A. “Potential Impacts of Alternative Fuel Vehicles on Transportation Revenue in North Carolina,” NC Clean Energy Technology Center, NC State University, 2019.

³⁰ NC General Assembly, <https://www.ncleg.gov/Sessions/2019/Bills/Senate/PDF/SB446v3.pdf>



Appendix A

Table 1 – Projections of NC ZEV sales as percent of light duty vehicle (LDV)

ZEV Adoption Rate Scenario	Data source	ZEV sales share (% of new LDV sales)			Projected Annual North Carolina ZEV new vehicle sales			Methodology
		2025	2030	2040	2025	2030	2040	
Low (current)	Auto Alliance 2018	1.3	2.0	3.1	6,900	10,300	17,200	Projected from cumulative NC ZEV registrations from 2015 to 2018 with polynomial curve fit
Medium	ChargePoint 2018	2.8	4.5	7.3	14,400	23,600	40,400	Projected from ChargePoint new EV sales estimates for 2017 to 2026 with linear curve fit
Medium	AEO 2019	4.4	6.6	9.9	22,900	34,800	55,000	National ZEV projection data through 2050, provided in AEO 2019, downscaled to state level based on population estimates
Medium	NREL 2013	2.8	5.7	15.4	14,400	30,200	85,000	National ZEV projection data through 2050, provided by NREL through 2050, downscaled to state level based on population estimates
High	Adjusted BNEF 2018*	9.2	26.1	47.7	47,300	137,600	263,900	Selected national data through 2050, provided by BNEF, downscaled to state level based on population estimates, a AEO 2019 BEV/PEV fraction applied

*BEV/PEV fraction is based on 2019 AEO data.

LDV sales in North Carolina in 2025, 2030, 2040 are 513,800/527,100/553,300, respectively downscaled from AE



Table 2 – Predictions of total ZEV in North Carolina LDV fleet

ZEV Adoption Rate Scenario	Data source	ZEV in LDV (% of vehicle fleet) *			Projected North Carolina ZEV Fleet*			Methodology
		2025	2030	2040	2025	2030	2040	
Low (current)	Auto Alliance 2018	0.5	1.1	2.7	40,600	85,500	226,000	Projected from cumulative NC ZEV registrations from 2015 to 2018 with polynomial curve fit
Medium	ChargePoint 2018	1.0	1.9	4.5	74,400	155,000	383,000	Projected from ChargePoint new EV sales estimates for 2017 to 2026 with linear curve fit
Medium	AEO 2019	1.0	2.4	5.9	76,800	196,000	502,000	National ZEV projection data through 2050, provided in AEO 2019, downscaled to state level based on population estimates
Medium	NREL 2013	0.7	1.7	6.3	50,600	136,000	532,000	National ZEV projection data through 2050, provided by NREL through 2050, downscaled to state level based on population estimates
High	Adjusted BNEF 2018**	1.7	7.2	31.5	129,200	577,000	2,680,600	Selected national data through 2050, provided by BNEF, downscaled to state level based on population estimates, a AEO 2019 BEV/PEV fraction applied

*all Medium and High scenarios assume a 4% scrappage rate

** BEV/PEV fraction is based on 2019 AEO data.

LDV fleet in North Carolina in 2025, 2030, 2040 are 7,768,800/8,015,559/8,503,154, respectively downscaled from AEO2019





9. Wind

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9.1 Wind Resources Introduction

North Carolina boasts high-rated resources for both on- and offshore wind energy generation, although the onshore resource areas in particular are both very geographically specific and limited by political and societal concerns.

According to its *2018 U.S. Wind Industry Annual Market Report*, the American Wind Energy Association (AWEA) announced that at the end of 2018, the U.S. onshore cumulative wind energy capacity totaled 96,433MW, a nearly 8% increase over the previous year's installed capacity.¹ Furthermore, in 2018, wind energy powered more than 20% of the electricity generated in six states (Iowa, Kansas, Maine, North Dakota, Oklahoma, and South Dakota) and accounted for 6.6% of total U.S. utility-scale electricity generation.^{2,3}

All of this installed capacity results from on-shore or land-based wind energy facilities, except for 30MW of installed capacity at the Block Island Wind Farm located in state waters off the coast of Rhode Island. The states of Virginia, New Jersey and New York are also moving to jumpstart offshore wind (OSW) projects. Dominion Energy began construction of two offshore turbines as a demonstration project⁴ in the second quarter of 2019. New Jersey selected a company in June 2019 through an RFP to build a 1,100-megawatt wind farm off the coast of Atlantic City and New York State reached an agreement in July 2019 for two large OSW projects to be built off the coast of Long Island⁵ the largest combined OSW contracts by any state to date, totaling 1,696 MW⁶.

It is estimated that through calendar year 2019, installed capacity for wind energy generation will grow, likely doubling the installations completed in 2018, due to the expiration of the Production Tax Credit (PTC).⁷ The US Energy Information Administration (EIA) predicts that US wind capacity additions in 2019 will total 12.7GW, exceeding annual capacity additions for the previous six years.⁸ The long-term outlook for OSW energy generation is similarly promising; the US Department of Energy (DOE) reports a total project pipeline of 25,434MW as of June 2018, of which 3,892 MW is in project-specific capacity

¹ AWEA. 2018 U.S. Wind Industry Annual Market Report.

https://www.awea.org/Awea/media/Resources/Publications%20and%20Reports/Market%20Reports/AWEA_AMR2018_ExecutiveSummary.pdf. Accessed May 15, 2019.

² Ibid.

³ https://www.eia.gov/energyexplained/index.php?page=wind_where

⁴ Washington Post. Utility taking cautious approach as Virginia offshore wind project gets underway. July 1, 2019.

https://www.washingtonpost.com/local/virginia-politics/utility-taking-cautious-approach-as-virginia-offshore-wind-project-gets-underway/2019/06/28/540493c6-99c3-11e9-916d-9c61607d8190_story.html?noredirect=on&utm_term=.ac52d8c0fb89.

Accessed July 31, 2019.

⁵ New York Times. New York Awards Offshore Wind Contracts in Bid to Reduce Emissions. July 18, 2019.

<https://www.nytimes.com/2019/07/18/business/energy-environment/offshore-wind-farm-new-york.html>. Accessed July 31, 2019.

⁶ Utility Dive. New York awards record 1,700 MW offshore wind contracts. July 19, 2019.

<https://www.utilitydive.com/news/new-york-awards-record-1700-mw-offshore-wind-contracts/559091/>. Accessed on July 31, 2019.

⁷ *The PTC provides operators with a tax credit per kWh of renewable electricity generation for the first 10 years a facility is in operation.*

⁸ U.S. EIA. Tax Credit Phase Out Encourages More Wind Power Plants to be Added by End of Year.

<https://www.eia.gov/todayinenergy/detail.php?id=39472#>. Accessed on May 17, 2019.



and 21,542MW of undeveloped lease area potential capacity.⁹ As of the date of this Report, only one utility-scale wind energy facility is in operation in NC; the 208MW nameplate capacity Amazon Wind Farm, US East.

9.1.1 Current Installation Capacity and Generation in North Carolina

Located in Perquimans and Pasquotank counties near Elizabeth City, Avangrid’s Amazon Wind Farm, US East,¹⁰ boasts 104-2 MW wind turbines with nameplate capacity of 208 MW. This facility generates enough electricity to power 61,000 homes annually. The electricity generated from the Amazon Wind Farm feeds into PJM regional transmission organization and Dominion Power in Virginia. Amazon Wind spans 22,000 acres and is leased from approximately 60 local land owners. The facility’s total permanent footprint is less than 200 acres and local land owners continue to farm corn, soybeans, and wheat on lands under lease. When Amazon Wind went into operation in 2017, Avangrid became the largest single taxpayer in both Perquimans and Pasquotank counties, with payments of over \$380,000 and \$260,000, made respectively.

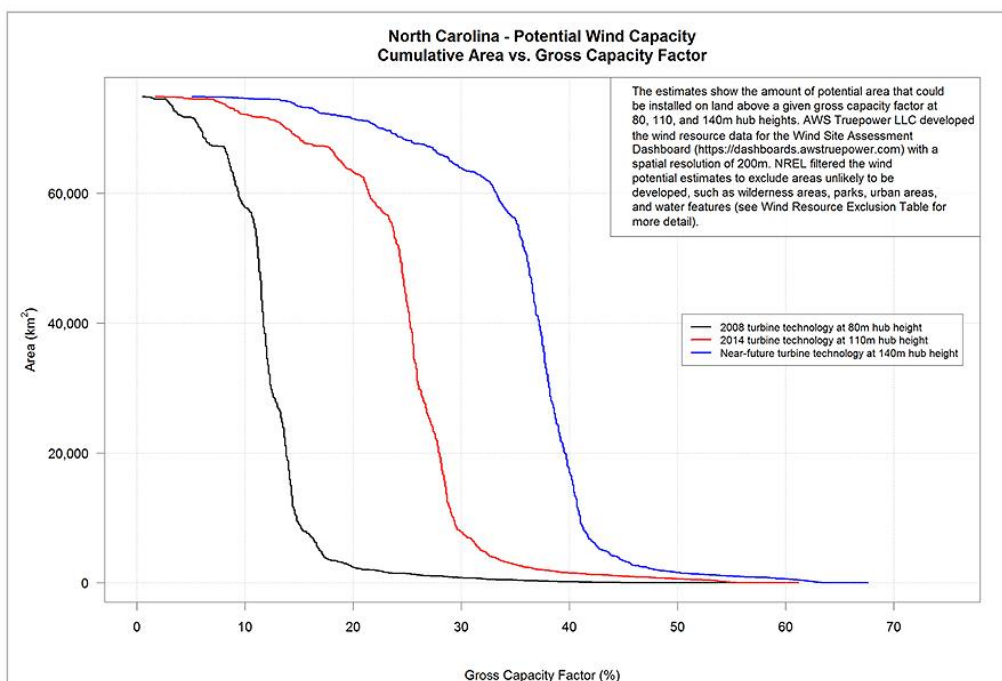


Figure 9-1: North Carolina Potential Onshore Wind Capacity^{11,12}

Source: U.S. Department of Energy, WINDEXchange

⁹ 2017 DOE Offshore Wind Technology Market Update.

¹⁰ About Amazon Wind, Avangrid Renewables: http://www.avangridrenewables.us/cs_amazon-wind-farm-us-east.html

¹¹ Office of Energy Efficiency and Renewable Energy. WINDEXchange: North Carolina Potential Onshore Wind Capacity Chart. <https://windexchange.energy.gov/maps-data/76>. Accessed on June 1, 2019.

¹² According to the 2018 AWEA Annual Market Report (footnote 3), as hub heights continue to increase, the 110m height represent the most realistic in North Carolina, which is why interest in development onshore in this State came after that in the Midwest, where the winds are strong at 80m height.



9.1.2 Planned Growth in North Carolina, Onshore Wind

At present, only one additional onshore wind energy project is in pre-permit development in NC; the Apex Clean Energy Timbermill Wind Project located near the Amazon Wind Farm in Chowan County. Timbermill is expected to include up to 48 wind turbines, with a capacity of up to 202MW, capable of producing enough energy to power up to 48,000 homes every year.¹³ According to the developer, existing high-voltage power lines and highways would limit the need for new infrastructure. Apex Clean Energy was granted a conditional use permit for Timbermill Wind from the Chowan County Commission in 2016, and continues its work with the community while conducting extensive studies, engineering, permitting, and other work before construction begins.

9.1.3 Planned Growth in North Carolina, Offshore Wind

With the second-highest average wind speeds on the Atlantic coast, NC’s outer continental shelf (OCS) waters harbor great potential for clean energy generation, where good wind speeds and shallow water depth are considered together. Development of the State’s OSW energy resources is currently underway with the first federal lease off the coast issued in 2017.

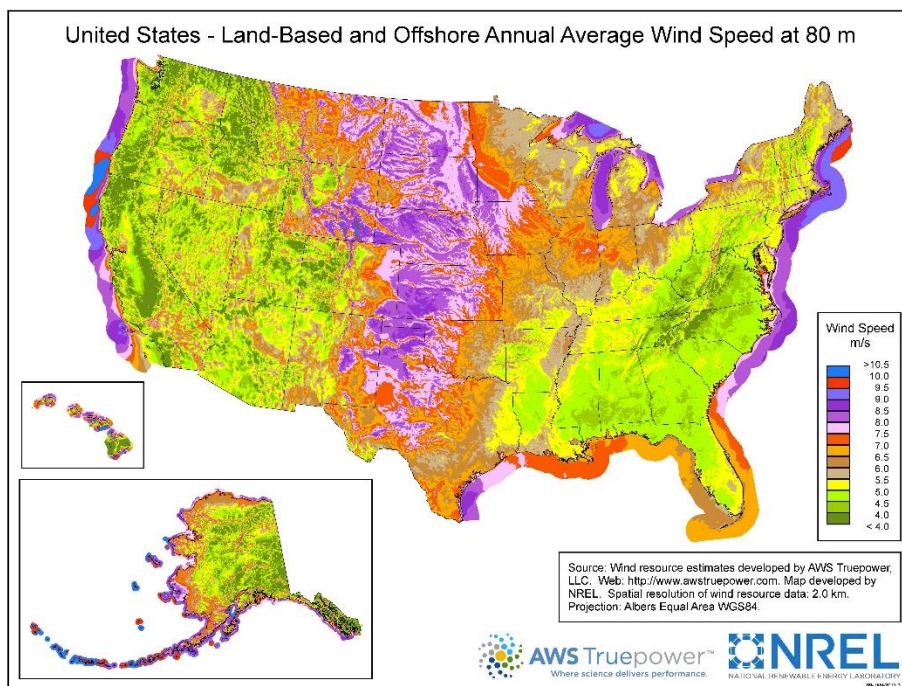


Figure 9-2: U.S. On- and Offshore Annual Average Wind Speed¹⁴

The Kitty Hawk wind energy area (WEA), located 24 nautical miles from Corolla, is over 122,000 acres in size and is under lease by Avangrid. According to the developer, the Kitty Hawk project will boast a capacity of 2,400MW. Avangrid is expected to finalize its planning, assessment, and stakeholder outreach necessary in order to submit its formal Site Assessment Plan (SAP) to the federal Bureau of Ocean

¹³ Apex Clean Energy. About Timbermill Wind. https://www.timbermillwind.com/about_timbermill. Accessed on May 17, 2019.

¹⁴ NREL. Wind Maps. https://www.nrel.gov/gis/images/80m_wind/awstwsdpd80onoffbigC3-3dpi600.jpg. Accessed on May 17, 2019.



Energy Management (BOEM) in the summer of 2019.¹⁵ After it receives approval of the SAP, Avangrid will prepare a detailed plan for the construction and operation of a wind energy project on the leasehold. BOEM will concurrently conduct both environmental and technical reviews of the Construction and Operation Plan (COP) and will decide whether to approve, approve with modification, or disapprove the COP. Construction and installation of the Kitty Hawk project could begin as early as 2023, and the facility would go into operation in 2025. Two additional WEAs were identified by BOEM off the NC coast, the Wilmington East and Wilmington West WEAs, which are 133,000 and 51,000 acres respectively. Progress on leasing the two Wilmington WEAs is presently on hold while BOEM evaluates and addresses local concerns that development and operation of wind near shore will negatively impact tourism. Based on these concerns, communities requested a 27-mile buffer to ensure the structures are not visible from shore. A 27-mile buffer would eliminate the Wilmington West WEA, significantly reduce the size of the Wilmington East WEA, and due to the locational proximity to SC’s coast, would significantly impact the proposed Grand Strand WEA as well.

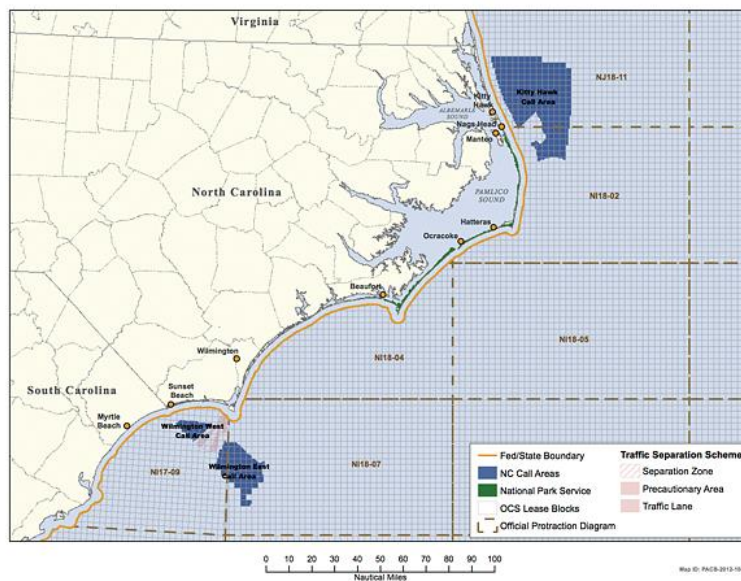


Figure 9-3: Location of the BOEM-identified WEAs off North Carolina’s Coast¹⁶

Source: Lumina News

In April 2018, BOEM issued a Request for Feedback (RFF)¹⁷ regarding its Proposed Path Forward for Future Offshore Renewable Energy Leasing OCS, wherein the Bureau proposes to conduct a high-level assessment of all waters offshore the Atlantic Coast for potential additional lease locations. The

¹⁵ For more information about the BOEM WEA selection and development process, see: <https://www.boem.gov/Renewable-Energy-Program-Overview/> and page 9 of this chapter.

¹⁶ Lumina News. Potential Offshore Wind Lease Blocks Outlined. August 27, 2014. Accessed on April 1, 2018. <http://luminanews.com/2014/08/potential-offshore-wind-lease-blocks-outlined/#prettyPhoto>.

¹⁷ Bureau of Ocean Energy Management, United States Department of the Interior. (2018, April 6). *Request for Feedback on BOEM’s Proposed Path Forward for Future Offshore Renewable Energy Leasing on the Atlantic OCS*. 83 Federal Register 67, pp. 14881-14884. Retrieved from <https://www.gpo.gov/fdsys/pkg/FR-2018-04-06/pdf/2018-07106.pdf>



assessment would rely on various factors to assess which areas along the Atlantic with the highest potential for OSW development in the next three to five years. On June 20, 2018, the Secretary of the Department of Environmental Quality (DEQ), Michael Regan, submitted a comment in support of BOEM's proposal to identify additional lease areas off the coast of NC for offshore renewable energy (RE) development, the status of BOEM's assessment is unknown as of the date of this Report.¹⁸

9.2 Wind Technology Overview and Application

9.2.1 Technology Description

Wind is, at its core, a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when harvested by wind turbines, can be used to generate electricity. To capture the potential energy from wind requires wind turbines that use blades to collect wind's kinetic energy and turn it into mechanical energy. As wind flows over the blades, it creates lift, and causes the blades to turn. The blades are connected to an internal drive shaft connected to a gearbox, which increases the speed of rotation by a factor of 100.¹⁹ This mechanical power can be used for specific tasks or a generator can convert this mechanical power into electricity to power the grid. Turbines, behave like an airplane's propeller blades, spinning the air, and powering an electric generator that supplies an electric current.

A wind turbine is made up of the following components: (i) a blade or rotor, which converts the energy in the wind to rotational shaft energy; (ii) a drive train, usually including a gearbox and a generator; (iii) a tower that supports the rotor and drive train; and (iv) other equipment, including controls, electrical cables, ground support equipment, and interconnection equipment (See Figure 9-4). Wind turbines are often configured together into a single wind power plant, also known as a wind farm or wind park, and generate bulk electrical power. Electricity generated from wind farms is fed into a utility grid and distributed to customers, akin to conventional power plants.

According to AWEA, in 2017, the average installed utility-scale wind turbine was rated at 2.32 MW. For the first time, new orders for wind include onshore turbines that are above 4 MW. Manufacturers are also pushing the capacity of offshore turbines. For example, in 2018, MHI Vestas launched its first-ever 10MW wind turbine and GE introduced the 12MW Haliade-X.^{20,21,22} It is expected that turbine technology will continue to evolve, and with increased efficiencies, will drive down the costs for

¹⁸ <https://www.regulations.gov/contentStreamer?documentId=BOEM-2018-0018-0090&attachmentNumber=1&contentType=pdf>.

¹⁹ AWEA. Basics of Wind Energy. <https://www.awea.org/wind-101/basics-of-wind-energy>. Accessed May 15, 2019.

²⁰ WindPower Engineering & Development. The Rise of Windpower: What to Expect in 2019. <https://www.windpowerengineering.com/business-news-projects/the-rise-of-wind-power-what-to-expect-in-2019/>. Accessed on June 19, 2019.

²¹ MHI Vestas. MHI Vestas Launches the First 10MW Wind Turbine in History. <http://www.mhivestasoffshore.com/mhi-vestas-launches-the-first-10-mw-wind-turbine-in-history/> Accessed on June 19, 2019.

²² GE Renewable Energy. Haliade-X Offshore Wind Turbine Platform. <https://www.ge.com/renewableenergy/wind-energy/offshore-wind/haliade-x-offshore-turbine>. Accessed on June 19, 2019.



construction and operations, putting wind energy economically on par with conventional fossil fuel energy generation (See Figure 9-5).

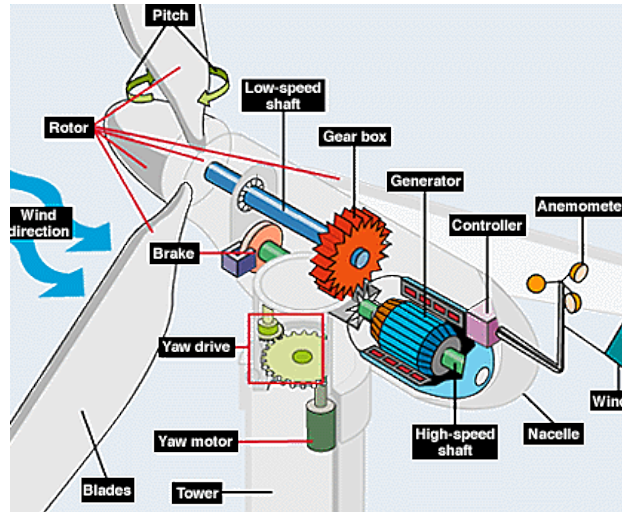


Figure 9-4: Wind Turbine Components²³

Source: NREL

9.2.2 Technology Benefits and Limitations

Wind energy is ubiquitous, clean, and comes with a free supply in NC, which advantages this resource over traditional fossil fuels that are subject to global market price instability due to supply and demand. However, wind energy generation is variable and its power capacity varies over time, mainly due to meteorological changes and fluctuations. At a system level, wind can be harnessed to provide stable energy generation regardless of whether the wind is blowing at a particular location at a particular time.

²³ Adapted from the Bureau of Land Management Wind Energy Development Programmatic EIS Information Center. <http://windeis.anl.gov/index.cfm>. Accessed on June 18, 2019.

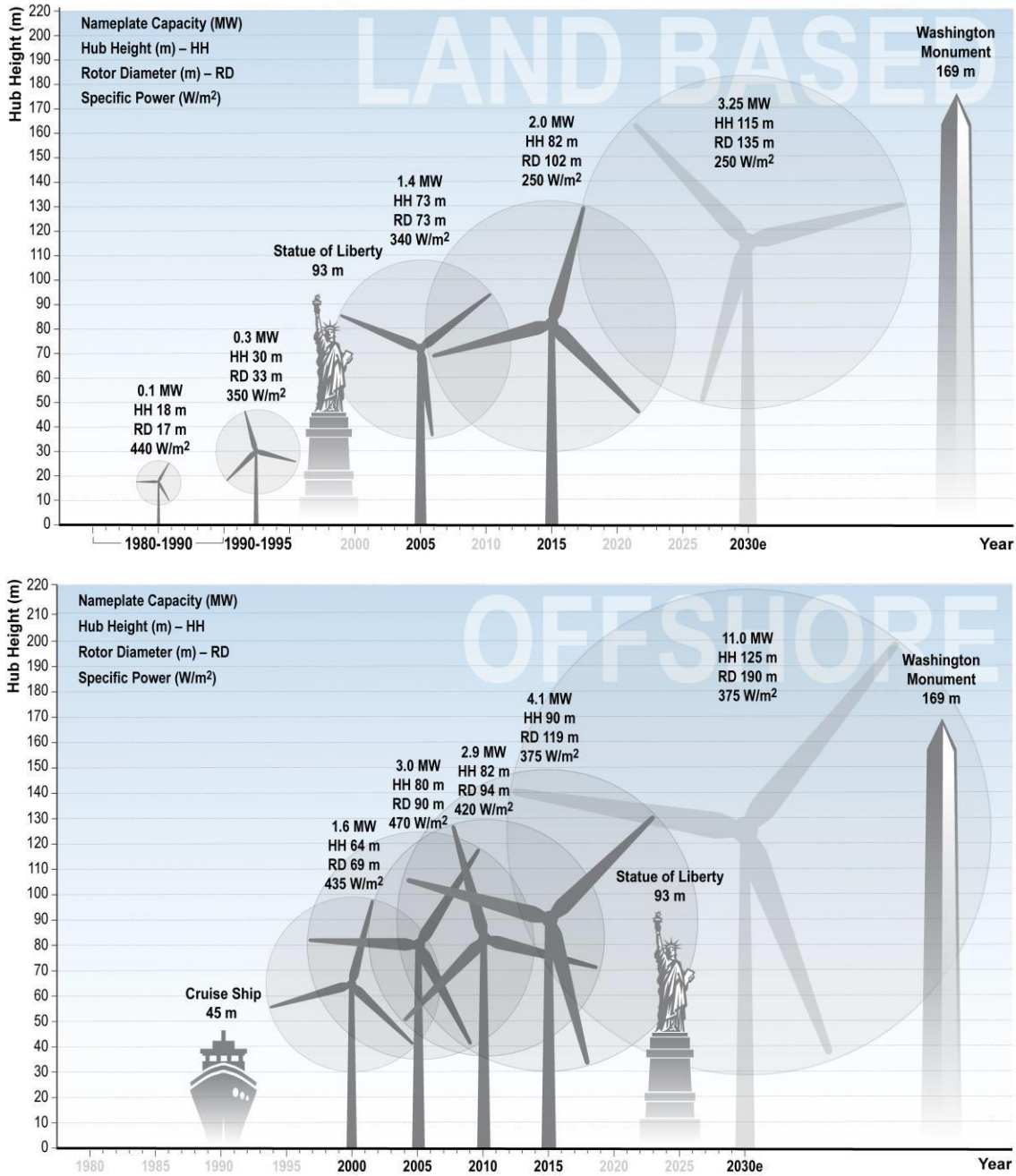


Figure 9-5: Expected Growth in Turbine Size: Onshore Nationally (top) and Offshore Globally (bottom)²⁴

Source: LBNL, 2016

Wind energy is often mischaracterized as an intermittent resource. Unlike conventional generation, at the power system level, wind power does not start and stop at irregular intervals. Periods with zero wind

²⁴ Lawrence Berkeley National Lab. Reducing Wind Energy Costs through Increased Turbine Size: Is the Sky the Limit? November 2016. https://emp.lbl.gov/sites/all/files/scaling_turbines.pdf. Accessed on June 19, 2019.



power production are predictable, especially with the advanced weather forecasting models employed today, and the transition to zero power generation is gradual. Wind turbines can continue to produce electricity during storms and can also be shut down in a matter of minutes if conditions become too dangerous to continue operations.

Another advantage of wind power is that it is distributed over a larger power system; the breakdown of a single turbine has a negligible effect on overall availability. Even in extreme conditions, wind has proven to be one of the more reliable sources of energy. Wind turbines can be remotely operated and are automated to turn out of the wind, and even shut down if conditions require.

9.2.3 Installation, Siting, Decommissioning, and Environmental Issues

Installation and siting of onshore wind energy facilities (WEF) in NC is governed by Article 21C of Chapter 143 of the North Carolina General Statutes.²⁵ Enacted in 2013, the law established a permitting program, implemented by DEQ, for the siting and operation of wind energy facilities in the State. Under the law, no person may undertake construction, operation, or expansion activities associated with a wind energy facility without first obtaining a permit from DEQ. As the permitting agency, DEQ must engage in a robust interagency (involving several federal, state, and local government entities) review, comment, and evaluation of all application materials submitted. In its consideration of a permit application, DEQ must evaluate impacts to the environment, natural resources, and public health including:

- Ecological systems, cultural sites, and recreation areas.
- Areas of more than “local significance,” which may include national or state parks, wilderness areas, historic sites, wildlife refuges, and critical fisheries habitats.
- Fish and wildlife, including avian and bat species.
- Navigation channels or coastal waters.
- Noise and shadow flicker.

In addition to requiring authorization from the US Department of Defense Siting Clearinghouse, the permit process requires a thorough review and consultation with base commanders on potential impacts to military operations, readiness, and capabilities at military installations proximate to the proposed WEF location. Although as of the date of this Report, DEQ has not yet received any applications for a WEF subject to the 2013 law, it is anticipated that the permit process will take approximately nine months to complete.

Permitting, installation, and siting of OSW facilities in NC’s OCS waters is governed by the Bureau of Ocean Energy Management (BOEM) in the US Department of the Interior, the lead agency responsible for development of energy projects in federal waters (between 3 and 200 miles offshore). To help inform BOEM’s planning and leasing process, BOEM established Intergovernmental Renewable Energy Task Forces in states that expressed interest in the development of offshore RE.

The role of each task force is to collect and share relevant information that would be useful to BOEM during its decision-making process. Task force meetings helped identify areas of significant promise for

²⁵ https://www.ncleg.gov/EnactedLegislation/Statutes/PDF/ByArticle/Chapter_143/Article_21C.pdf



offshore development and provided early identification of, and steps toward resolving, potential conflicts.²⁶ While task forces were initially developed for individual states, in June 2019, BOEM announced it would move to regional task forces to reflect the nature of OSW and its impact on multiple states, even for single projects. NC will participate in two different task forces: VANC (covering Virginia and NC) and Carolina Long Bay (covering the Wilmington area of NC and SC).²⁷ BOEM conducts its RE program in four distinct phases: (1) planning and analysis, (2) lease issuance, (3) site assessment, and (4) construction and operations (COP), as illustrated in detail in Figure 9-6 below.

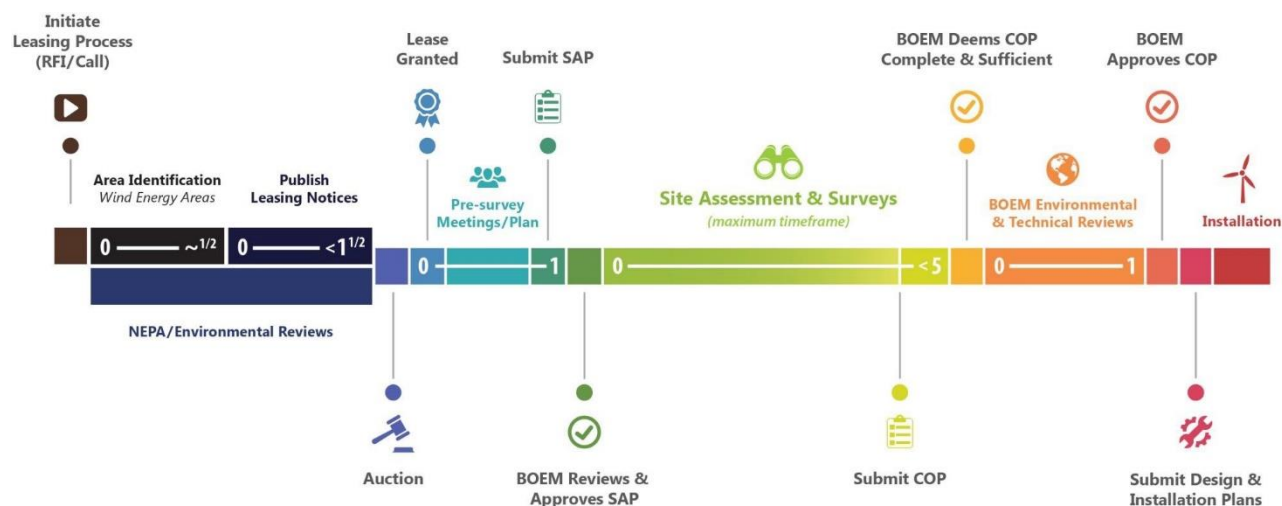


Figure 9-6: Offshore Renewable Energy Process: Leasing to Operations²⁸

Source: BOEM, 2017

During the planning and analysis phase, BOEM works to de-conflict potential WEAs with other users of the OCS waters including: military conflicts that extend beyond a state’s OCS boundary, viewshed impacts, potential ancillary impacts on tourism industries that rely on the OCS waters, fisheries, and other environmental and natural resources.

9.2.4 Decommissioning and Financial Assurance

Developers of OSW projects must adhere to specific decommissioning requirements set out by BOEM in Subpart I of 30 CFR 585.²⁹ In general, decommissioning for a facility authorized under a SAP or COP must be (1) approved by BOEM, (2) completed within two years following termination of a lease, and (3) coordinated with and documented by the affected states, local, and tribal government. This process

²⁶ Bureau of Ocean Energy Management (BOEM). Wind Energy Commercial Leasing Process Fact Sheet. <https://www.boem.gov/Commercial-Leasing-Process-Fact-Sheet/>. Accessed on June 19, 2019.

²⁷ BOEM. The Path Forward to Offshore Wind Leasing. <https://www.boem.gov/The-Path-Forward-for-Offshore-Wind-Leasing/>. Accessed on June 28, 2019.

²⁸ BOEM, Overview of Lease Activities Offshore North Carolina and Virginia. December 2017. <https://www.boem.gov/Regional-Leasing-Authorization-Process/> Accessed on June 19, 2019.

²⁹ 30 CFR 585, Subpart I. <https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=e4ebde11c6066eaa6df5e0a6c43eafd0&mc=true&n=pt30.2.585&r=PART&ty=HTML#sp30.2.585.i>



involves removing or decommissioning all facilities, projects, cable, pipelines, and obstructions as well as clearing the seafloor of all obstructions created by the activities on the lease.

Subpart E of 30 CFR 585³⁰ includes requirements for financial assurance and payments from leaseholders during each stage of a commercial lease, in an amount determined by BOEM based on the complexity, number, and location of all facilities involved in the planned activities and commercial operation. For decommissioning, BOEM will determine the amount and require either a bond or other mechanism for financial assurance based on anticipated decommissioning costs. BOEM will allow the developer to provide financial assurance for decommissioning in accordance with the number of facilities installed or being installed. BOEM must approve the schedule for providing the appropriate financial assurance coverage.

Pursuant to N.C.G.S. §143-215.119(a)(13),³¹ in order to construct and operate an onshore WEF in NC, a developer must include in their permit application, a plan for decommissioning and removal of the WEF. The plan must include: an estimate of the cost to decommission and remove the WEF; the anticipated life of the project; a description of the manner in which the facility will be decommissioned; and a description of the expected condition of the site once the WEF is decommissioned and removed. In addition, N.C.G.S. §143-215.121 requires the permit holder to establish financial assurance that ensures sufficient funds are available to decommission the facility and reclaim the property to its condition prior to commencement of activities on the site, even if the applicant or permit holder becomes insolvent or ceases to reside in, be incorporated, do business, or maintain assets in the State.³²

9.3 Future Wind Energy Resource Deployment in North Carolina

Cost trends, technological innovation, environmental benefits, and consumer demand combined with regulatory certainty can lead to increasing wind energy development and generation in NC.

9.3.1 Policies and Programs Driving Wind Energy Deployment

While the NC Renewable Energy and Energy Efficiency Portfolio Standard (REPS) established the Southeast's first REPS and set RE generation goals for the State's investor-owned utilities in 2007, it did not carve out a requirement for energy derived from wind, similar to those required for energy efficiency, solar, poultry, and swine. Several states have adopted procurement or generation goals for wind energy, both on- and offshore. Unlike those states where mandates and policies (in conjunction with federal tax incentives) drove wind development, the progress of NC's existing wind energy industry, both on- and offshore, has and continues to be, developer-driven.

³⁰ 30 CFR 585 Subpart E. <https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=e4ebde11c6066eaa6df5e0a6c43eafd0&mc=true&n=pt30.2.585&r=PART&ty=HTML#sp30.2.585.e>

³¹ https://www.ncleg.gov/EnactedLegislation/Statutes/PDF/ByArticle/Chapter_143/Article_21C.pdf

³² Ibid.

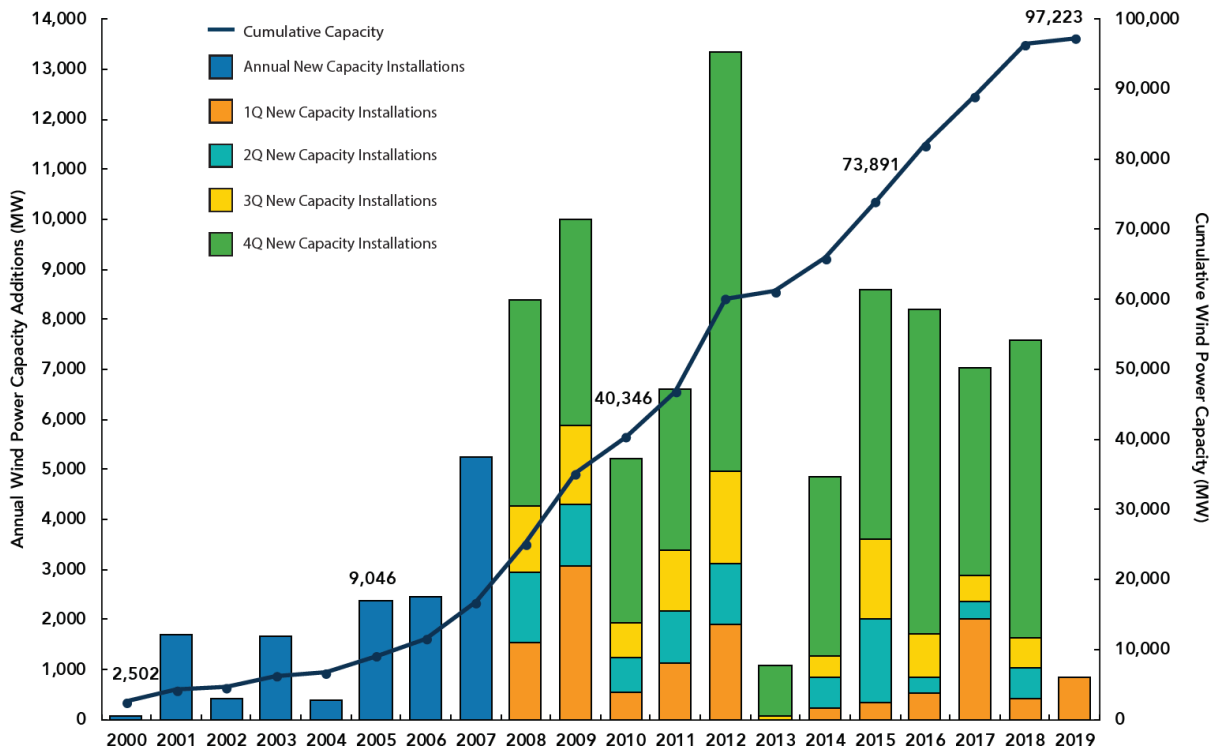


Figure 9-7: U.S. Annual and Cumulative Wind Power Capacity Growth³³

Source: AWEA

The US wind industry installed 841MW of new wind power capacity in the first quarter of 2019, which amounts to a 107% increase over installations in the first quarter of 2018 (Figure 9-7). According to AWEA, more than 56,600 wind turbines are now operating across 41 states and 2 US territories. Much of this development can be attributed to federal tax credits.

The federal Production Tax Credit (PTC) for wind began a step-down phase out in 2016, fully expiring in 2020. Because projects are still eligible for the PTC as long as 5% of the capital expense is made by the year-end deadline and the project is operational within 4 years, some projects built through 2023 will continue to benefit from the PTC. This, in combination with continued cost reductions, the result of technology improvements, the adoption of bigger turbines with larger blades, and a sweeping supply chain reorganization will keep wind competitive on a pure-cost basis in much of the US wind belt region during and after the PTC phase-out. Once the phase-out is complete in 2024, Wood-Mackenzie predicts that wind will still cost less than new combined-cycle natural-gas facilities on a Levelized Cost of Energy (LCOE) basis in 20 states, with this figure growing to 28 states by 2027. Although the PTC is the tax credit nearly always employed by the wind industry, the Business Energy Investment Tax Credit (ITC) enables developers to deduct a certain percentage of their cost of capital from their federal taxes. The

³³ AWEA. U.S. Wind Industry Quarterly Market Report, First Quarter 2019.



incentive amount depends on when the project commences construction. In 2019, it is 12% for large wind projects, and, without Congressional action, will expire starting in 2020.³⁴

9.3.2 Constraints to Deployment

While wind resources are widely spread across the State, there are several factors that constrain its growth in NC. Enacted by the General Assembly in 1983, the Mountain Ridge Protection Act³⁵ prohibits the erection of tall buildings or structures taller than 40 feet along ridges at or above 3,000 feet elevation.³⁶ The Act does include an exemption for both windmills and other tall, slender structures. Section § 113A-206 (Definitions) states: ““Tall buildings or structures” do not include: a. Water, radio, telephone or television towers or any equipment for the transmission of electricity or communications or both. b. *Structures of a relatively slender nature* and minor vertical projections of a parent building, including chimneys, flagpoles, flues, spires, steeples, belfries, cupolas, antennas, *poles, wires, or windmills* [emphasis added]. But in 2002 the NC Attorney General submitted comments to TVA regarding a proposed wind project on the Tennessee side of the NC/TN border saying that NC’s Mountain Ridge Protection Act of 1983 would prohibit construction of the windfarm. The resulting policy uncertainty from the Ridge Act and the letter, combined with the increasing height of modern wind turbines has effectively precluded development of the high-wind energy resources in NC’s mountain west to date.³⁷ In addition, while legislative efforts to block wind development in the east have been unsuccessful since the expiration of an initial 18-month moratorium in December 2018, the uncertain regulatory and political environment that has been present in NC since 2017 has also constrained growth in eastern NC development opportunities for this nascent industry.^{38 39}

Furthermore, nearly fully subscribed transmission infrastructure and proximity to load centers hinder wheeling energy generated from OSW into NC’s electric grid. In 2013 and 2015, Duke Energy Carolinas (DEC), US DOE, and other partners studied OSW integration into DEC territory and in 2012, the NC Transmission Planning Collaborative evaluated scenarios for onshoring OSW in the DEC/PJM territories. The Collaborative found that in order to accommodate three modeled scenarios of increasing OSW energy penetration on the grid, DEC would have to make significant infrastructure investments to the existing grid, including substation, switching station, and other improvements as follows:⁴⁰

- For 2000 MW OSW, an additional 250 miles of transmission, estimated at \$932 million.

³⁴ Level 10 Energy. What Corporate Buyers of Renewable Energy Need to Know About Wind and Solar Tax Credits. <https://leveltenenergy.com/blog/energy-procurement/renewable-energy-tax-credits/>. Accessed on June 19, 2019.

³⁵ Mountain Ridge Protection Act of 1983 (14 NCGS § 113A)

³⁶ Article 14 of Chapter 113A of the North Carolina General Statutes.

https://www.ncleg.net/EnactedLegislation/Statutes/HTML/ByArticle/Chapter_113A/Article_14.html

³⁷ Blue Ridge Environmental Defense League. The NC Ridge Law Is No Obstacle to Wind Power. August 24, 2003.

www.bredl.org/pdf/RidgeLaw-WindFactsheet24aug03.pdf. Accessed on July 31, 2019.

³⁸ H589, enacted in 2017, included an 18-month moratorium on permitting new WEFs that expired on December 31, 2018.

<https://www.ncleg.gov/BillLookUp/2017/h589>

³⁹ Coastal Review Online. July 30, 2019. Brown Says Wind Energy Bill Dead For Now.

<https://www.coastalreview.org/2019/07/brown-says-wind-energy-bill-dead-for-now/>. Accessed on July 31, 2019.

⁴⁰ North Carolina Transmission Planning Collaborative. Report on the NCTPC 2012-2022 Collaborative Transmission Plan.

January 2013. http://www.nctpc.org/nctpc/document/REF/2013-02-01/2012-2022_NCTPC_Report_FINAL_011713.pdf.

Accessed on June 3, 2019.



- For 3000 MW OSW, an additional 365 miles of transmission, estimated at \$1,214 million.
- For 5500 MW OSW, an additional 550 miles of transmission, estimated at \$1,736 million.

The primary reason for the high costs stems from the assumed location of the wind farms, which were not sited to minimize transmission costs in the scenarios. As these scenarios were modeled in 2011 and 2012, it is likely that the estimated costs will increase, at least commensurate with inflation. Interestingly, the study conducted by DEC and DOE in 2015 found negligible upgrades required to integrate 1GW, 3GW, or 5.6GW, provided the projects were sited based on both resource and minimizing transmission costs. It is expected that estimated costs for both studies will increase as has become more difficult to site large transmission projects in the last 5 to 10 years. It is partly because of this lack of onshore transmission infrastructure in NC, that Avangrid is seeking to wheel power generated from the Kitty Hawk WEA into Virginia instead. Avangrid has applied to the Virginia State Corporation Commission queue to onshore the Kitty Hawk generation in Landstown, near Virginia Beach, where excess transmission capacity is available to accommodate the OSW-generated energy.

9.4 Grid Integration, Reliability, and Resiliency

As previously described, individual wind turbines or farms are inherently more variable than traditional dispatchable generation resources that have historically provided a majority of grid-supplied electricity. The unique characteristics of wind as a source of variable RE have resulted in misperceptions regarding its contribution to a low-cost and reliable power grid including:

1. The potential need for increased operating reserves.
2. The potential need for increased backup capacity.
3. The impact of variability and uncertainty on operating costs and pollutant emissions of thermal plants.
4. The technical limits of variable RE penetration rates to maintain grid stability and reliability.

Aggregation of wind resources decreases variability and reduces the need for additional reserves. The output of a single wind turbine can change within a few seconds when the wind stops blowing, but by aggregating geographically dispersed resources, the impact of variability on the whole system can be minimized. Generally, the relative variability of wind decreases as the generation of more wind power plants is combined. Figure 9-8 illustrates how aggregating the output of a small set of wind turbines with a larger set has a smoothing effect on the net variability.

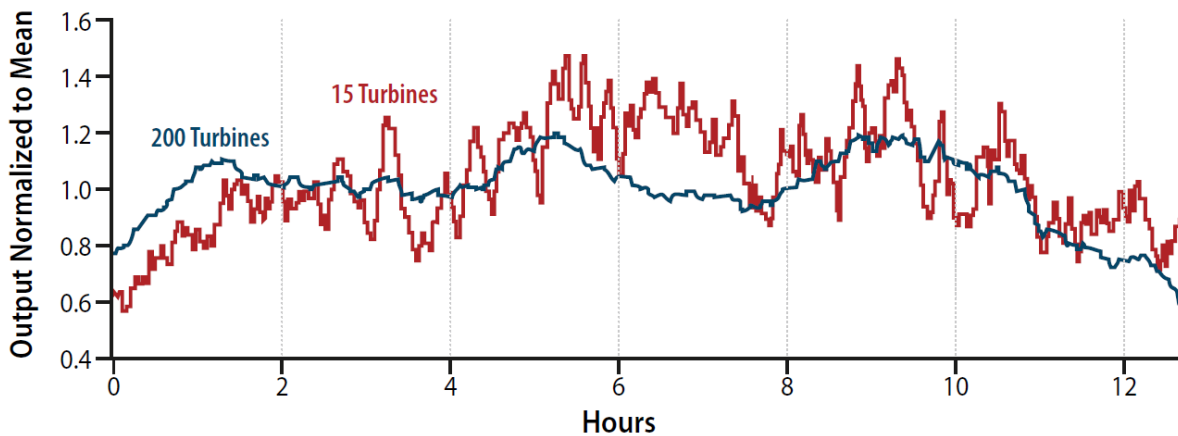


Figure 9-8: Aggregating Small to Large Set of Wind Turbines, Smoothing Effect on Variability⁴¹

Source: NREL, 2015

9.4.1 Grid Integration

According to NREL, integration of wind energy into power systems can take place without adverse impacts on system costs or emissions. A 2013 study found that “high penetration scenarios in the Western US found that lower fuel costs (utilizing less fuel overall) more than offset modest increases in cycling costs...resulting in overall cost savings, primarily due to fuel savings [and] ...also led to a net reduction of carbon dioxide (CO₂) emissions of 29% [to] 34% across the Western Interconnection, with a negligible impact from the additional emissions associated with increased cycling.”⁴²

9.4.2 Grid Reliability

With respect to reliability, wind energy does not provide primary frequency response in a conventional manner like thermal generators to ensure grid stability during normal and unstable conditions. Rather wind has the ability “to provide active power control services including synthetic inertia, primary frequency response, and automatic generation control ... [such that both] studies and recent operational experience...found that when providing active power control, wind and solar can provide a very large fraction of a system’s energy without a reduction in reliability.”⁴³ AWEA advocates for the use of ancillary service markets to efficiently ensure reliability across the grid with the most economic resources selected to deliver the service. Advances in technology like “smart inverters and fast controls expand the reliability services wind can cost-effectively supply to the market. Advanced power electronics and output controls enable wind to provide automatic generation control, primary frequency response, and synthetic inertia, among other services.”⁴⁴

⁴¹ Ibid.

⁴² Lew, D.; Brinkman, G.; Ibanez, E.; et al. (2013). Western Wind and Solar Integration Study Phase 2. NREL/TP-5500-55588. <https://www.nrel.gov/docs/fy13osti/55588.pdf>.

⁴³ Ela, E.; Gevorgian, V.; Fleming, P.; et al. (2014). Active Power Controls from Wind Power: Bridging the Gaps. NREL/TP-5D00-60574. <https://www.nrel.gov/docs/fy14osti/60574.pdf>

⁴⁴ AWEA. Reliability. <https://www.awea.org/policy-and-issues/electricity-policy/market-design/reliability>. Accessed on June 20, 2019.



9.4.3 Resiliency

Similar to the performance of solar during and following extreme weather events, wind turbines and farms appear to fare well. Within a week of Hurricane Harvey hitting the coast of Texas in August 2017, the Papalote Creek Wind Farm near Corpus Christi was back online and producing power, and the delay in restarting was largely due to damage to nearby power lines.⁴⁵ Wind turbines are designed to produce maximum power until their “cut-out” speed is reached, at which time, the turbines automatically shut down until wind speeds recede below the cut-out speed. When winter storm Stella pounded the Block Island Wind Farm with speeds of greater than 70mph, the turbines shut down and automatically powered back up as soon as the winds diminished.

9.5 Resource Costs and Benefits

9.5.1 Initial Investment Costs: Onshore Wind

According to the 2018 NREL Annual Technology Baseline (ATB), capital expenditures (CAPEX) required to achieve commercial operation in a given year include the wind turbine, the balance of system (e.g., site preparation, installation, and electrical infrastructure), and financial costs (e.g., development costs, onsite electrical equipment, and interest during construction).⁴⁶ CAPEX represents a typical onshore wind plant and varies with annual average wind speed. Regional cost effects associated with labor rates, material costs, and other regional effects expand the range of CAPEX. Figure 1-9, taken from the 2018 ATB illustrates the historical, current, and future projections for CAPEX for onshore wind.

9.5.2 Operating and Maintenance Costs: Onshore Wind

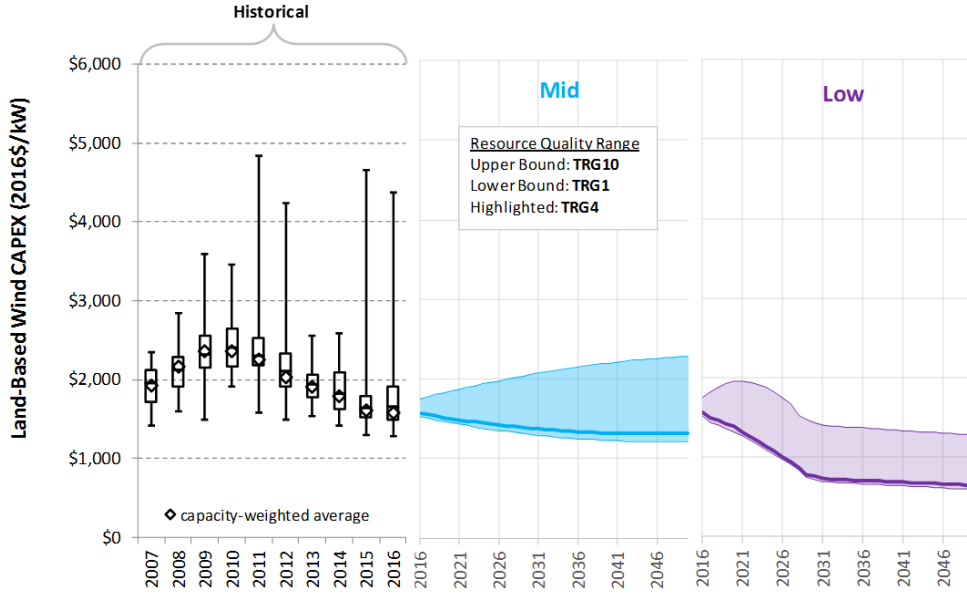
Operations and maintenance (O&M)⁴⁷ costs depend on capacity and represent the annual fixed expenditures required to operate and maintain a wind plant, including:

- Insurance, taxes, land lease payments, and other fixed costs.
- Present value and annualized large component replacement costs over technical life (e.g., blades, gearboxes, and generators).
- Scheduled and unscheduled maintenance of wind plant components, including turbines and transformers, over the technical lifetime of the plant.

⁴⁵ Wall Street Journal. In Big Test of Wind Farm Durability, Texas Facility Quickly Restarts After Harvey. September 1, 2017. <https://www.wsj.com/articles/texas-wind-farm-back-online-1504294083> Accessed on June 20, 2019.

⁴⁶ <https://atb.nrel.gov/electricity/2018/index.html?t=lw>

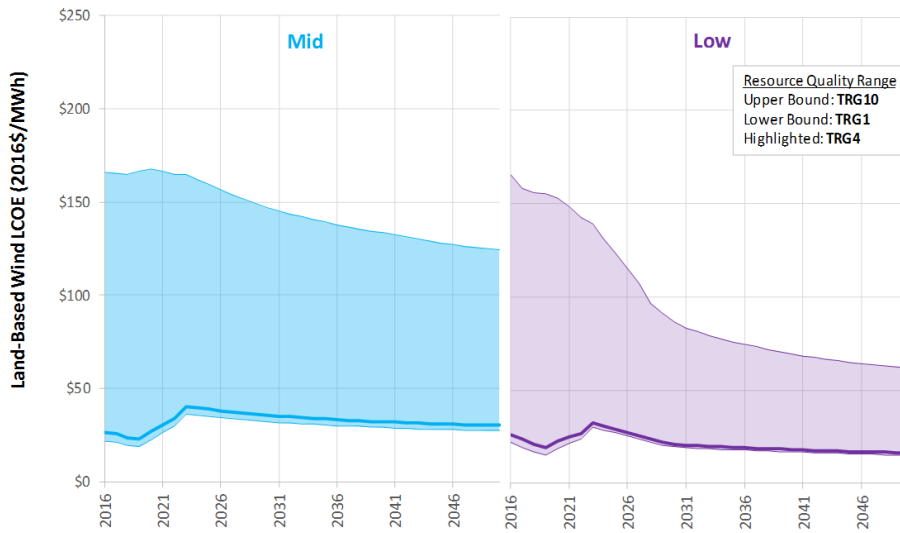
⁴⁷ Ibid.



CAPEX historical trends, current estimates, and future projection for land-based wind
Source: National Renewable Energy Laboratory Annual Technology Baseline (2018), <http://atb.nrel.gov>

Figure 9-9: CAPEX Historical Trends, Current Estimates, and Future Projections for Onshore Wind

NREL modeled three cost scenarios for fixed O&M compared to the base 2016 year, the low- and mid-technology resource groups project reduced O&M costs. Finally, with respect to levelized cost of energy (LCOE), NREL’s 2017 ATB reveals decreasing LCOE through 2046, as illustrated in Figure 9-10.



Land-based wind plant LCOE projections with RD+Market financials
Source: National Renewable Energy Laboratory Annual Technology Baseline (2018), <http://atb.nrel.gov>

Figure 9-10: Onshore Wind Plant LCOE with Market and R&D Financials



9.5.3 Initial Investment Costs: Offshore Wind

According to Utility Dive, OSW project costs have “have fallen 75% since the 2014 Block Island Wind Farm in Rhode Island, in contracts for 1.2 GW of projects awarded for the next five years” following a similar learning curve to other clean power technologies.⁴⁸ It is estimated that OSW will continue to experience CAPEX cost declines as additional capacity comes online (Figure 9-11).⁴⁹ In 2017, NREL evaluated CAPEX for a reference OSW project and illustrated the breakdown of cost expenditures by percentage, a full third of the costs attributed to the turbines (Figure 9-12).

9.5.4 Operating and Maintenance Costs: Offshore Wind

NREL found that O&M can vary greatly between projects for a number of reasons but the two largest cost drivers are the distance from the project to the maintenance facilities and the meteorological climate at the site.⁵⁰ The 2018 NREL ATB for OSW calculated future projections for fixed cost O&M OSW against a 2016 base year and expects at least 7% cost declines by 2050 (Figure 9-13).

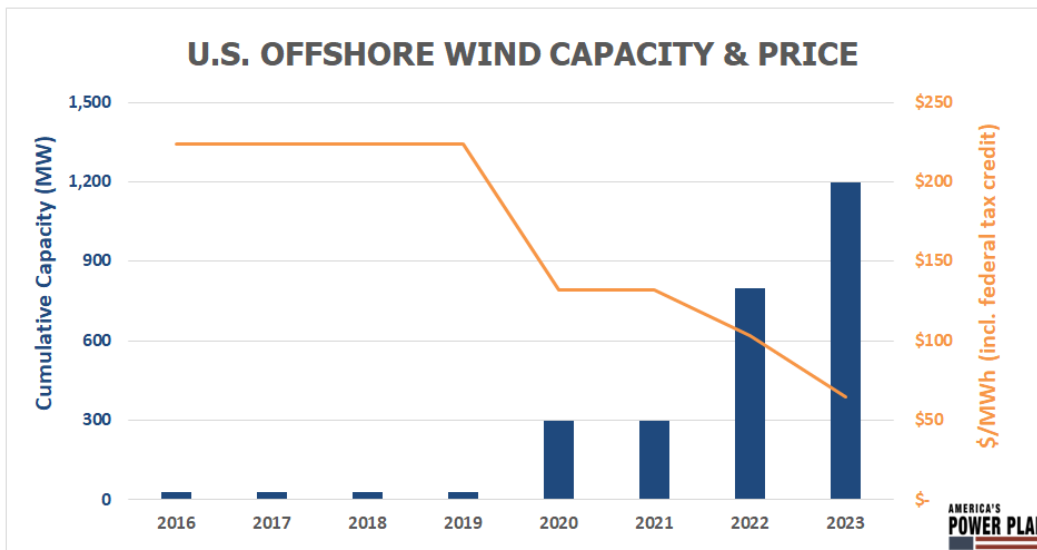


Figure 9-11: U.S. Offshore Wind Capacity and Price through 2023.

Source: Utility Dive/America’s Power Plan-Energy Innovation.

⁴⁸ Utility Dive. Offshore Wind Prices Have Fallen 75% Since 2014 – Here’s How to De-Risk Projects Even Further. December 3, 2018. <https://www.utilitydive.com/news/offshore-wind-prices-have-fallen-75-since-2014-heres-how-to-de-risk-pro/543384/>

⁴⁹ Energy Innovation. America’s Power Plan. Accessed on June 20, 2019.

⁵⁰ NREL. 2017 Cost of Wind Energy Review. <https://www.nrel.gov/docs/fy18osti/72167.pdf>. Accessed on June 23, 2019.

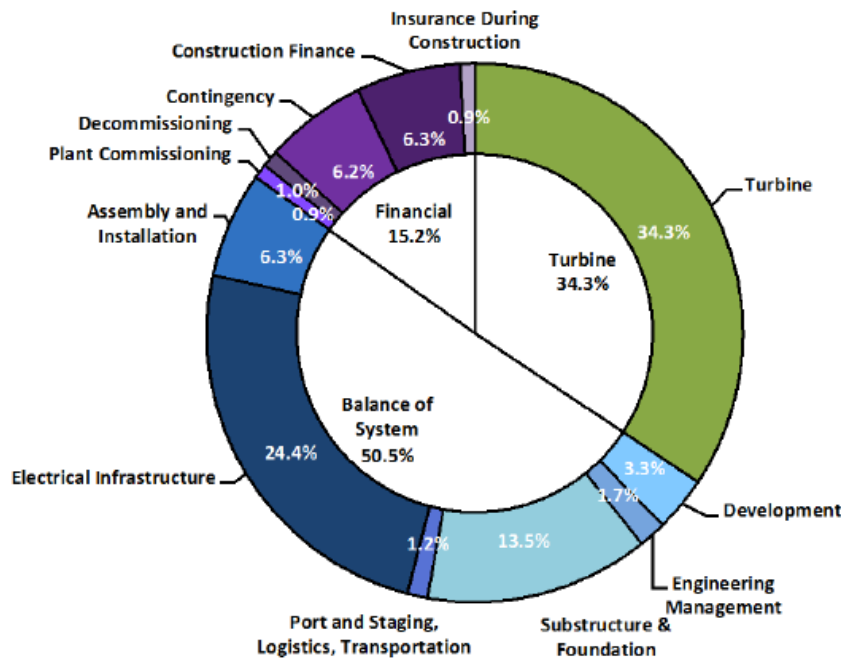
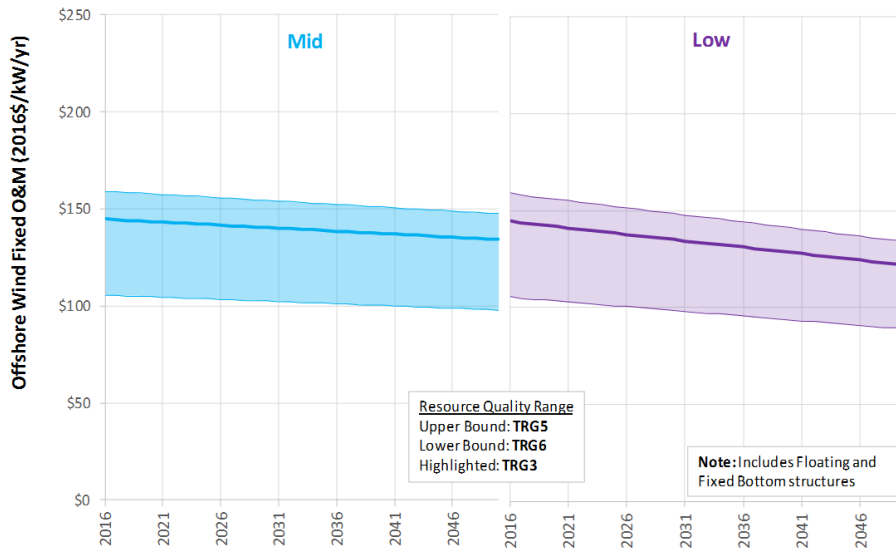


Figure 9-12: CAPEX for Fixed-Bottom Offshore Wind Reference Project⁵¹

Source: NREL, 2017.



Offshore wind plant O&M projections

Source: National Renewable Energy Laboratory Annual Technology Baseline (2018), <http://atb.nrel.gov>

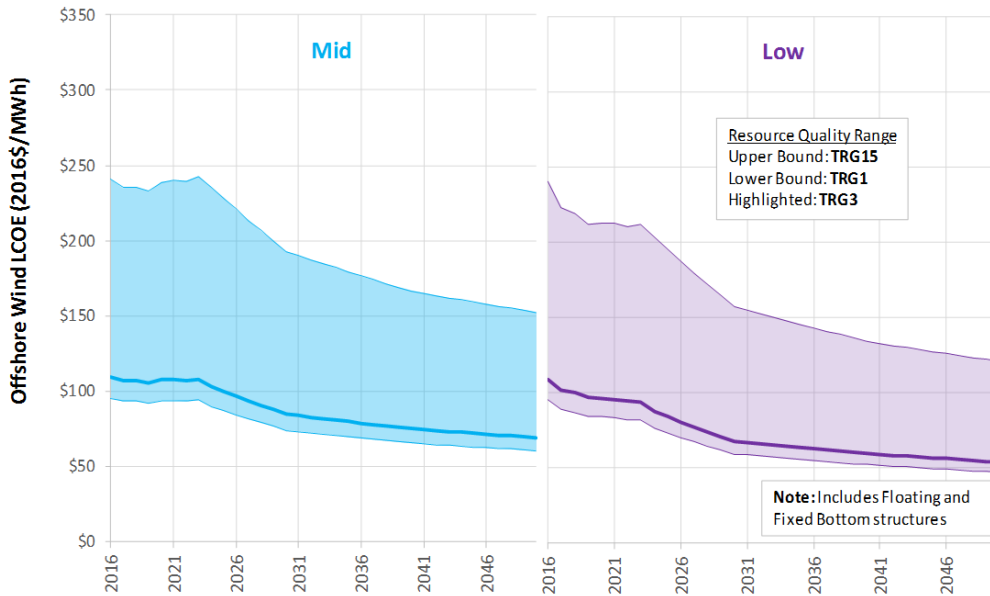
Figure 9-13: Offshore Wind O&M Projections⁵²

⁵¹ Ibid.

⁵² NREL. Annual Technology Baseline, Offshore Wind. <https://atb.nrel.gov/electricity/2018/index.html?t=ow>. Accessed on June 23, 2019.



Similar to LCOE for onshore wind development, NREL projects LCOE for OSW to continue to decline (Figure 9-14). This aligns with industry projections for the OSW market and is similar in scope to the declines witnessed with the costs associated with onshore wind development. In addition, with the burgeoning OSW industry comes a new supply chain that is estimated at approximately \$70 billion by 2030.⁵³



Offshore wind plant LCOE projections with RD+Market financials

Source: National Renewable Energy Laboratory Annual Technology Baseline (2018), <http://atb.nrel.gov>

Figure 9-14: Offshore Wind Plant LCOE with Market and R&D Financials⁵⁴

⁵³ Special Initiative on Offshore Wind. Supply Chain Contracting Forecast for U.S. Offshore Wind Power, <http://www.ceoe.udel.edu/File%20Library/About/SIOW/SIOW-White-Paper---Supply-Chain-Contracting-Forecast-for-US-Offshore-Wind-Power-FINAL.pdf>. Accessed on May 31, 2019.

⁵⁴ NREL. Annual Technology Baseline, Offshore Wind. <https://atb.nrel.gov/electricity/2018/index.html?t=ow>. Accessed on June 23, 2019.





10. Additional Energy Resources

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10.1. Additional Resources Introduction

Hydrogen, fuel cells, and geothermal energy are viable resources and technologies. Their use in North Carolina (NC) is limited due to unique challenges; however, their potential benefits drive continued research efforts that may lead to increased use in the future. The emphasis on new energy resources and the limited lifespan of conventional power plants may increase future adoption rates of these technologies.

10.1.1 Technology Definition and Description

Hydrogen

Hydrogen is a high energy fuel used for combustion in conventional engines and turbines, most notably for space vehicles. Its primary advantage is that combustion of hydrogen in air produces only energy and water. Its primary disadvantages are that hydrogen gas must be compressed for storage and it has a low ignition temperature, making it explosive.

While hydrogen is an abundant resource and found in many common chemical compounds, such as methane or water, it does not exist freely in nature and therefore must be produced. Production of hydrogen requires the use of energy. Most hydrogen is produced by natural gas reforming, which heats the natural gas methane (CH_4) to separate the hydrogen from the methane molecule (CH_4). The reforming process is the least expensive means of producing hydrogen, but it results in carbon dioxide (CO_2) emissions, a greenhouse gas (GHG).¹ Another means of producing hydrogen is to run electric current through water (H_2O), which separates the hydrogen and oxygen molecules in a process called electrolysis.² Electrolysis is a more expensive method for producing hydrogen using conventional electrical power sources. Less expensive renewable power such as wind or solar may make producing hydrogen environmentally and economically viable.³

Fuel Cells

Fuel cells were used as early as the 1960's for the Apollo space program. Today, fuel cell technology is used for energy in vehicles and electricity generation. Fuel cells reverse the electrolysis process by taking oxygen from the air and recombining it with hydrogen. This chemical process produces electricity, heat, and pure water.⁴ This allows the fuel cell to act like an engine that produces electricity as long as it is refueled. In their search for fossil fuel alternatives, automakers have developed efficient electric fuel cell vehicles designed to use hydrogen. Hydrogen fuel cell technology has no associated GHG emissions, if the hydrogen is produced with renewable energy (RE), and is preferable to other fuel cell technologies that use methane and emit GHG. Since hydrogen can be piped, compressed, shipped, and stored for future use, hydrogen fuel cells are a dispatchable electricity resource.

¹ US EIA: https://www.eia.gov/energyexplained/index.php?page=hydrogen_production

² US EIA: https://www.eia.gov/energyexplained/index.php?page=hydrogen_production

³ National Renewable Energy Laboratory: <https://www.nrel.gov/hydrogen/wind-to-hydrogen.html>

⁴ 8 Things You Need to Know About Hydrogen Fuel-Cell Cars: <https://www.edmunds.com/fuel-economy/8-things-you-need-to-know-about-hydrogen-fuel-cell-cars.html>



Geothermal

There are two main types of geothermal systems; (1) geothermal heat energy and (2) ground source heat pumps. Geothermal heat from deep within the earth is seen in nature as volcanic eruptions, geysers, or hot springs. In some geological regions, geothermal energy can be readily accessed to produce steam that can be used for electric generation. However, these geothermal wells can be up to two miles below the earth's surface.⁵ Geothermal energy is not an economically viable resource for NC in the near term.

Ground source heat pumps use the earth as a heat exchanger in heating, ventilation, and air conditioning (HVAC) applications. The ground temperature is relatively constant at 55 degree Fahrenheit 10 feet below the surface with only a 10-degree variance.⁶ This constant temperature relative to air temperature makes the ground a more efficient heat exchanger and heat source than the air. When summer cooling is needed, the heat pump takes heat out the conditioned space and carries it into the ground. For winter heating, it takes heat from the ground and carries it into the conditioned space. The heat exchange occurs in the refrigerant filled piping loops that are buried below the ground surface in vertical or horizontal configurations.

10.1.2 Background & Historical Use in North Carolina

Fuel Cells

Most major cities have had commercial access to hydrogen supply networks from industrial gas suppliers for decades. The supply lines have been used commercially as a non-polluting alternative energy source for electric generation and the transportation industry for buses and trains. Apple's data center in Maiden, NC has 10 MW of fuel cells that use hydrogen from landfill gas (LFG) to produce electricity for its site.⁷

The North Carolina Department of Transportation's (NCDOT) Rail Division is currently researching hydrogen as a possible future alternative to its traditional diesel-electric locomotive engines on its Piedmont passenger rail service. The implementation of hydrogen fuel cell based trains (hydrail) would have far-reaching, positive environmental and technological impact across NC. The Mooresville Hydrail Initiative, Appalachian State University and University of North Carolina Charlotte have had a long working history with the United Kingdom's hydrail transition and the US Department of Energy's (DOE) national hydrogen railway initiative.⁸ For over a decade Mooresville's Hydrail Initiative has given NC global visibility in hydrogen technologies by convening annual International Hydrail Conferences, and by working to ensure NCDOT stays up to date with international hydrail implementation efforts.

⁵US EIA: https://www.eia.gov/energyexplained/index.php?page=geothermal_power_plants

⁶ US EIA: https://www.eia.gov/energyexplained/index.php?page=geothermal_heat_pumps

⁷ <https://appleinsider.com/articles/16/06/24/apples-campus-2-to-use-updated-bloom-energy-fuel-cells-first-deployed-at-nc-data-center>

⁸ https://www.statesville.com/news/iredell-born-hydrail-concept-goes-international/article_7ef0c662-52a9-11e7-934e-af3621e2d387.html



Geothermal

Since the 1970's, over two thousand geothermal heat pump system installations have been permitted within NC.⁹ In 2009, the North Carolina's Renewable Energy Investment Tax Credit was revised to include geothermal heat pump systems, which increased the use of heat pumps for residential heating and cooling. By 2016 the level of energy used by heat pumps increased almost 5 times over the levels in 2000 (See Energy Landscape, Figure 14). However, the tax credit expired at the end of 2015 and geothermal installation rates have since slowed.¹⁰

10.2 Technology Benefits and Limitations

Hydrogen

Hydrogen is odorless and has no safety odorant for leak detection, but it can be detected by sensors.¹¹ Storage of large-scale hydrogen gas is expensive and requires facilities with a sizeable footprint.¹² Hydrogen is a combustible material which could result in an explosion if leaking from storage tank. There are currently no large scale hydrogen storage facilities in NC.

Fuel Cells

The high cost of fuel cell technology and fueling infrastructure remains a barrier. Even though hydrogen fuel cell vehicles would have longer travel ranges than conventional plug-in electric vehicles (PEV) due to the ability to refuel more easily, no hydrogen fueling point infrastructure exists in NC. This absence of a hydrogen infrastructure remains a barrier to the introduction of hydrogen vehicles. The NC supply of hydrogen gas from existing supply networks serving industries should be large enough for market entry of hydrogen fuel cell vehicles, but the cost of installing and availability of fueling point infrastructure is an obstacle.

Geothermal

Geothermal heat pump systems can reduce the consumer's utility costs for heating and cooling. They are more efficient, quieter, longer lasting, and require less maintenance than traditional air-source heat pumps.¹³ High upfront costs and fewer trained technicians make geothermal heat pumps more difficult to finance, design, and repair. Vertical loops require drilling, while horizontal loops require a wide area excavation. If the loop installations require existing utility infrastructure to be relocated, installation costs may be higher than if the system is installed during initial construction. No geothermal power plants are

⁹ North Carolina's Geothermal Industry, NCSEA 2015: https://energync.org/wp-content/uploads/2017/03/NCs_Geothermal_Industry.pdf

¹⁰ DSIRE: <http://www.dsireusa.org/>

¹¹ <http://metersolution.com/wp-content/uploads/2013/02/Proton-Energy-systems.pdf>

¹² US DOE: <https://www.energy.gov/eere/fuelcells/hydrogen-storage-challenges>

¹³ US DOE, Geothermal Heat Pumps: <https://www.energy.gov/energysaver/heat-and-cool/heat-pump-systems/geothermal-heat-pumps>



operating in NC, and according to the US Geological Survey (USGS), NC does not have suitable geologic sites for geothermal power plant operations.¹⁴

10.2.1 Emerging Technology Trends

Hydrogen

One particularly unique property of hydrogen is that it can be stored not just in tanks under high pressure, but also on the surface of powdered nickel at room temperature in large amounts.¹⁵ This stored hydrogen can be released as needed by applying moderate heat. Research is being performed to identify other practical uses for this property of hydrogen.

Geothermal

The US Department of Energy (DOE) recognizes that geothermal resources have the potential for a greater impact in the US energy sector. There is constant research to find ways to reduce costs and thereby increase installations of geothermal technologies. The Sandia National Laboratory has been researching new drilling technologies that would increase resource availability, reduce environmental footprints, and reduce costs for geothermal power plant installations across the nation. The DOE Geothermal Technologies Office is studying the feasibility of Deep Direct Use (DDU) geothermal technology replacing large-scale heating and cooling units for universities, military installations, and other large end-users in order to reduce energy use and electric system peaks.¹⁶

Fuel Cells

Fuel cells have been around for decades. Current trends in fuel cell research tend to focus on cost reductions in order to make fuel cells a more economically viable option in the power and transportation sectors.

10.3 Grid Integration and Reliability

Hydrogen combustion can be used as an energy resource for electricity generation. It poses the same grid integration and reliability advantages and disadvantages as other combustible fuels, except that problems in its storage or distribution at a power plant can result in an explosion.

Fuel Cells

Fuel cells can be used for backup power systems or to store power for use during peak demand times by all economic sectors. Fuel cells and hydrogen together have the potential to complement NC's electric grid operations in ways similar to hydroelectric pumped storage, but without the geographic limitations. It is a dispatchable energy storage resource that can be used to augment the grid integration of intermittent RE resources. Electrolysis operations could produce and store hydrogen for future use during periods of generation overproduction or during off-peak periods. As a result, hydrogen fuel cells could serve as a

¹⁴ USGS Assessment of Geothermal Resources of the US: <https://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf>

¹⁵ <https://www.jmcusa.com/hydrogen-storage-alloy.html>

¹⁶ US DOE Geothermal Technologies Office 2017 Annual Report: <https://www.energy.gov/sites/prod/files/2018/01/f47/GTO%202017%20Annual%20Report.pdf>



grid balancing option if appropriate storage facilities were available. Large, dedicated hydrogen production and storage facilities could be co-located with fuel cells to provide load-leveling services for the power grid and serve as filling facilities for large rail vehicles.

Geothermal

Geothermal heat pumps are mechanical devices run by electricity. Due to their greater efficiency, they use less electricity than conventional HVAC systems. A greater penetration of installed geothermal heat pumps would help reduce summer and winter peak loads related to heating and cooling.

10.4 Resource Costs and Benefits

Hydrogen and Fuel Cells

The costs of hydrogen fuel cells, hydrogen storage facilities, catalyst materials, and fueling point infrastructure are significantly higher than those of conventional technologies. Costs are likely to drop if adoption increases for hydrogen and fuel cell technologies.

Geothermal

The initial cost of a geothermal heat pump is significantly higher than a conventional HVAC system. A similar 3-ton geothermal system may cost twice as much as a traditional system. The increased expense is primarily because of the excavation or drilling needed to install the heat exchange piping. Without incentives to reduce the high installation costs, installation rates will likely remain low.