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& MITCH ROLLING

LIGHTING THE PATH

MEETING NORTH CAROLINA'S COMING ENERGY NEEDS

locke

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Meeting North Carolina's
Coming Energy Needs

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Executive Summary

North Carolina has tremendously benefited from tax reforms begun over a decade ago. Energy efficiency mandates that began in the late 2000s and continued into the early 2010s created an energy cushion capable of absorbing the influx of new businesses and residents. If utilities fail to keep pace with growing electricity demand, however, then continued economic growth will inevitably crash into an energy supply wall.

North Carolina's unique geography has created an equally unique energy grid. Through mergers and acquisitions, Duke Energy has become the largest provider of electricity in the state, responsible for servicing densely populated, power-hungry metros and isolated, rural communities. Duke Energy supplies more than 90 percent of North Carolina's retail electricity sales. Dominion Energy, Tennessee Valley Authority, municipal utilities, electric cooperatives, and businesses with independent generation are marginal suppliers of electricity to North Carolina's grid. Consequently, Duke Energy will be largely responsible for meeting North Carolina's emissions reduction targets.

Meeting House Bill (HB) 951's state-mandated emissions reduction targets, given North Carolina's unique geography and lack of in-state energy resources, will require costly energy solutions that will increase utility bills for businesses and households across North Carolina. Aware of the inevitable rate increases concomitant with building energy generation and transmission infrastructure, the North Carolina Utilities Commission made it clear to Duke Energy that it is to "investigate and doggedly pursue every opportunity to apply downward pressure on rates and to optimize the use of the electric system to reduce system average cost."[1]

Fortunately, Duke Energy has already significantly reduced carbon dioxide (CO_2) emissions by retiring and upgrading coal-fired power plants and running them on cleaner-burning natural gas. As part of the Carbon Plan, Duke Energy has already committed to permanently retiring its six remaining coal-fired power plants by 2035. How Duke Energy decides to replace the baseload capacity generated by these coal plants while simultaneously increasing total generation capacity to meet North Carolina's growing demand for energy will ultimately determine how much North Carolinians' monthly utility bills will rise.

Under HB 951, by 2030 or shortly thereafter, utilities are required to have reduced emissions by 70 percent below 2005 levels, and by 2050 they must achieve total carbon neutrality. Doing so will require the largest expansion of electric infrastructure since electrification began in the early 1920s. What path utilities take to reconcile North Carolina's decarbonization requirements with the state's energy needs will ultimately determine the prices consumers will pay for energy, set the limits for North Carolina's economic growth and development, and influence the amount of infrastructure needed to serve electricity customers reliably.

The first part of this report takes stock of North Carolina's energy infrastructure. It looks at trends in state electricity demand and in-state electricity generation. It compares capacity factors and emissions of different electricity sources in North Carolina and gives an overview of them. It discusses the Carbon Plan, electricity markets, and transmission infrastructure. Finally, it examines natural gas: its transportation, its rise as a primary fuel, and its storage.

The next two sections of this report compare two different scenarios to achieve carbon neutrality by 2050 while meeting North Carolina's growing energy needs. Always On Energy Research (AOER) modeled both scenarios to determine the amount of power plant capacity and associated energy infrastructure each would need to meet the requirements of HB 951.

Favored by Gov. Roy Cooper, his environmentalist allies, and solar and wind advocates, the Renewable Scenario would require a resource mix that relies on onshore wind, offshore wind, solar, and battery storage, while maintaining North Carolina's existing nuclear and hydroelectric power plants. This resource portfolio would require a nearly tenfold increase in energy infrastructure and consume much more land than the current electric grid. It would require a 426-fold increase in onshore wind capacity (more than twice the amount of onshore wind capacity installed in the state of Texas) and a 21-fold increase in solar capacity (nearly double the amount of solar capacity currently installed in the rest of the United States). It would also require nearly 13 times as much four-hour battery capacity as the entire United States. All this solar and onshore wind would require enormous amounts of land, especially in comparison with what would be needed by new nuclear facilities.

By contrast, the Nuclear Scenario would require a resource mix that utilizes the built-in flexibility in HB 951 that allows existing coal and natural gas plants to remain online as needed to ensure reliability and keep electricity prices low while new nuclear power plants are constructed to replace them. Compared with the Renewable Scenario, this resource portfolio would produce far more electricity with far less energy infrastructure. The land needed by all this new nuclear power would amount to just 38 percent of the land consumed by all of North Carolina's existing solar facilities. As a result, the Nuclear Scenario would require fewer new power plants and less transmission infrastructure and would consume much less land than the Renewable Scenario.

The final section of this report estimates the cost to North Carolinians of reaching the governor's zero-emissions vehicle (ZEV) goals stated in Executive Order (EO) 246 of registering 1.25 million expensive ZEVs by 2030 and having half of all new vehicle sales be ZEVs. AOER estimates that the total cost — which would include getting North Carolina's financial infrastructure, roads and highways, households, and electrical infrastructure ready for so many ZEVs — would fall between $16.5 billion and $30.5 billion. Furthermore, just over the next seven years EO 246 would entail North Carolinian drivers having to spend an extra $19.0 billion to $20.5 billion more to purchase more expensive ZEVs instead of conventional, gasoline-powered cars and diesel trucks.

NORTH CAROLINA'S ENERGY INFRASTRUCTURE

Overview

Nearly 11 million North Carolinians depend on reliable and affordable electricity and natural gas to power their daily lives.[2] And with the population growing by 140,000 people per year,[3] burgeoning businesses, a manufacturing boom, and high-tech industries expanding their footprint in the Tar Heel State,[4] North Carolina's public utilities will need to find cost-effective ways to meet these power-hungry customers' demand for electricity and natural gas that fit within the state's prescribed emissions reduction rules and cost-increase mitigation guidance.

North Carolina's unique geography has played a profound role in shaping the state's existing energy infrastructure. A lack of native oil and natural gas deposits has forced North Carolina to rely on energy-dense fuels imported from other states and invest large amounts of financial capital to harness sources of renewable energy. North Carolina's geography further complicates building and maintaining energy transmission infrastructure in and between the state's varied geographies. Stretching electricity wires and laying natural gas pipelines across the state's rugged mountain west; central, hilly Piedmont; and sandy eastern shores have made energizing the state a costly and labor-intensive endeavor since electrification began in the late 19th century.[5] Several of North Carolina's westernmost Appalachian counties still lack adequate transmission infrastructure and natural gas service lines. North Carolina's energy-poor geography has resulted in a low per-capita energy consumption, placing the state in the bottom third nationally.[6]

"Meeting the legislature's commitment to decarbonization will require the largest expansion of electric infrastructure since electrification began in the early 1920s."

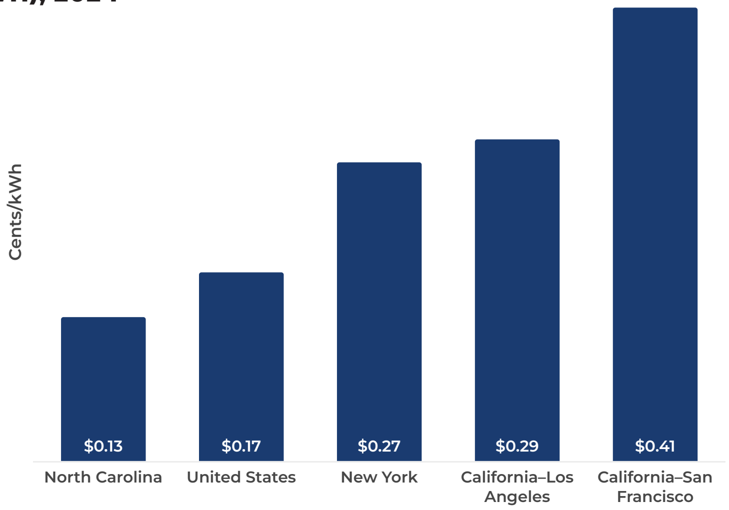
But in spite of geographic challenges and relatively low energy consumption, North Carolina is the eighth-largest electric power generator among the 50 states.[7] Electricity generation itself is a massive industry within the state. Over 43,000 North Carolinians are directly employed in the state's electricity generation and energy transmission industries (see Appendix A).[8] Even so, North Carolina imports 10 percent of its electric power needs from shared electricity generating units (EGUs) and transmission lines from neighboring South Carolina, Virginia, and Tennessee.[9]

House Bill (HB) 951 has pigeonholed North Carolina's utilities into meeting future demand with low- and zero-emissions sources of electricity. By 2030 or shortly thereafter, utilities are required to have reduced emissions 70 percent below 2005 levels, and by 2050 they must achieve total carbon neutrality.[10] Meeting the legislature's commitment to decarbonization will require the largest expansion of electric infrastructure since electrification began in the early 1920s and the largest expansion of natural gas transportation infrastructure since the completion of the Transcontinental natural gas pipeline (Transco) in the 1950s. How utilities choose to reconcile North Carolina's decarbonization requirements with the state's energy needs will ultimately determine the prices consumers will pay for energy and set the limits for North Carolina's economic growth and development.

A Decade of Economic Growth

There are nearly 11 million North Carolinians spread across the state's 4.1 million households.[11] Since 2010, North Carolina's population has grown by 1.5 million people and it continues to grow. North Carolina's population increases by 140,000 people per year. Roughly 90 to 95 percent of these new North Carolinians are Americans migrating from states with high taxes and high energy costs, such as California and New York, to take advantage of North Carolina's comparatively lower taxes and cost of living (Figure 1.1).[12] North Carolina's competitive tax reforms and low energy costs have made the state incredibly attractive for energy-intensive industries like manufacturing, transportation, and data centers.[13] North Carolina's pro-growth tax reforms will likely continue to draw in people and businesses from around the country, but they will inevitably increase energy demand, and if it is not met cost effectively, it will result in significantly higher rates on ratepayers.

FIGURE 1.1 AVERAGE ELECTRICITY CENTS PER KILOWATT-HOUR (KWH), 2024[14]



North Carolina began comprehensive individual income and business tax reforms in 2013.[15] As of 2024, North Carolina has the lowest corporate income tax rate in the country (of the 44 states that levy a corporate income tax),[16] and in 2023, North Carolina's General Assembly accelerated planned individual income tax cuts while making additional modifications to business taxes.[17] Among its Southern peers, North Carolina has one of the best business climates, ranking ninth nationally according to the Tax Foundation.[18] North Carolina topped CNBC's rankings in their Top State for Business in 2023.[19] In workforce and overall economy, the Tar Heel State placed first and third, respectively.[20] Income and business tax reforms have primed the state for business creation, business relocation, and high-income earners — all of which are high consumers of energy.

According to the Reshoring Initiative's 2022 Data Report, North Carolina was the fifth most popular destination for reshoring businesses and foreign direct investment. In 2022 alone, 93 companies reshoring to the U.S. brought 26,965 jobs to North Carolina.[21] Apple, Toyota, and Bosch have already poured hundreds of millions of dollars into research campuses and manufacturing plants into North Carolina.[22] These new factories will draw significantly from North Carolina's power grid and natural gas supply. The average American factory uses 95.1 kilowatt-hours (kWh) of electricity and 536,000 British thermal units (Btus) of natural gas per square foot per year.[23] Per-employee energy consumption for factories based in the South was 2,246 million Btus — the highest in the nation.[24] With companies moving to North Carolina to harness the manufacturing and technical expertise of the best workforce in the nation, industrial energy consumption is guaranteed to increase.

North Carolina's superb business climate, coupled with its pleasant weather, has made it a prime destination for high-income earners and businesses. According to the 2023 United Van Lines Movers Study, North Carolina ranked sixth for inbound moves.[25] Half of all inbound movers boasted salaries at or exceeding $150,000 in annual income.[26] Household energy consumption and income are positively correlated. North Carolina drawing high-income earners into the state is also drawing in the highest energy consumers.[27]

North Carolina's economy and population have tremendously benefited from tax reforms begun over a decade ago. But if utilities fail to keep pace with electricity demand, then continued economic growth will inevitably hit an energy supply wall. In fact, signs flagging an imminent crash into the energy supply wall are starting to appear. When CNBC updated their Top States for Business rankings for 2024, North Carolina fell to second place, ceding first to neighboring Virginia. North Carolina's drop in the ranking is attributed to a four-point decline in the state's infrastructure score, which sank from 16 in 2023 to a mediocre 20 in 2024. North Carolina's public utilities are largely responsible for failing to keep pace with growing power demand, which has resulted in lengthy, business-disrupting blackouts. The average North Carolina business will experience about eight hours of blackouts per year.[28] These prolonged blackouts are unacceptable for businesses — especially tech companies, which need an uninterrupted power supply for their data centers.

"Despite placing eighth in power generation, North Carolina paradoxically ranks in the bottom third of states in energy consumption."

North Carolina's supply of natural gas is limited to the capacity of the Transcontinental pipeline's volume. While the Mountain Valley Pipeline (MVP)'s recent completion has ameliorated some of the tension in North Carolina's tight natural gas market, natural gas power plants have already siphoned off most of MVP's additional capacity, leaving little left for North Carolina manufacturers and households.

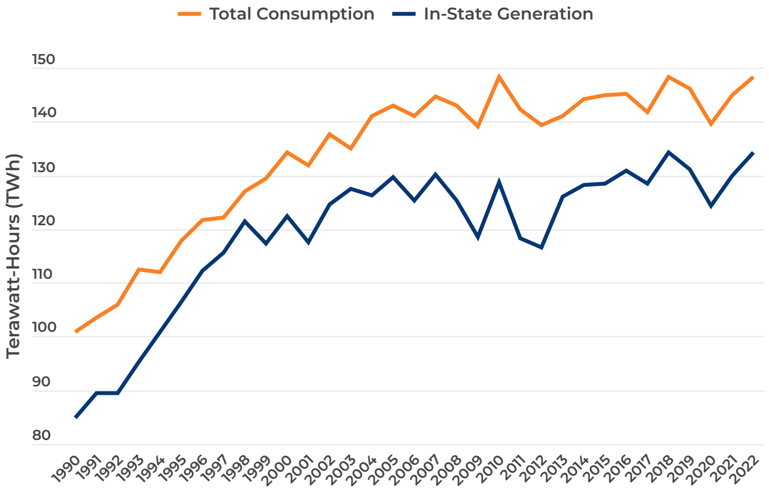
Continued economic growth in North Carolina depends on increasing access to energy resources. As energy inputs to production, electricity and natural gas are the foundation of economic development, and North Carolina will need more of both to avoid hitting the economically debilitating energy supply wall.

Trends in Electricity Demand

As the ninth most populous state, North Carolina is one of the largest producers of electric power. According to the Energy Information Agency, North Carolina generated 134.25 terawatt-hours (TWh) of electricity, making it the eighth-largest producer of electric power in 2022.[29] Despite placing eighth in power generation, North Carolina paradoxically ranks in the bottom third of states in energy consumption.[30] North Carolina's total electricity consumption has not changed much in the last 15 years. North Carolina's in-state power generation has grown only 4 percent since 2007. And total electricity consumption peaked in 2010 at 148.4 TWh.[31] In 2022, North Carolina drew 148.3 TWh from the grid. Electricity consumption still has yet to pass the peak it achieved over a decade ago (Figure 1.2).

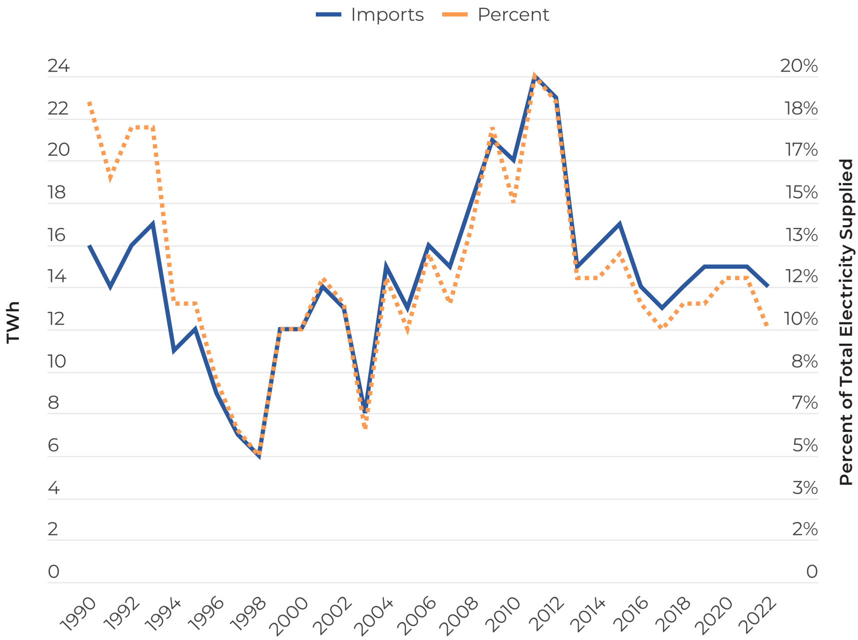
North Carolina's history of electricity demand followed the national trend by and large. Between 1990 and 2005, North Carolina's power consumption grew at an average rate of 2.39 percent per year.[32] The American energy crisis in the early 2000s resulted in energy efficiency policies at the national level. The goal of these policies was to reduce business and households' demand for power by improving the energy efficiency of lighting and appliances. LED light bulbs replaced incandescent ones, and energy efficiency mandates on water heaters, washing machines, and other appliances stymied growth in electricity demand.[33] These efficiency improvements coincided with the Great Recession, which also worked to suppress demand for electricity between 2008 and 2012.[34] Electricity consumption in North Carolina has grown at a sluggish 0.26 percent per year between 2005 and 2022.[35]

FIGURE 1.2 NORTH CAROLINA ELECTRICITY CONSUMPTION AND IN-STATE GENERATION[36]



Since 2005, North Carolina has consistently imported from other states at least 10 percent of total electricity consumed (Figure 1.3). It is not a problem, however; rather, it is the response to the unique power market that has emerged around North Carolina's geography. North Carolina and South Carolina's Piedmont regions share power plants and transmission lines owned by Duke Energy and several local electric co-ops. Power produced at facilities in North and South Carolina is frequently traded over the border as needed by the states. Due to the immense costs of building transmission to North Carolina's Appalachian and coastal counties, Tennessee Valley Authority[37] and Dominion Energy,[38] respectively, service these regions.

FIGURE 1.3 POWER IMPORTS IN TERAWATT-HOURS (TWH) AND PERCENT OF ELECTRICITY SUPPLIED[39]



The lull in power consumption growth gave North Carolina an energy buffer that furthered cheap economic growth and facilitated utilities' transition away from coal. Energy efficiency mandates created spare generation capacity, which new North Carolina households, businesses, and industries could absorb and metabolize into economic activities without impacting power prices. Stalled electricity demand growth also gave Duke Energy a window of opportunity to replace coal-fired electricity with natural gas–fired electricity with minimal disruptions to grid reliability. The emissions reduction benefit has enabled Duke Energy to get a decade head start on the Carbon Plan.

Fifteen years ago, coal-fired power plants were the largest source of electric power in North Carolina. At its peak in 2007, coal generated 62 percent of all power generated in North Carolina (Figure 1.4), over 79.98 TWh of electric power. But by 2022, total coal-fired generation had fallen 82 percent to just 14.67 TWh. Only 11 percent of North Carolina's electricity is generated by coal-fired power plants (Figure 1.6). Over half of coal's usage is limited to winter and summer months to ensure additional generation capacity is available to handle increased air conditioning and heating demand. The shift away from coal was spurred by two key developments, primarily the shale revolution, but also the political promotion of solar power through mandates and incentives.

FIGURE 1.4 NORTH CAROLINA ELECTRICITY GENERATION IN 2007[40]

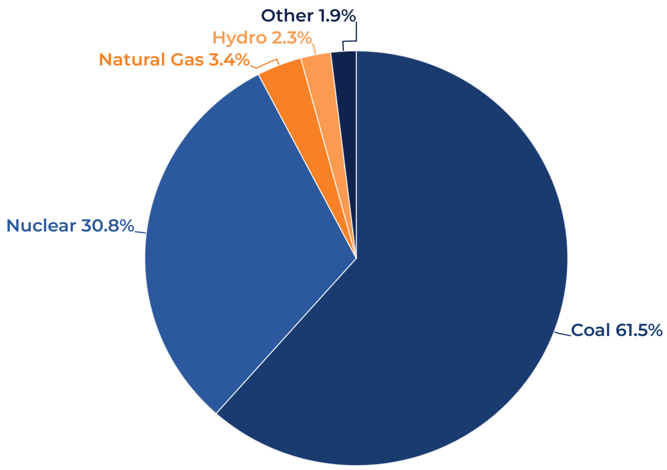


FIGURE 1.5 GENERATION CAPACITY BY SOURCE, 2000–2022[41]

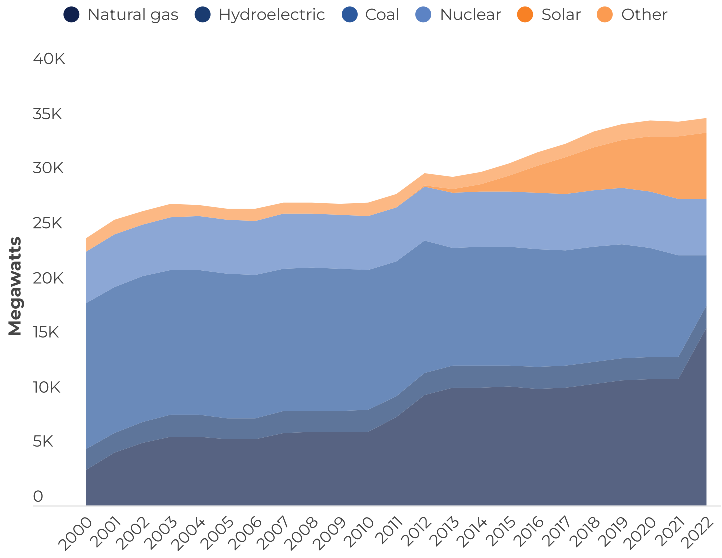
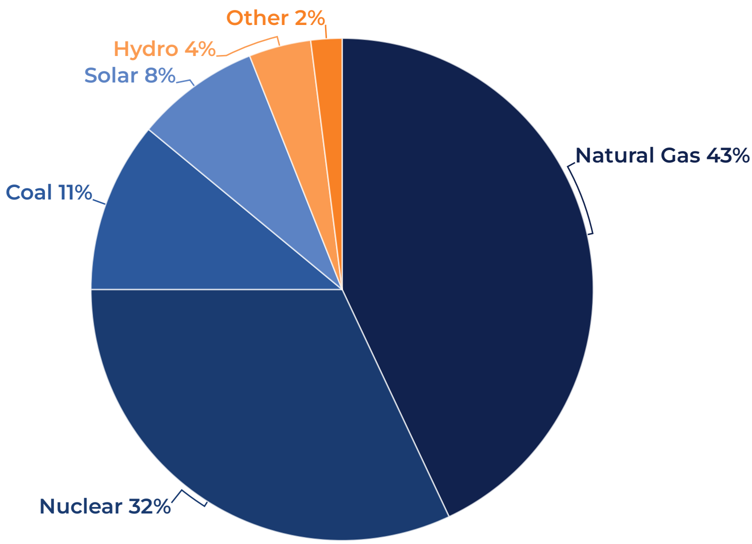


FIGURE 1.6 NORTH CAROLINA ELECTRIC POWER GENERATION IN 2022[42]



The shale revolution inadvertently created a national natural gas glut. Cheap natural gas spurred Duke Energy and hundreds of other utilities across the country to use natural gas as a fuel to generate electricity. The switch to natural gas expedited the retirement of coal-fired power plants. By 2022, North Carolina's natural gas–fired generation capacity had tripled in the 15 years spanning peak coal generation in 2007, displacing nearly 8,000 megawatts (MW) of coal-fired generation (Figure 1.5). In 2022, natural gas–fired turbines generated 58.1 TWh of electricity, roughly 43 percent of North Carolina's electric power (Figure 1.6).

One benefit of natural gas–fired power is its ability to respond in real-time to changes in electricity supply and demand. This near-instantaneous response time is necessary for maintaining grid stability, especially when weather-dependent, renewable power generators stop producing electricity. While all natural gas generators can be turned on or off on short notice, utilities typically use different types of natural gas generators for meeting baseload and peak power demand. Natural gas combined-cycle gas turbine (CCGT) generators are designed to be highly efficient providers of baseload power.[43] The average CCGT generator in North Carolina has a nameplate capacity of 215 MW[44] and a heat rate of 7,596 Btus per kilowatt-hour (KWh), making CCGT generators the most efficient of any thermal power plant, including nuclear. Gas turbines, meanwhile, are basically jet engines that lack the heat-recovery methods used to increase CCGT generators' power output. The average nameplate capacity of a gas turbine in North Carolina is 100 MW.[45] Their heat rate is 45 percent higher than CCGT generators.[46]

While CCGT generators may appear superior to gas turbines in efficiency and generation output, utilities opt to use gas turbines for meeting peak power because they are the most cost-effective. Gas turbines operate for several hours daily, beginning when solar power retires for the evening and supporting the grid through on-peak hours. Gas turbines also see seasonal usage when demand for air conditioning and heating increase during summer heatwaves and winter storms. Rather than build an entire CCGT generator and idle half its capacity, utilities prefer to purchase a gas turbine and operate it only when power is urgently needed.[47] The smaller plants save ratepayers costs and ensure capacity is being efficiently utilized.

Capacity factor is a metric that measures a generator's total capacity utilization. By comparing total power generated by a generator to the generator's maximum potential power output over a time period — usually a year — utilities can determine how efficiently that generator is using its capacity. Figure 1.7 shows how capacity factor is calculated.

FIGURE 1.7 CAPACITY FACTOR EQUATION[48]

$$\text{Capacity Factor} = \frac{\text{Total Megawatt-Hours Generated}}{\text{Nameplate Capacity x Time}}$$ [49]

CCGT's role as a baseload power supplier means that its total megawatt-hours (MWh) produced are close to the maximum achievable. The capacity factor equation reveals that North Carolina's CCGT generators achieved a capacity factor of 76.6 percent (Table 1.1). Analogizing capacity factor to calendar days, CCGT's 76.6 percent capacity factor implies that these generators operated three out of every four days. Gas turbines' nightly and seasonal operation lowers their total power produced. Relative to their nameplate capacity, gas turbines produce only 13.4 percent of their designed capacity. Borrowing the days of the week analogy from above, gas turbines operate roughly only one out of every 10 days.

TABLE 1.1 CAPACITY FACTORS OF NORTH CAROLINA ELECTRICITY SOURCES[50]

Nuclear Power	94.5%
Natural Gas (Combined Cycle)	76.6%
Natural Gas (Steam Turbine)	44.8%
Conventional Hydroelectric Power	26.6%
Biomass	54.7%
Wind	29.5%
Coal	25.0%
Solar Photovoltaic	21.5%
Natural Gas (Gas Turbine)	13.4%
Battery	1.6%
Petroleum	0.2%
Pumped Hydro	0.1%

While capacity factor is useful for determining efficiency, it understates the importance of gas turbines in maintaining grid stability. Wind and solar power both have higher capacity factors than gas turbines. But weather disruptions and the Earth's daily rotation on its axis relative to the sun make these sources unreliable. Without gas turbines ramping up power generation to compensate for inactive wind and solar generators, it would be impossible to add utility-scale renewable energy onto the grid.

Utility-scale solar power was nonexistent in North Carolina prior to 2007. In less than 15 years, solar power had become the fourth-largest source of electricity, but it was generating only 8 percent of all electricity in North Carolina (Figure 1.6). The state's 6,000 MW of solar capacity generates 11.2 TWh of electricity every year at a capacity factor of 21.5 percent

(Table 1.1).[51] Solar's low capacity factor is due to nightly and weather-related interruptions to power generation. Without gas turbines backing up the nightly decline in solar power, adding solar to the grid would be impossible. Expanding solar power has also come at an immense cost to North Carolinians. Ratepayers in Duke Energy Progress' (DEP) service area pay 19 percent more than ratepayers residing in Duke Energy Carolinas' (DEC) service area owing to DEP's larger procurements of solar power and necessary expansion of transmission infrastructure needed to bring solar power onto the grid.[52]

Despite its high cost and intermittency, solar energy is one of the only energy resources North Carolina can harness locally.[53] This fact gives solar two small advantages in certain scenarios. First, rural communities in western, mountainous counties lacking adequate transmission infrastructure can utilize solar microgrids to guarantee power is available when storms sever connections to the grid. Additionally, building the solar grid may result in a lower rate increase for mountain residents than a full transmission upgrade. Second, every kilowatt generated by solar power during the day allows North Carolina to conserve natural gas for other uses. The high cost of building natural gas pipelines leaves North Carolina with a fixed daily supply of gas. Generating more power from solar allows gas that would have been used for generating baseload power during the day to be redirected to storage or for residential, commercial, manufacturing, or industrial use. Nevertheless, North Carolina's renewable energy policies were not designed with these two benefits in mind.

North Carolina's original Renewable and Energy Efficiency Portfolio Standard (REPS), investment tax credits, and mandatory procurements begat a financially unsustainable buildout of solar panels. And now, the state's Carbon Plan seeks to double down on that initial buildout by requiring Duke Energy to build even more solar panels with battery backups. This slapdash, state-mandated overbuild of solar power will cost ratepayers dearly.

Emissions Impact

As an added benefit of the transition from coal-fired power to natural gas, North Carolina has already made a significant reduction in total electric power sector emissions and put the state on a path to achieve North Carolina's legislatively set emissions reduction targets. In 2021, Gov. Roy Cooper signed House Bill (HB) 951. That legislation introduced North Carolina's Carbon Plan, which requires Duke Energy to reduce carbon dioxide (CO_2) emissions to 70 percent below their 2005 level by 2030 or shortly thereafter.[54] Under HB 951's direction, the North Carolina Utilities Commission (NCUC) directed Duke Energy to retire all six of its remaining coal-fired power plants by 2035.[55]

Total emissions peaked in 2007 along with coal-fired power. Thereafter, emissions from electric power generation decreased at an average rate of 3 percent per year. As of 2022, power sector emissions have declined 51 percent below 2005 levels (Figures 1.8 and 1.9). Sulfur dioxide and nitrogen oxide emissions declined by 95 percent and 62 percent, respectively.[56] The large decline in emissions is due to Duke Energy and private industries closing or converting their coal-fired power plants. Total CO_2 emissions from coal-fired power have declined 80 percent since 2005 (Figures 1.8 and 1.9). And by 2035, total coal emissions will be zero.

As of 2022, CO_2 emissions from coal plants were 37 percent of North Carolina's remaining power sector emissions. When the last coal-fired generator retires at the Roxboro Steam Plant in 2035 as currently scheduled, North Carolina's power sector emissions will fall to 65 percent below 2005 levels. Reducing power sector emissions by an additional 5 percent will achieve HB 951's emissions reduction target, albeit five years later than 2030. Achieving the emissions reduction goal sooner will require emissions from recently built natural gas–fired power plants to be offset with intermittent renewables within the next six years.

HB 951 does allow North Carolina's utilities to extend the emissions reduction deadline if building new nuclear power generators "requires additional time for completion due to technical, legal, logistical, or other factors beyond the control of the electric public utility, or in the event necessary to maintain the adequacy and reliability of the existing grid."[57] As a zero-emission source of baseload electricity, nuclear power can replace coal- and natural gas–fired power.

FIGURE 1.8 ELECTRIC POWER SECTOR EMISSIONS IN NORTH CAROLINA, 2000–2022[58]

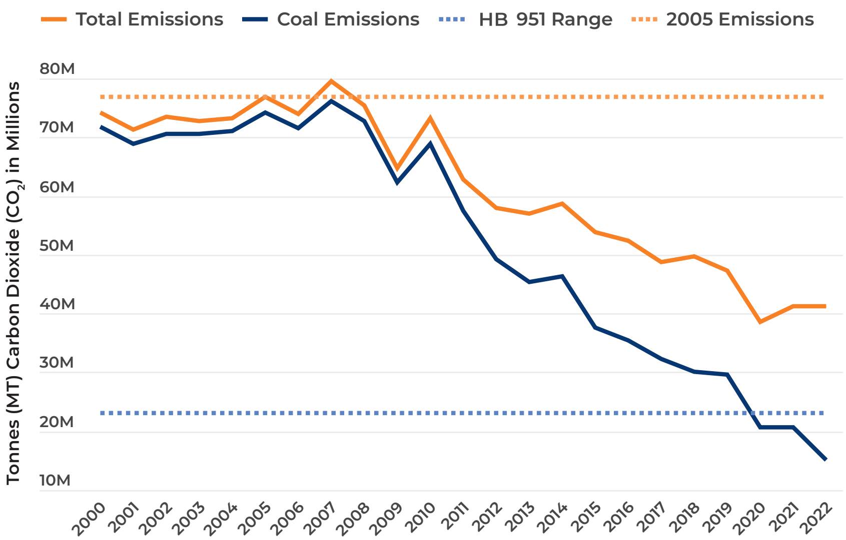
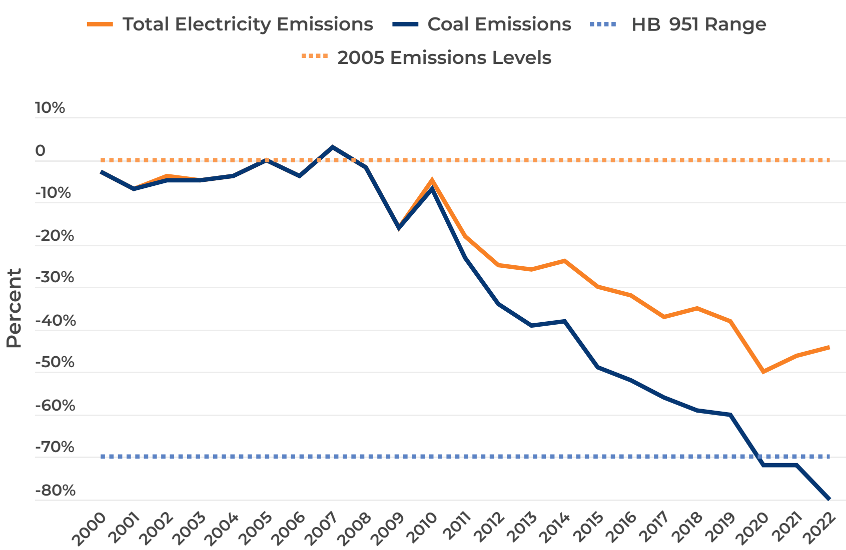


FIGURE 1.9 ELECTRIC POWER SECTOR EMISSIONS IN NORTH CAROLINA (IN PERCENTAGES OF 2005 EMISSIONS), 2000–2022[59]



Generation Overview

There are 1,215 electricity generation units (EGUs) operating in North Carolina.[60] This is a 180 percent increase in the number of EGUs since 2007, when there were only 405 operating electricity generation units.[61]

Of these new EGUs, 763 are utility-scale solar plants. This rapid buildout of solar panels is rooted in North Carolina's REPS, adopted in 2007.[62] The law specifically excluded zero-emissions nuclear power and also limited hydroelectric power facilities to those with a capacity of 10 MW or less. Investor-owned utilities (IOUs) and municipal utilities therefore almost exclusively relied on solar panels to achieve this goal due to North Carolina's limited prospect for commercially viable onshore wind projects.[63]

Natural gas, nuclear, coal, and solar plants comprise more than 96 percent of North Carolina's in-state power production (Figure 1.6). The remaining 4 percent comes from hydro, biomass and wood-fired power, and wind. Below are specific summaries by source of electricity generation.

Natural Gas

In 2007, thousands of miles beyond North Carolina's borders, oil drillers in Texas' Permian, Mid-Atlantic Marcellus, and North Dakota's Bakken shale basins were experimenting with several different well stimulation techniques to extract crude oil trapped in impermeable oil source rocks (shales).[64] These independent techniques were combined into a suite of best practices that revolutionized oil production from shales — a shale revolution. Drillers quickly discovered immense volumes of natural gas were stored in suite with the oil and produced as a free byproduct. The shale revolution created a national natural gas glut, which saw prices fall to decade lows. Even in North Carolina, where natural gas imports are restricted by the capacity of the Transcontinental (Transco) pipeline, natural gas prices declined precipitously. Furthermore, the increasing regulatory burden on coal-fired power increased costs. Together, these factors made natural gas–fired electricity cost-competitive and sparked a coal-to-gas switch in North Carolina.[65]

In 2007, there were 78 natural gas–fired EGUs operating in North Carolina with a combined nameplate capacity of 8,160 MW. By 2022, 108 steam plants used natural gas as a primary fuel. The combined nameplate capacity of these gas plants is 19,014.8 MW (Table 1.2). The average capacity factor of North Carolina's natural gas turbines is 44.9 percent. Combined-cycle turbines have the highest capacity factor at 76.6 percent, while steam turbines' capacity factor is just 13.4 percent.[66] Total natural gas–fired electricity has increased 13-fold.[67] These new natural gas generators resulted in the retirement of over 30 coal-fired boilers with over 5,000 MW of capacity.[68]

Ownership of North Carolina's generators is split between Duke Energy subsidiaries, municipal utilities and electric cooperatives, and private industries. Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) operate 64 natural gas turbines with a combined nameplate capacity of 15,363.1 MW. Municipal electrics operate 40 power plants with nameplate capacity of 3,595.2 MW (Table 1.2). Duke Energy controls 59 percent of North Carolina's generators (Table 1.3) and 81 percent of total natural gas nameplate capacity (Table 1.2 and Figure 1.10).

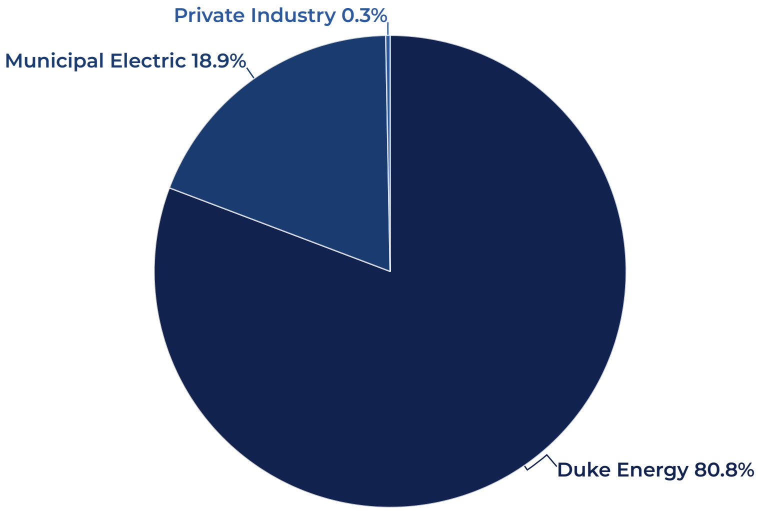
TABLE 1.2 NATURAL GAS GENERATOR AND CAPACITY OWNERSHIP[69]

Owner	Number of Generators	Nameplate Capacity (MW)	Summer Capacity (MW)	Winter Capacity (MW)
Duke Energy	64	15,363.1	13,029.0	14,476.0
Municipal Electric Utility	40	3,595.2	3,218.2	3,218.2
Private Industry	4	56.5	48.5	56.5
Total	108	19,014.8	16,247.2	17,750.7

TABLE 1.3 NATURAL GAS GENERATOR AND CAPACITY OWNERSHIP (PERCENTAGES)[70]

Owner	Generators	Capacity
Duke Energy	59.3%	80.8%
Municipal Electric Utility	37.0%	18.9%
Private Industry	3.7%	0.3%

FIGURE 1.10 NATURAL GAS CAPACITY OWNERSHIP (PERCENTAGES)[71]



Every household in North Carolina is functionally dependent on reliable and affordable natural gas. Natural gas is consumed in North Carolina indirectly through electric power or directly through a gas line hookup. Over 1.5 million North Carolina households, businesses, and manufacturers use natural gas as a direct fuel source. In winter, 65 percent of North Carolinians rely on electricity generated by natural gas power plants for home heating, and over 90 percent of households use electricity for air conditioning in summer months.[72]

An unexpected driver of the natural gas buildout was North Carolina's REPS. Because solar is intermittent, operating only during daylight hours, solar needs to be backed up by a controllable and reliable source of generation. In 2015, for every 1,000 MW of solar capacity added, Duke Energy added 457 MW of natural gas peaking capacity. Duke Energy's proposed near-term action as part of the Carbon Plan would install 2,125 MW of natural gas combustion turbines to provide peak-power support for the 6,460 MW of nameplate solar capacity to be completed by 2031.[73]

All of North Carolina's natural gas enters the state through the Transco Pipeline and is distributed by four local distribution companies (LDCs). The total amount of natural gas that utilities and households can consume is limited by these pipelines. Currently, North Carolina is among the bottom 10 states in terms of per-capita natural gas consumption.[74] New residential gas hookups grow at a sluggish 1 to 2 percent per year.[75] North Carolina will need to substantially expand its natural gas transportation and storage infrastructure to ensure natural gas is made more available and affordable for usage outside of utility power generation.

"Every household in North Carolina is functionally dependent on reliable and affordable natural gas."

A detailed summary of natural gas fuel consumption, pipeline, and storage infrastructure is provided in the "Natural Gas" section under the heading "North Carolina's Costly Carbon Plan."

Nuclear

Nuclear power is North Carolina's second-largest source of electricity. Five reactors spread across North Carolina's Piedmont region generate nearly a third of North Carolina's electricity. Total nameplate capacity of the five reactors is 5,150 MW of capacity (Table 1.4). The average capacity factor of North Carolina's five reactors is 94.5 percent.[76] In 2022, these five reactors generated 42.6 TWh of electricity.[77] All five power plants are operated and maintained by Duke Energy.

TABLE 1.4 NORTH CAROLINA NUCLEAR REACTORS[78]

Reactor Name	Owner	Capacity (MW)	Commercial Operation	License End Year
Brunswick 1	Duke Energy Progress	938	1975	2036
Brunswick 2	Duke Energy Progress	932	1977	2034
Harris 1	Duke Energy Progress	964	1987	2046
McGuire 1	Duke Energy Carolinas	1,158	1981	2041
McGuire 2	Duke Energy Carolinas	1,158	1984	2043

North Carolina also receives a portion of electricity from Duke Energy's Catawba Nuclear Station in South Carolina; several North Carolina electric companies have purchased generation stakes in that power plant. The North Carolina Electric Membership Corporation (NCEMC) and North Carolina Municipal Power Agency No. 1 (NCMPA) own a membership stake in Catawba Nuclear Station. These electric co-ops' ownership stake entitles them to 1,532 MW of Catawba's 2,310 MW generation capacity.[79] Power produced from Catawba and McGuire is traded back and forth between North and South Carolina as needed.

In addition to electricity, North Carolina's five reactors generate significant economic cobenefits. More than 1,400 North Carolinians are employed directly by the nuclear power industry.[80] And for every 10 residents employed at the plant, an estimated 18 additional North Carolinians are employed in jobs that support the power plants and their employees.[81] The state of North Carolina collects $368 million in tax revenue from the nuclear industry.

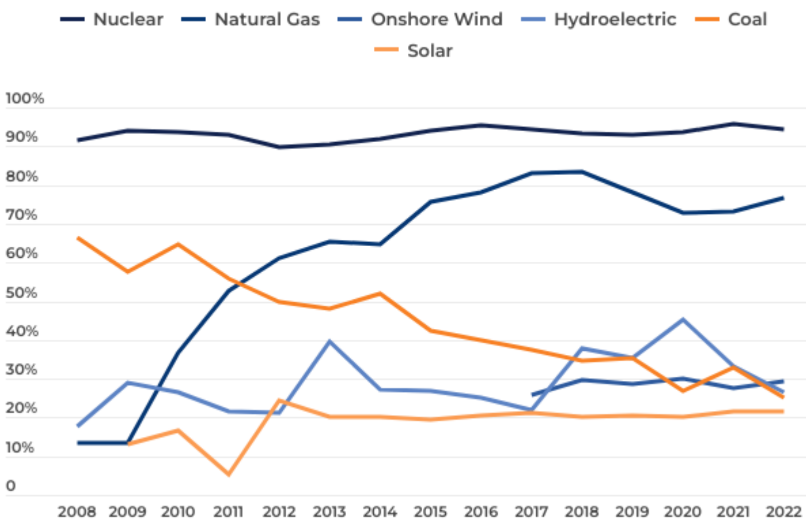
North Carolina's nuclear reactor fleet is aging, which will inevitably pose a challenge to their operations. North Carolina's youngest reactor, McGuire 2, is 40 years old. The average age of the fleet is 43.2 years old. All reactors have received licensing extensions into the 2030s. Most nuclear reactors have an operational lifespan of 40 to 60 years, but several reactors in the United States have received permission from regulators to continue operating up to year 80.[82]

The North Carolina Utilities Commission (NCUC) and the legislature have mandated the preservation and expansion of North Carolina's nuclear reactor fleet. In December 2022, the NCUC required Duke to seek license extensions for North Carolina's five existing reactors at the expiration of their licenses.[83] North Carolina's Carbon Plan encouraged renewing all existing reactors and set a goal of installing 570 MW of new nuclear capacity from two small modular reactors (SMRs) by 2034.[84] Duke Energy plans to site one of these small modular reactors at Belews Creek as a replacement for the retiring coal-fired generation units.[85] In October 2023, over Gov. Cooper's veto, the General Assembly passed the bipartisan "Promote Clean Energy Bill" (Senate Bill 678).[86] SB 678 replaced the statutory definition of "renewable energy" with "clean energy," a change that includes nuclear power. North Carolina law now paves the way for Duke Energy to expand North Carolina's nuclear generating capacity.

Coal

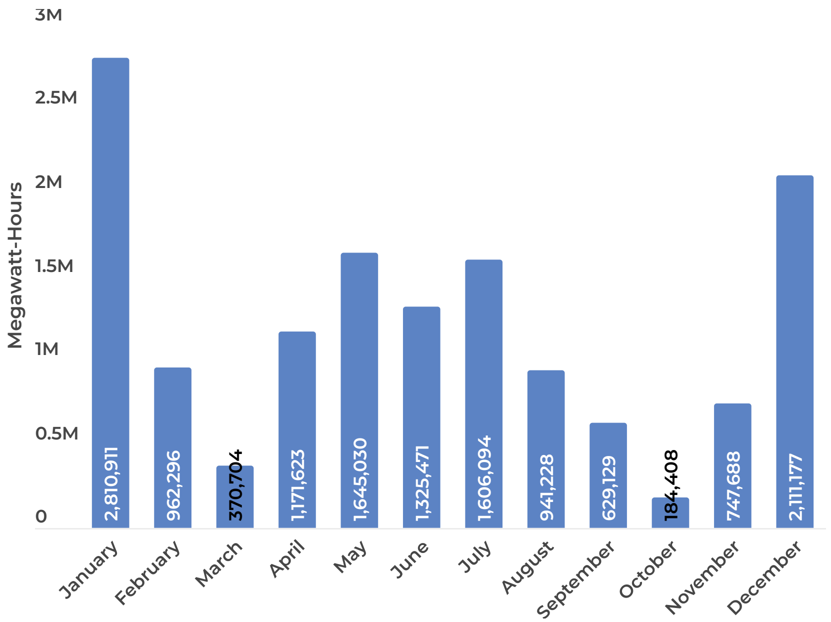
Coal is North Carolina's third-largest source of electricity, and it is the only major source of electricity that has declined. When coal peaked in 2007, North Carolina had 77 operating coal-fired EGUs operated by public utilities, private industries, and state universities.[87] Since the transition from coal to natural gas began in 2010, 4,100 MW of generation capacity spread over 32 coal boilers have been retired.[88] As of 2023, there are only 14 utility-scale coal-fired EGUs, five of which have been converted to natural gas co-firing (Table 1.5).[89] With natural gas co-firing, actual coal-fired generation capacity is just 4,594 MW.[90] Coal-fired generation capacity has declined 75 percent since 2007. As natural gas combined-cycle power plants displaced baseload coal-fired power, coal's utilization fell precipitously. In 2008, coal's capacity factor was 66.4 percent (Figure 1.11). In 2022, coal's capacity factor was 25.0 percent (Table 1.1).[91]

FIGURE 1.11 CAPACITY FACTORS BY GENERATION SOURCE, 2008–2022[92]



While coal's capacity factor is lower than wind and slightly higher than solar power, the mitigating reason behind coal's declining capacity factor has been political mandates aimed at curtailing its use, rather than the uncertainty of weather-related interruptions. Federal regulators and state policymakers pressured North Carolina's utilities to reduce coal-fired power due to high greenhouse gas, sulfur, and other emissions. Complying with these rules, utilities have started limiting coal plant use to the winter and summer seasons to meet the additional baseload power demand spurred by rising use of heaters and air conditioning units. Figure 1.12 shows how Duke Energy uses coal power intermittently as a seasonal resource, generating more power from coal boilers in the winter and summer and less in spring and autumn.

FIGURE 1.12 NORTH CAROLINA'S NET COAL-FIRED POWER GENERATION, JANUARY TO DECEMBER 2022[93]



Despite coal's seasonal role providing baseload power, NCUC required Duke Energy to retire 14 remaining coal-fired EGUs by 2035.[94] Duke Energy's proposed schedule for decommissioning 14 remaining coal-fired boilers is presented in Table 1.5.

TABLE 1.5 DUKE ENERGY'S COAL-FIRED ELECTRIC POWER GENERATING UNITS[95]

Generating Unit	Utility	Nameplate Capacity (MW)	Summer Capacity (MW)	Winter Capacity (MW)	Shutdown Target Year
G.G. Allen 1	Duke Energy Carolinas	163.2	162	167	2024
G.G. Allen 5	Duke Energy Carolinas	272.0	259	259	2024
Belews Creek 1*	Duke Energy Carolinas	1,245.6	1,110	1,110	2036

Generating Unit	Utility	Nameplate Capacity (MW)	Summer Capacity (MW)	Winter Capacity (MW)	Shutdown Target Year
Belews Creek 2*	Duke Energy Carolinas	1,245.6	1,110	1,110	2036
Cliffside 5*	Duke Energy Carolinas	621.0	544	546	2026
Marshall 1*	Duke Energy Carolinas	348.5	370	380	2029
Marshall 2	Duke Energy Carolinas	348.5	370	380	2029
Marshall 3*	Duke Energy Carolinas	711.0	658	658	2033
Marshall 4	Duke Energy Carolinas	711.0	660	660	2033
Mayo 1	Duke Energy Progress	763.2	704	713	2029
Roxboro 1	Duke Energy Progress	410.8	379	380	2029
Roxboro 2	Duke Energy Progress	657.0	668	673	2029
Roxboro 3	Duke Energy Progress	745.2	694	698	2028–2034
Roxboro 4	Duke Energy Progress	745.2	698	711	2028–2034

Retiring North Carolina's remaining coal plants comes with reliability and transmission challenges. North Carolina's challenging geography has made many regions dependent on a local power plant. Duke Energy stated that the retirement of coal plants will "potentially [require] significant transmission upgrades … if replacement generation is not developed commensurate with the retirement of the coal units and interconnected at the retiring generation brownfield site."[96] Mayo and Roxboro coal-fired power plants are situated in DEP's service territory, which currently lacks an adequate transmission connection to Duke Energy Carolinas' service territory.[97] Duke Energy's plan to replace the Roxboro coal plant with natural gas generation is contingent on completion of several pipelines.[98]

Over the last 17 years, several old coal-fired power plants were converted to natural gas–fired power plants.[99] All of Asheville's coal boilers and several at the G.G. Allen Steam Station were replaced with natural gas–fired EGUs. Duke Energy has also partly converted EGUs at several power plants to co-fire natural gas with coal (Table 1.6). Duke Energy is considering using the Belews Creek station, which currently co-fires natural gas and coal, as a potential location for one of two small modular reactors.[100]

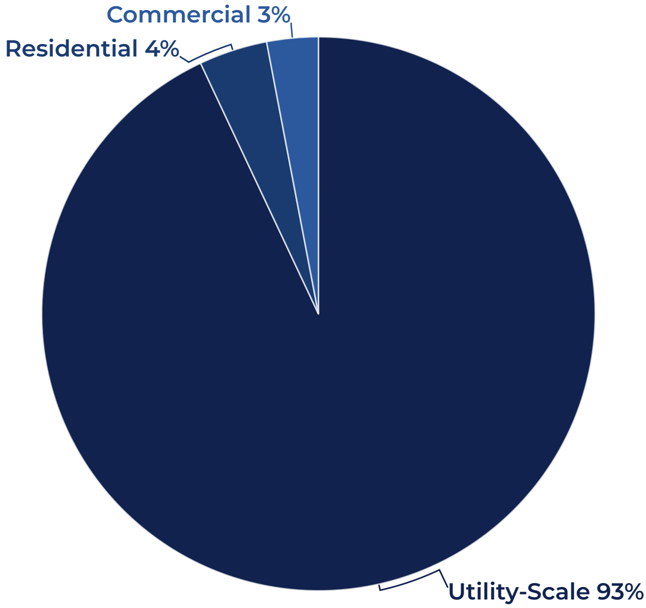
TABLE 1.6 NORTH CAROLINA'S REMAINING OPERATIONAL COAL PLANTS[101]

Plant Name	Owner	Capacity (MW)	Retirement Schedule	Transmission Complications
G.G. Allen Steam Station	Duke Energy Carolinas	435.2	2023–2025	—
Rogers Energy Complex (formerly Cliffside)*	Duke Energy Carolinas	621.0	2025–2026	—
Roxboro Power Station	Duke Energy Progress	2,558.2	2027–2028	Yes
Marshall Steam Station*	Duke Energy Carolinas	2,119.0	2028–2033	—
Mayo Power Plant	Duke Energy Progress	711.0	2035	Yes
Belews Creek Power Station*	Duke Energy Carolinas	2,491.2	2035	Yes
University of North Carolina at Chapel Hill's Cogen Facility*	University of North Carolina	32.0	N/A	—

Solar

Utility-scale solar was nonexistent in North Carolina in 2007. In the 17 years following, solar-powered EGUs proliferated throughout the state so rapidly that solar energy became the state's largest source of renewable electricity, surpassing hydropower in 2017, and the fourth-largest source of electricity in the state.[102] North Carolina has over 763 utility-scale solar EGUs[103] and over 37,000 residential and commercial systems.[104] Total nameplate solar capacity is estimated at 6,234 MW.[105] Over 90 percent of this new solar capacity is from utility-scale solar projects (Figure 1.13). Solar's capacity factor is 21.5 percent.[106]

FIGURE 1.13 NORTH CAROLINA SOLAR INSTALLATION BY CLASS, 2022[107]



North Carolina's governmental mandates and incentives and geography catalyzed the rapid expansion of solar power. The adoption of North Carolina's REPS set generation requirements for the state's public utilities, municipal utilities, and electric co-ops. Duke Energy and Dominion were required to reach 12.5 percent of their electricity generation from renewable sources of power, and municipal utilities and electric cooperatives were required to achieve 10 percent of generation from renewable sources.[108]

In addition to state policy mandates, solar developers also received generous financial incentives from the state and federal government. The federal government's investment tax credit (ITC) allowed developers to claim tax credits equal to 30 percent of a project's value. On top of the federal benefits, North Carolina offers an additional 7 percent in state ITCs per year for the first five years of the project's life. A 2015 report from the North Carolina Department of Environment and Natural Resources (now the Department of Environmental Quality) found that stacking these financial incentives "return[ed] almost all of [the solar developer's] investment within six years."[109] Table 1.7 recreates the cost recovery table presented in the report.

TABLE 1.7 SOLAR PROJECT TAX INCENTIVES

Year	Federal ITC	State ITC	Federal Depreciation	State Depreciation	Cumulative Total
1	30%	7%	17.85%	2.97%	57.82%
2	—	7%	4.76%	0.79%	12.55%
3	—	7%	2.86%	0.48%	10.34%
4	—	7%	1.73%	0.29%	9.02%
5	—	7%	1.73%	0.29%	9.02%
6	—	—	0.83%	0.14%	0.97%
Total	30%	35%	30%	5%	100%

North Carolina's REPS-mandated expansion of solar and the generous state and federal tax credits offered to developers are largely responsible for the creation of North Carolina's 763 utility solar arrays.

To achieve the legislatively set generation requirements, Duke Energy and local electric utilities regularly entered purchase power agreements (PPAs) with solar developers. PPAs allow renewable energy developers to receive a fixed payout per kWh generated by the solar arrays for a fixed number of years, usually 15.[110] HB 951 permitted utility companies to renew PPAs for 10 years with existing solar facilities.[111] One problem with PPAs is the market value of the electricity may fall below the fixed price. When this happens, the utility loses money when power is purchased from the developer. While HB 951 attempted to fix this problem by requiring PPAs to take the current market-clearing price of the electricity produced, PPAs will inevitably lose money from solar plant overbuild.

For example, when California adopted its REPS in the early 2000s, Pacific Gas and Electric Company (PG&E) issued two large rounds of bids for renewable energy and signed 30-year PPAs with renewable energy developers[112] to achieve rapid compliance with the standard. PG&E's slapdash overbidding and overbuilding resulted in persistently higher electricity prices for ratepayers in southern California. Higher prices for power forced wealthier ratepayers to purchase residential solar panels.[113] To compensate for customer exit, PG&E had to increase prices on the remaining, low-income ratepayers.[114]

The NCUC has placed Duke Energy in a similar position to that of PG&E. In November 2022, the NCUC instructed Duke Energy to procure 1,200 MW of solar power. Then, when the initial Carbon Plan was finalized weeks later, the NCUC directed Duke Energy to conduct two additional procurements of 2,350 MW of solar power and 1,000 MW of battery backup as part of a measure to reduce emissions.[115] Building solar arrays haphazardly with PPAs lasting 15 years is following California's recipe for rising power prices to the letter. Worse still, bringing more solar generation onto North Carolina's saturated grid will dissuade investment in baseload power sources,[116] nuclear power especially. Adverse market conditions created by solar power has caused 13 reactors to shut down nationally since 2013, with seven more expected to cease operation by 2025.[117] Duke Energy will need to reconcile whether advanced nuclear power and 3,550 MW of new solar power can share the same grid.

Solar's Limited-Use Case

In its westernmost counties, North Carolina's rugged mountain geography has made building natural gas and electric transmission infrastructure costly and difficult. Solar power is one of the few natural resources that most communities in North Carolina can produce. Although solar radiation in the mountains is low, solar panels may provide a cheaper and more reliable alternative to upgrading transmission lines in North Carolina's isolated and energy-poor mountains.

Solar power has been used since the 1960s by developing countries lacking energy resources and reliable transmission infrastructure. Energy consumption in many mountain and coastal counties in North Carolina is limited by the voltage of their transmission lines.

Western North Carolina's hard-to-develop geography and sparse populations are the worst of both worlds for utilities. Building or upgrading transmission lines is expensive, and there usually are not enough residents to recover capital costs on a medium- to long-term investment time horizon. This disincentivizes utilities from improving transmission line spurs that run power through the Blue Ridge Mountains. The advent of solar microgrids with battery backups, however, has given utilities a second, potentially more cost-effective option for meeting isolated communities' power needs.

"Building solar arrays haphazardly with PPAs lasting 15 years is following California's recipe for rising power prices and will dissuade investment in baseload power sources, nuclear power especially."

If the cost of building a solar microgrid is less than improving transmission lines, then building the microgrid will reduce costs passed onto ratepayers. Many of North Carolina's existing solar facilities are small and designed to serve the needs of rural communities, ranging from under 1 MW to 5 MW in nameplate capacity.[118] The limited scale of these projects compared with other, larger utility-scale solar projects keeps costs down and makes them competitive with upgrading transmission lines. A 1 MW solar system will cost between $890,000 and $1.01 million.[119] The cost to build transmission wires is $1.4 to $1.6 million per mile with an additional $500,000 if site preparation work is required.[120]

In California, it was estimated that a community distributed solar project could save four cents per kilowatt-hour versus the costs of upgrading and expanding transmission lines.[121] If North Carolinians find that solar microgrids are cheaper than upgrading transmission, then solar microgrids can benefit ratepayers in rural communities by reducing the costs of upgrading transmission lines and maintaining grid reliability.

Small-scale solar projects like these can be used to bolster local energy security by shoring up grid reliability. Many rural mountain counties have only a single power line connecting them to the grid. Fierce snowstorms can knock out a town's single power line connecting them to the grid, leaving the city without power for days or even weeks. Duke Energy demonstrated with the Hot Springs project in Madison County that small solar power with battery storage can maintain electricity reliability in these isolated communities when the town's main connection to the grid is separated. The Hot Springs 2-MW microgrid was able to pick up from black start instantly without assistance from the grid, ensuring that the small community of 500 had access to electricity.[122] Microgrids may be beneficial to Alleghany, Clay, Cherokee, and Graham counties, which have limited access to electricity and no natural gas utility. There are 102 residential and commercial solar systems providing 16.92 MW of generation capacity in these isolated communities.[123]

"Hydro was the second-largest source of renewable capacity and the second-largest source of renewable electricity generated in the state, second to solar in both."

While small-scale solar offers potential cost savings and additional grid security for small communities, most solar additions have been a net negative for North Carolina. HB 951 and other mandated procurements of utility-grade solar facilities have saddled the state with expensive, inefficient, and unreliable power generators. The utilities building these state-mandated solar facilities bear a fraction of the cost since they can recover most of the infrastructure costs from their customers by raising base rates. Solar should be used only when it makes financial sense and other energy resources are unavailable.

Hydroelectricity

Hydroelectric sources of power are the fifth-largest source of electric power in North Carolina. The state has 41 hydro dams with a capacity of 2,100 MW.[124] Hydro was the second-largest source of renewable capacity and the second-largest source of renewable electricity generated in the state, second to solar in both. Pumped storage hydro, however, is currently North Carolina's best battery technology, with over 86 MW of capacity.[125]

In 1956, the Hiwassee Dam facility became the first hydropower dam in the United States to use a reversible pump turbine.[126] Despite North Carolina's innovative history in pumped hydro, North Carolina's pumped storage is based in South Carolina. In 2023, Duke Energy added 335 MW of capacity to the Bad Creek hydro project in Salem, South Carolina.[127] Duke Energy anticipates that a second pump station will be in service at Bad Creek by 2033. Duke Energy has included Bad Creek's 1,700 MW of pumped hydro capacity as part of their near-term action plan for meeting the emissions reduction goals in North Carolina's Carbon Plan.[128]

Wood and Biomass

Waste generated from North Carolina's timber, pulp, paper, and agricultural industries produce fuel for biomass power plants.[129] Biomass is only a minor source of electricity, however. In 2022, just 1.36 percent of North Carolina's electric power came from wood or biomass. Several coal plants have been converted to biomass-burning pilot programs.[130]

Wind

Wind is a minimal source of electricity in North Carolina. North Carolina's only operational wind facility consists of 104 wind turbines with 208 MW of capacity.[131] The wind facility sprawls over Pasquotank and Perquimans counties and is near Elizabeth City.[132] By the end of 2024, a second wind facility, with 45 turbines and a nameplate capacity of 189 MW, will be brought online,[133] bringing North Carolina's combined wind capacity up to 397 MW.

These wind facilities were developed as part of power purchase agreements (PPAs) between renewable energy developers and big tech companies. North Carolina's first wind facility was built by Avangrid under a PPA with Amazon in 2015.[134] North Carolina's second wind facility is being built by Apex Clean Energy as part of a PPA made between Google and Apex Clean Energy. As wind technologies improve, wind power has become more commercially viable in North Carolina's windy coastal region.[135]

The motivation behind Big Tech's renewable spending spree is to offset carbon emissions from the electricity used to power their data centers. Tech companies have effectively created shadow renewable energy credit (REC) markets. A tech company will sign a PPA to build a wind or solar facility and then claim that the shadow RECs generated by the facilities "offset" the carbon-intensive electricity used to power the data centers.[136] Often, the renewable electricity created by the PPA is not located in the same city, state, or even country as the data center.

Tech companies will likely be signing more PPAs with renewable developers to offset the massive carbon footprint of artificial intelligence (AI). In Google's "2024 Environmental Report," the tech giant reported total greenhouse gas emissions increased 13 percent as its data centers drew more electricity to power the AI revolution.[137] Google, along with the rest of the tech industry, will offset these emissions through renewable PPAs. North Carolina may see more solar facilities and wind turbines paid for by big tech in the near future.

North Carolina's Costly Carbon Plan

Meeting North Carolina's emissions reduction goal requires an immense buildout of generation assets and transmission. Combined with other clean energy mandates, Duke Energy's near-term action plan risks building generation capacity beyond North Carolina's power needs. The cost of this overinvestment will be passed onto ratepayers through much higher power bills.

HB 951 mandates that the electricity generation sector reduce carbon emissions 70 percent from the 2005 level by 2030 or shortly thereafter, prematurely retire all existing coal-fired power plants, and achieve carbon neutrality (zero emissions) by 2050.[138] HB 951 directed NCUC to work with Duke Energy, North Carolina's largest IOU, to determine the best portfolio for reducing emissions.[139] Duke Energy prepared several portfolios for the commission's consideration. But rather than pigeonholing Duke Energy into a single generation portfolio, the NCUC merely mandated several requirements and deferred to Duke Energy to figure out the remaining details. The mandates set by the NCUC included the retirement of all coal-fired power by 2035, a requirement for Duke Energy to solicit competitive bids for 2,350 MW of new solar power and 600

MW of solar battery storage, seek license renewals for North Carolina's five nuclear reactors, and design a plan to develop small modular reactors.[140] The NCUC also authorized Duke Energy to make any transmission upgrades necessary to achieve the goals in the Carbon Plan.[141]

Since receiving the guidelines from NCUC, Duke Energy has made several revisions to its near-term action plan (NTAP) for achieving HB 951's emissions reduction goal. Table 1.8 shows Duke Energy's NTAP as of August 2023.[142]

TABLE 1.8 DUKE ENERGY'S NEAR-TERM ACTION PLAN AS OF AUGUST 2023[143]

New Electricity Generation	Capacity (MW)	Year
Solar	6,460	2031
Battery Storage	2,700	2031
Natural Gas Combustion Turbine	2,125	2031
Onshore Wind	1,200	2033
Natural Gas Combined Cycle	6,800	2033
Pumped Storage Hydro	1,834	2034
Advanced Nuclear	600	2035
Offshore Wind	2,400	2035
Total	24,119	2035

If fully implemented by 2035, Duke Energy's NTAP would increase generation capacity by more than 24,000 MW by 2035. It is incredibly unlikely that Duke Energy would need to build this much new electricity generating capacity, however. Duke Energy would need to replace only 9,000 MW of coal-fired power by 2035. These 9,000 MW could easily be replaced by the 8,925 MW of natural gas combined-cycle and combustion turbines and the 600 MW of advanced nuclear power presented in Duke Energy's NTAP. These reliable sources of electricity are more than capable of replacing the 9,000 MW of retiring coal boilers.

Duke Energy's plan to install 6,460 MW of utility-scale solar with 2,700 MW of battery backup would require a massive buildout of battery capacity. As of 2022, North Carolina had only 26 MW of battery storage capacity,[144] 1.4 MW of which is residential power.[145]

North Carolina currently has 35,000 MW of electric generation capacity.[146] Between 2004 and 2022, electricity usage in North Carolina increased 1 percent per year. By 2030, North Carolina would need no more than 1,000 MW of new baseload power generation to meet annual demand growth. The additional 15,000 MW of electricity generation in Duke Energy's NTAP is significantly more than North Carolina will likely need. The majority of this additional capacity will be used to replace natural gas plants that are through barely a quarter of their service life. The additional costs of these new generation sources will ultimately be passed onto ratepayers through higher electricity prices.

Offshore Wind Expansion

In 2022, Gov. Cooper issued Executive Order 218, challenging offshore wind facility developers to install 2,800 MW of offshore wind capacity by 2030 and 8,000 MW by 2040.[147] While the numbers may seem large and impressive, EO 218 was Cooper's guise to take credit for two offshore wind projects currently in development that have a projected combined capacity exceeding 3,000 MW by 2030.

The Bureau of Ocean Energy Management lists two ongoing offshore wind projects in North Carolina: Carolina Long Bay and Kitty Hawk Wind.[148] Carolina Long Bay is anticipated to have a nameplate capacity of 1,000 MW.[149] Kitty Hawk Wind will have a nameplate capacity ranging from 2,400 to 3,500 MW.[150] Kitty Hawk Wind is expected to break ground in 2024.

Costs of building 8,000 MW of offshore wind were initially estimated between $55.7 billion and $71.5 billion by the Center of the American Experiment. In August 2023, the North Carolina Department of Commerce estimated that the offshore wind industry will require $100 billion in capital expenditure in North Carolina to build out the offshore wind supply chain. High material costs and rising interest rates[151] have also likely increased costs, far in excess of the Center of the American Experiment's highest estimated cost.[152]

Hydrogen

North Carolina currently has no infrastructure for creating or transporting green hydrogen. Green hydrogen is hydrogen gas created via electrolysis powered solely by renewable energy. With less than 14 percent of North Carolina's generation capacity, it is impossible to produce green hydrogen with the state's current energy mix. Nevertheless, Duke Energy claims that by 2032, their new natural gas power plants will be able to co-fire natural gas blended with hydrogen. Co-firing hydrogen will help Duke maintain compliance with North Carolina's Carbon Plan and the EPA's 2024 power plant emissions rules.

Unless the hydrogen is created onsite at the power plant where it is blended and burned with natural gas, North Carolina will need either to upgrade its existing natural gas pipeline fleet or build a new hydrogen pipeline transportation network. Given how geography, permitting, and financial challenges have limited the expansion of natural gas in North Carolina, the former is more likely than the latter. Retrofitting North Carolina's natural gas pipelines for green hydrogen will cost ratepayers from $826.8 million up to $8.3 billion (Table 1.9). An issue brief published by Colorado's Independence Institute found that annual costs accrued to ratepayers for upgrading natural gas pipelines to run blended hydrogen could range from $584 to $5,840.[153]

> "North Carolina will need either to upgrade its existing natural gas pipeline fleet or build a new hydrogen pipeline transportation network."

North Carolina's ratepayers would ultimately pay less than their Coloradan peers because North Carolina's natural gas pipeline network is only one-tenth the size of Colorado's. Nevertheless, North Carolina's 1.4 million gas customers would pay $584 to $5,840 in additional service charges (Table 1.10). Should the hydrogen buildout coincide with North Carolina's target to hit carbon neutrality by 2050, then ratepayers would be paying up to $224 per year to support the transition to hydrogen.

TABLE 1.9 ESTIMATED COSTS OF UPGRADING OR REPLACING EXISTING NATURAL GAS PIPELINES FOR HYDROGEN[154]

Percentage of Lines Needing Replacement	Miles of Pipeline Needing Replacement	Estimated Cost
10%	418.5	$826,775,177
50%	2,092.5	$4,133,875,883
100%	4,185.0	$8,267,751,765

TABLE 1.10 ESTIMATED COSTS ACCRUED PER NORTH CAROLINA NATURAL GAS CUSTOMER FOR UPGRADING OR REPLACING EXISTING NATURAL GAS PIPELINES FOR HYDROGEN[155]

Percentage of Lines Replaced	Cost Share per Customer
10%	$584
50%	$2,920
100%	$5,840

North Carolina does not currently have an operational electrolysis facility capable of producing hydrogen. Nevertheless, in October 2023, Duke Energy announced it will break ground on a 100 percent solar-powered hydrogen combustion turbine in DeBary, Florida.[156] If this pilot project proves commercially viable, then Duke Energy will likely deploy hydrogen-producing electrolysis plants in North Carolina. Beholden to investors, Duke Energy sees hydrogen as a means of appeasing North Carolina's 2050 carbon-neutrality goals and increasing its ESG rating presented in annual reports. While Duke Energy will receive the credit for achieving these political and financial objectives, North Carolinians will ultimately be the ones footing the bill.

Electricity Markets and Transmission

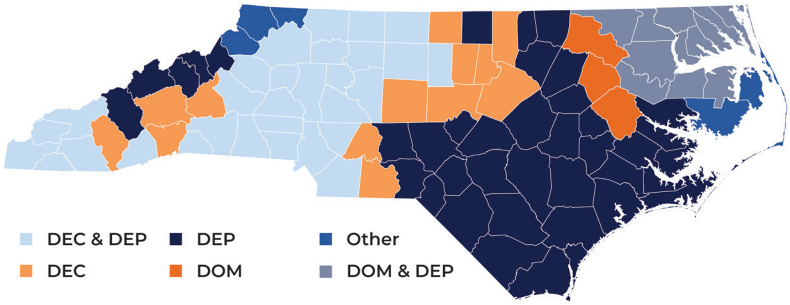
North Carolina has three main transmission companies: Duke Energy Carolinas (DEC), Duke Energy Progress (DEP), and Dominion Energy. DEC and DEP provide 96 percent of all electricity sold by IOUs in North Carolina (Table 1.11).

TABLE 1.11 ELECTRICITY SALES IN NORTH CAROLINA (GWH)[157]

	Retail Sales	Wholesale	Total Sales (NC)
Duke Energy Carolinas	38,640	25,586	64,226
Duke Energy Progress	56,950	4,881	61,831
Dominion Energy	4,078	47	4,125

Figure 1.14 is a map showing the operation region of each IOU.

FIGURE 1.14 SERVICE AREAS OF NORTH CAROLINA'S MAJOR ELECTRIC UTILITIES[158]



Duke Energy oversees over 100,000 miles of transmission wires across North and South Carolina.[159] Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) operate and maintain over 19,250 miles of transmission lines that run power through North and South Carolina (Table 1.12).[160] Figures 1.15 and 1.16 are taken from the Energy Information Administration's (EIA) "Energy Atlas" and showcase North Carolina's existing transmission infrastructure.

TABLE 1.12 TRANSMISSION LINE BY CLASSIFICATION (IN MILES)[161]

Line Type	Residential/ Rural Power Lines	State Level Transmission	Interstate Transmission Wires
Voltage (KV)	44–69	100–230	500+
Voltage Class	Low–Medium	High	Ultra-High
DEC	2,873	9,508	576
DEP	12	5,998	292
Total Lines (Miles)	2,885	15,506	868

FIGURE 1.15 HIGH-VOLTAGE TRANSMISSION LINES (220–500 KV)[162]

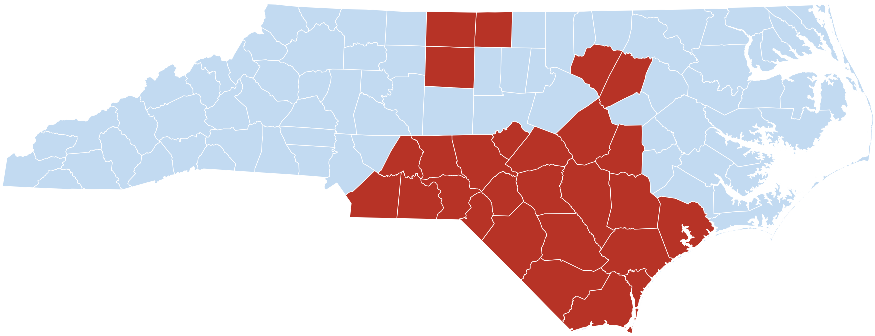
FIGURE 1.16 HIGH-VOLTAGE TRANSMISSION LINES (100–500 KV)[163]

Duke Energy has explained how the retirements of the Roxboro and Mayo coal power plants will require expansions in transmission:

> Currently, there is no available import capability from [Duke Energy Carolinas (DEC)] to [Duke Energy Progress (DEP)] … if the Roxboro/Mayo replacement generation is located in DEC and requires import into DEP, then additional, more costly and time-consuming upgrades would be required. Conceptual transmission projects that would likely be needed would be a Durham-Parkwood Tie 500 kV interconnection, a Bynum 500/230 kV Switching Station interconnection along with associated line upgrades, and potentially a Roxboro Plant-Sadler Tie 230 kV interconnection.[164]

DEP and DEC plan to spend more than $560 million over five and a half years to upgrade the transmission network in the Piedmont and southern coastal region, which both lack the infrastructure to bring power from newly built solar panels onto the grid. Duke Energy denotes these regions as "red zones."[165] The influx of intermittent power will help Duke Energy meet HB 951's decarbonization commitments. Counties that are part of the "red zones" receiving transmission upgrades are shown in red in Figure 1.17.[166]

FIGURE 1.17 RED ZONES IN NORTH CAROLINA THAT LACK SUFFICIENT TRANSMISSION INFRASTRUCTURE FOR A LARGE INFLUX OF NEW SOLAR GENERATION[167]



Duke Energy has already begun recovering the cost of upgrading "red zone" transmission lines from ratepayers by increasing customers' base utility rates. In January 2024, NCUC approved Duke Energy Carolinas' plan to pass the cost of these transmission upgrades onto ratepayers. Residential customers using 1,000 kWh per month saw electricity bills immediately increase by $10 per month. Two subsequent rate hikes will combine to increase power bills by another $8 per month by 2026.[168] In September 2023, NCUC approved similar rate increases for Duke Energy Progress customers, increasing electricity bills for residential customers using 1,000 kWh per month by $8 per month immediately and by another $10 per month over the next two years.[169]

Dominion plans to spend $71 million enhancing system transmission in its service territory.[170] At least 3,122 MW of solar power accompanied by 318 MW of battery storage capacity are queued to enter service in Dominion's service territory.[171]

As North Carolina continues to require utilities to lower CO_2 emissions per HB 951's requirements, utilities will recover costs by raising rates on ratepayers.

Natural Gas

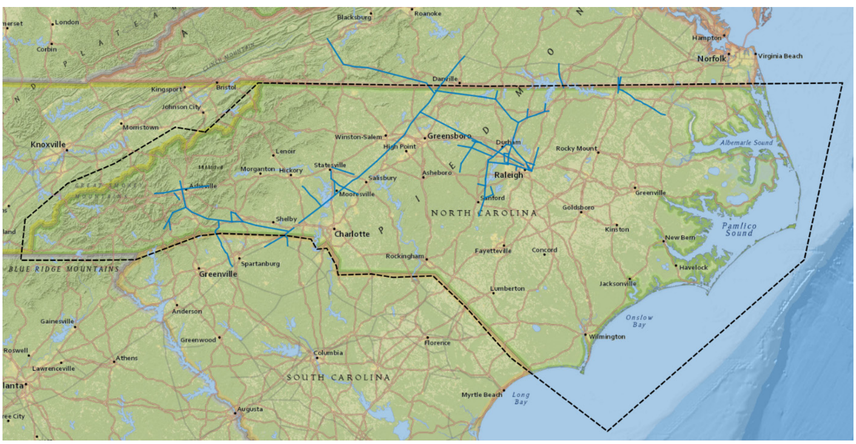
North Carolina's geologic history prevented the formation of oil and natural gas deposits that are commercially viable using today's drilling and hydraulic fracturing techniques. Consequently, with a few notable exceptions, all of North Carolina's natural gas is imported from other states via pipeline. North Carolina's natural gas is distributed to residents by four local distribution companies (LDCs) and eight municipal systems.[172]

North Carolina has four shale basins spanning the middle third of the state. Geologic theory suggests that the Deep River, Dan River, Davie, and Ellerbe shales could have an estimated 309 billion cubic feet (bcf) of natural gas, along with condensates.[173] These basins, however, formed as in-land lakes during the Triassic period 200 to 232 million years ago.[174] Current oil and gas drilling techniques were perfected to extract oil and gas from marine shales. Extracting hydrocarbons from lacustrine shale basins requires advancements in drilling sciences to become commercially viable.[175] Even if recovery of hydrocarbons from lacustrine shale basins were commercially feasible today, North Carolina would be better off building out infrastructure to import supplies of cheap natural gas produced in the Permian, Gulf of Mexico, and Marcellus basins. Until prices for natural gas rise to support the development of North Carolina's domestic gas industry, North Carolina will continue to import natural gas from other states.

Natural Gas Transportation

The Transcontinental (Transco) natural gas pipeline is North Carolina's primary source of natural gas. The Transcontinental Gas Pipeline Corporation — later Transco Energy Company — began constructing the pipeline in May of 1949.[176] North Carolina received its first delivery of natural gas from the pipeline in 1951.[177] In 1995, Transco Energy Company was acquired by Williams Partners L.P. (Williams).[178] As of May 2024, Williams continues to operate the Transco pipeline.

FIGURE 1.18 NORTH CAROLINA TRANSCO PIPELINE AND MAJOR INTRASTATE PIPELINES[179]



Being the only interstate pipeline that crosses through the state, the Transco pipeline is functionally North Carolina's sole supplier of natural gas (Figure 1.18). The Transco pipeline brings 2.5 billion cubic feet (bcf) of natural gas per day from Texas and the Gulf of Mexico to Georgia, South Carolina, and North Carolina. Following approval from the Federal Energy Regulatory Commission to reverse the pipeline's flow in 2018, natural gas now flows from the Marcellus region[180] into North Carolina.[181] The reversal of the pipeline brought approximately 300 million cubic feet per day (MMcf/d) of natural gas from the Marcellus south into Virginia and North Carolina.[182] The East Tennessee Natural Gas LLC's Jewell Ridge pipeline supplies 235 MMcf/d of natural gas, interconnecting with Transco's mainline in Cascade Creek, North Carolina.[183]

North Carolina has five pipeline companies responsible for the distribution of natural gas from the Transco pipeline to residential and commercial customers and public utilities. The Cardinal Pipeline Company is a company owned by subsidiaries of Williams Partners L.P. and two intrastate local distribution companies (LDCs): Piedmont Natural Gas (Piedmont) and Public Service Company of North Carolina (PSNC).[184] North Carolina's two remaining LDCs are Toccoa Natural Gas (Toccoa) and Frontier Natural Gas (Frontier).[185] Piedmont and PSNC serve more than 99 percent of North Carolina's natural gas users (Table 1.13). Frontier and Toccoa serve counties in the North Carolina mountains.

TABLE 1.13 APPROXIMATE DISTRIBUTION OF NATURAL GAS CUSTOMERS IN NORTH CAROLINA[186]

Natural Gas Distribution	Customers	Percent
Piedmont Natural Gas	810,000	57.21%
PSNC	600,000	42.38%
Frontier Natural Gas	4,950	0.35%
Toccoa Natural Gas	805	0.06%

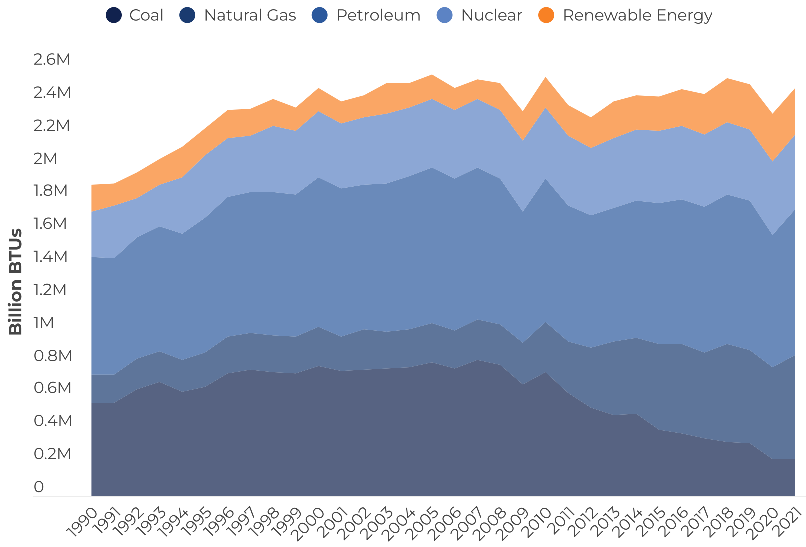
PSNC and Piedmont are the only LDCs that interconnect directly with the Transco pipeline within the state of North Carolina and are the sole suppliers of natural gas to DEP's and DEC's natural gas–fired power plants.[187] Piedmont is owned by Duke Energy. In 2019, PSNC was acquired by Dominion Energy.[188] In 2023, Enbridge purchased PSNC from Duke Energy.[189]

The Rise of Natural Gas as a Primary Fuel

Despite pipeline capacity constraints, natural gas has become the second-largest source of primary energy in North Carolina behind petroleum and ahead of nuclear power (Figure 1.19). While every North Carolinian depends on natural gas for electricity in the dog days of summer and the dead of winter, 1.5 million households and businesses in North Carolina use natural gas to power their appliances and factories. North Carolina's dependency on natural gas will only increase as the number of power-hungry jobs increases and the population continues to grow. With the nation's 13th-highest natural gas prices, North Carolina must inevitably increase its pipeline and storage capacity to keep energy available and affordable for utilities, homeowners, and businesses.[190]

North Carolina's lack of recoverable natural gas necessitates that all natural gas be imported via pipeline. Because of the difficulties associated with building pipelines, North Carolinians have always used less natural gas than Americans living in other states. Nevertheless, since 2009, North Carolina has seen a meteoric increase in natural gas consumption, even with existing pipeline capacity constraints.

FIGURE 1.19 NORTH CAROLINA ENERGY CONSUMPTION BY SOURCE OF PRIMARY ENERGY, 1990–2021[191]



At last count, 1,525,982 North Carolinian households, businesses, and manufacturers consumed natural gas as a fuel for home heating, appliances, and machinery. The number of natural gas consumers has increased 29 percent since 2007 at an average annual rate of increase of 2 percent. Nearly a quarter (24.3 percent) of North Carolinians use natural gas for heating their homes.[192] Residential gas hookups have led the way, increasing 30 percent over the last 15 years (Figure 1.20). Commercial gas consumers have also experienced robust growth, increasing 19 percent over the last 15 years. The total number of industrial natural gas users has declined.[193]

FIGURE 1.20 NORTH CAROLINA NATURAL GAS CUSTOMERS[194]

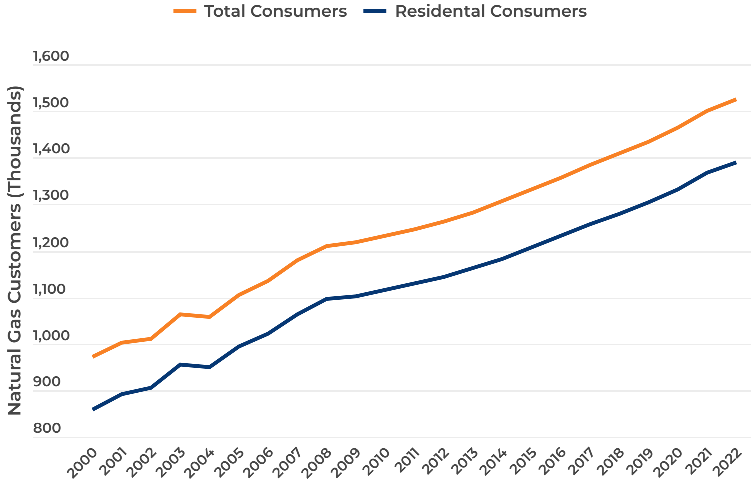


FIGURE 1.21 NATURAL GAS CONSUMPTION IN NORTH CAROLINA, JANUARY 2001 TO JANUARY 2024[195]

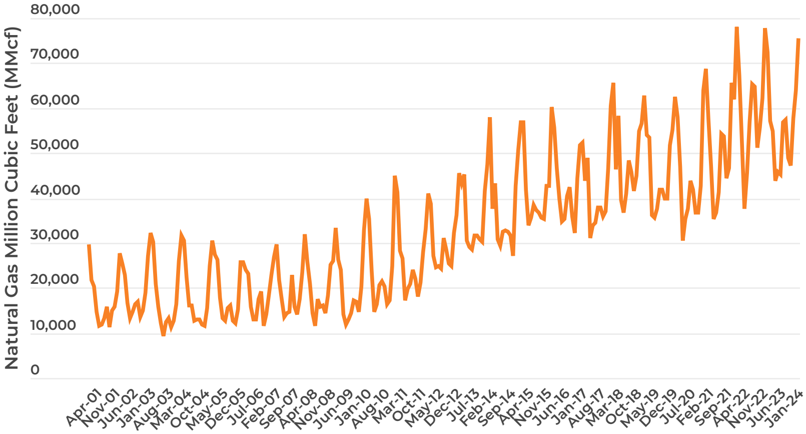
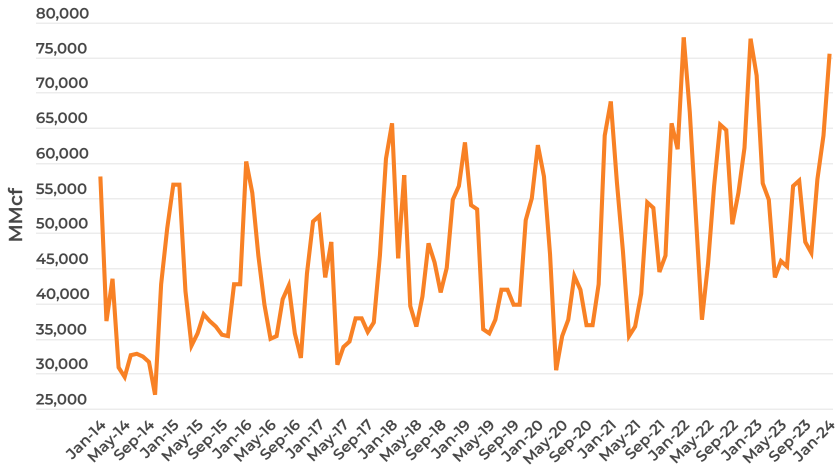


FIGURE 1.22 10-YEAR NATURAL GAS CONSUMPTION IN NORTH CAROLINA, JANUARY 2014 TO JANUARY 2024[196]



The peaks in Figures 1.21 and 1.22 follow North Carolina's seasonal demand for natural gas. North Carolinians use more natural gas during the winter months for heating their homes, whether directly through gas-powered appliances or indirectly through electric power generated at gas power plants. While Figure 1.22 suggests that natural gas consumption in North Carolina is stuck in a demand rut between 30,000 MMcf and 78,000 MMcf, this is not the case.

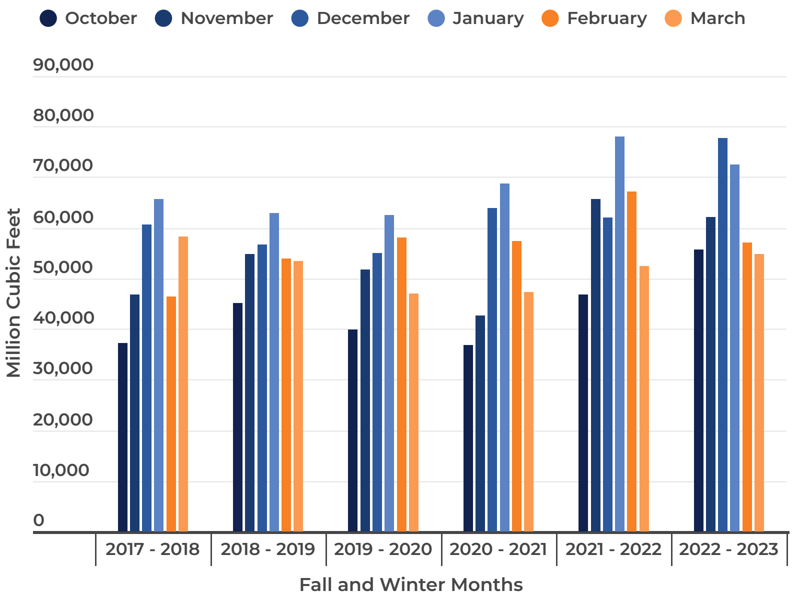
Table 1.14 and Figure 1.23 show that both total and average natural gas consumed during winter months is increasing irrespective of the severity of winter. In January 2022, natural gas deliveries peaked at 77.943 bcf. Then 11 months later, during Winter Storm Elliott in December 2022, 77.718 bcf of natural gas were delivered to consumers.[197] Natural gas deliveries during Winter Storm Elliott would have passed the peak set just 11 months prior if service interruptions caused by the severe weather had not impeded deliveries. Total natural gas delivered in the fall and winter months has increased every winter season going back to 2019–20 (Table 1.14).

The 2023–24 winter season will likely set another record. January 2024, even amid a warm winter for North Carolina,[198] saw the third-largest amount of natural gas delivery of 75.567 bcf. North Carolina's increasing gas consumption during a relatively mild winter reflects North Carolinians' growing dependency on natural gas' reliability and flexibility both as a source of electricity and as an in-home fuel source.

TABLE 1.14 FALL/WINTER NATURAL GAS CONSUMPTION IN NORTH CAROLINA, MILLION CUBIC FEET (MMCF)[199]

	2017–18	2018–19	2019–20	2020–21	2021–22	2022–23
October	37,168	45,054	39,823	36,826	46,759	55,628
November	46,755	54,774	51,745	42,589	65,669	62,051
December	60,579	56,658	55,019	63,899	62,003	77,718
January	65,653	62,834	62,439	68,729	77,943	72,457
February	46,369	53,864	58,086	57,350	67,140	57,032
March	58,187	53,401	47,015	47,284	52,450	54,760
Totals	314,711	326,585	314,127	316,677	371,964	379,646
Averages	52,452	54,431	52,355	52,780	61,994	63,274

FIGURE 1.23 FALL/WINTER NATURAL GAS CONSUMPTION IN NORTH CAROLINA[200]



Since 2019, total and average natural gas consumed in fall and winter months in North Carolina has increased. The current state of pipeline infrastructure in North Carolina, however, sets a ceiling on natural gas consumption. Fortunately, pipeline extensions, expansions, and new storage facilities will increase the amount of natural gas and, by extension, the availability of energy in North Carolina.

Proposed Pipeline Infrastructure

North Carolina's limited natural gas capacity has cost North Carolina's households and businesses dearly over the years. In October 2022, when natural gas contracts for January delivery were priced at $7.00/Mcf at Henry Hub in October 2022, North Carolina's contracts were trading at $17.50/Mcf.[201] Natural gas costs nearly twice as much in North Carolina as it does in other parts of the country because of North Carolina's limited pipeline capacity.[202]

North Carolina has several pending natural gas pipeline expansion projects that will ameliorate its supply constraints. The Southgate extension was originally designed as a 75-mile southern spur off the Mountain Valley Pipeline (MVP). MVP Southgate was originally designed to bring 0.3 bcf per day (bcf/d)[203] from MVP's terminus at the Lambert Compressor Station in Pittsylvania County, Virginia, to Alamance County, North Carolina.[204] In January 2024, however, Equitrans Midstream, a 47.2 percent stakeholder in the Southgate extension company, announced that the Southgate spur would be cut down to just 31 miles and terminate in Rockingham County, North Carolina.[205] At the same time, Equitrans increased the pipeline's capacity to 0.55 bcf/d by using a 30-inch diameter pipe. Reducing the length will also eliminate the need to build a compressor station.[206] MVP Southgate will not be completed until 2028.[207]

In November 2023, Williams announced the Southern Supply Enhancement project (SSE), which will bring an additional 1.4 bcf/d of natural gas into Virginia, the Carolinas, and Georgia. North Carolina would receive a 26.3-mile loop adjacent to the Transco mainline that would increase deliveries to Rockingham, Guilford, Forsyth, and Davidson Counties. Also, Williams has implemented the Southeast Reliability (SRE) project, which will enter service by December 2024, delivering an additional 160,000 Mcf per day[208] of natural gas to customers.[209]

TABLE 1.15 IMPACT OF IMPENDING NATURAL GAS CAPACITY EXPANSIONS[210]

	Mcf/day	Percent of Current Capacity	Year Complete
Current Capacity	660,720	—	—
Transco SRE	160,000	24%	2024
MVP Southgate	550,000	83%	2028
Transco SSE	TBD	N/A	TBD

The SRE and MVP Southgate pipelines will more than double North Carolina's daily natural gas import capacity (Table 1.15). MVP Southgate and Transco SRE's doubling the daily supply of natural gas may seem like an unsustainable business practice, but power plants are already preparing to siphon off large quantities of natural gas.

Dominion Energy announced plans to construct a 45-mile-long spur off the Southgate extension for delivery at a proposed natural gas power plant near Roxboro, North Carolina. The natural gas delivered to these plants will be able to replace the Roxboro coal-fired power plant and produce enough electricity to power over 430,000 North Carolinians' homes.[211]

Any natural gas not used by the power sector is natural gas that North Carolina's four LDCs can use to establish a new market. Many farmers in North Carolina depend on propane for energy and heating needs.[212] By expanding natural gas pipelines into Eastern North Carolina to bring over excess natural gas from the Piedmont, North Carolina's LDCs can offer poultry farmers uninterrupted natural gas service for their farm heating needs. Excess natural gas will inevitably be stored for use in the winter.

Natural Gas Storage

As North Carolina uses more natural gas, the importance of storage increases. Natural gas storage guarantees North Carolina an adequate supply of natural gas during winter, tropical storms, or service interruptions to the Transco pipeline. The realities of operating pipelines and North Carolina's geography, however, complicate natural gas storage. Expanding natural gas storage capacity will be paid for in part by raising rates on natural gas customers.

North Carolina's lack of salt dome caverns means natural gas providers rely on pressurized aboveground tanks to store liquified natural gas. North Carolina's natural gas storage is divided by several large-scale storage facilities and rural municipal storage sites. North Carolina has five liquified natural gas (LNG) storage facilities owned by Williams and Piedmont, which control the majority of the state's natural gas storage capacity. Williams' Pine Needle Facility is North Carolina's largest natural gas storage facility by volume. [213] The site's two storage tanks have a combined capacity of 4 billion cubic feet (bcf). The natural gas siloed in Pine Needle is often drawn down in the winter to help utilities meet daily spikes in home-heating demand. When power is urgently needed, Pine Needle can dispatch a maximum of 400 Mcf per day, 10 percent of the facility's total storage capacity. Without technical limitations, deploying natural gas to power plants and households at the maximum rate, Pine Needle has fewer than 10 days of supply.[214]

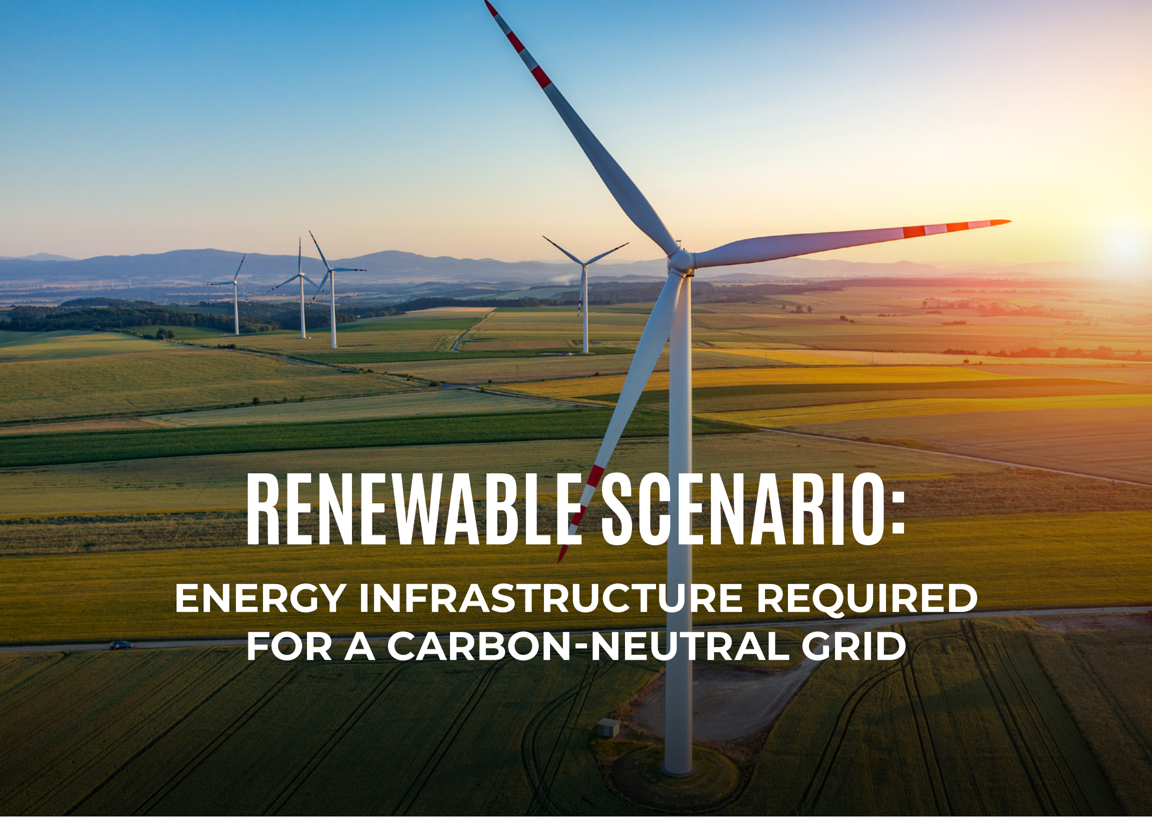
Piedmont Natural Gas, a subsidiary of Duke Energy, operates several LNG storage facilities. The Robeson County LNG facility has a capacity of 1 bcf of natural gas storage and can provide enough LNG to meet 80,000 homes' energy needs on a cold day.[215] The Robeson storage facility was paid for in part by increasing rates on customers. Business and residential customers saw rates increase by $65 per year to fund the facility.[216] Piedmont operates two more natural gas storage facilities in Huntersville and Bentonville, which together make up roughly half of Robeson's peak-shaving capacity.

In addition to large-scale storage managed by Transco and Piedmont, several municipalities maintain small aboveground storage facilities to ensure natural gas availability for households and businesses.[217] An example of these facilities is presented in Figure 1.24.

As North Carolina's pipeline capacity and natural gas–fired power plants increase, more storage facilities like Pine Needle will be needed to ensure power, industrial, and residential demand for natural gas can be met. Dominion Energy is preparing to build a 2-bcf natural gas storage plant in Person County.[218] The city of Greenville uses six horizontal LNG storage tanks with a combined capacity of 25.5 Mcf of natural gas. Greenville had plans to add two additional storage tanks, but satellite imaging of the site from March 2024 indicates that the expansion has yet to be completed (Figure 1.24).[219] Appendix B shows a map of North Carolina natural gas local distributors, and Appendix C contains a map showing the location of major LNG storage facilities and a graph showing utility-scale winter peak-shaving capacity in North Carolina. Also, Appendix D includes a brief discussion of North Carolina's relatively high propane consumption and propane importation.

"More storage facilities like Pine Needle will be needed to ensure power, industrial, and residential demand for natural gas can be met."

FIGURE 1.24 GREENVILLE MUNICIPAL UTILITIES ABOVEGROUND STORAGE TANKS[220]



RENEWABLE SCENARIO:

ENERGY INFRASTRUCTURE REQUIRED FOR A CARBON-NEUTRAL GRID

Passed in 2021, House Bill (HB) 951 has pigeonholed North Carolina's utilities into meeting future demand with low- and zero-emissions sources of electricity. By 2030 or shortly thereafter, utilities are required to have reduced emissions by 70 percent below 2005 levels, and by 2050 they must achieve total carbon neutrality (i.e., produce zero carbon dioxide (CO_2) emissions).[221]

Meeting the legislature's commitment to decarbonization will require the largest expansion of electric infrastructure since electrification began in the early 1920s.

How utilities choose to reconcile North Carolina's decarbonization requirements with the state's energy needs will ultimately determine the prices consumers will pay for energy, set the limits for North Carolina's economic growth and development, and influence the amount of infrastructure needed to serve electricity customers reliably.

In this assessment, Always On Energy Research (AOER) has modeled the amount of power plant capacity and associated energy infrastructure needed to meet the requirements of HB 951 using a resource mix that relies on onshore wind, offshore wind, solar, and battery storage, while maintaining North Carolina's existing nuclear and hydroelectric power plants. (See Appendix E for assumptions.)

We have determined that this resource portfolio would require a nearly tenfold increase in energy infrastructure and consume much more land than the current electric grid.

Infrastructure

Figure 2.1 shows the change in electric generating capacity from 2022 through 2050. Coal and natural gas power plants would be phased out and replaced with a combination of onshore wind, offshore wind, solar, and battery storage. The state's existing nuclear and hydroelectric plants remain in service throughout the model run.

FIGURE 2.1 NORTH CAROLINA'S ANNUAL CAPACITY MIX UNDER THE RENEWABLE SCENARIO

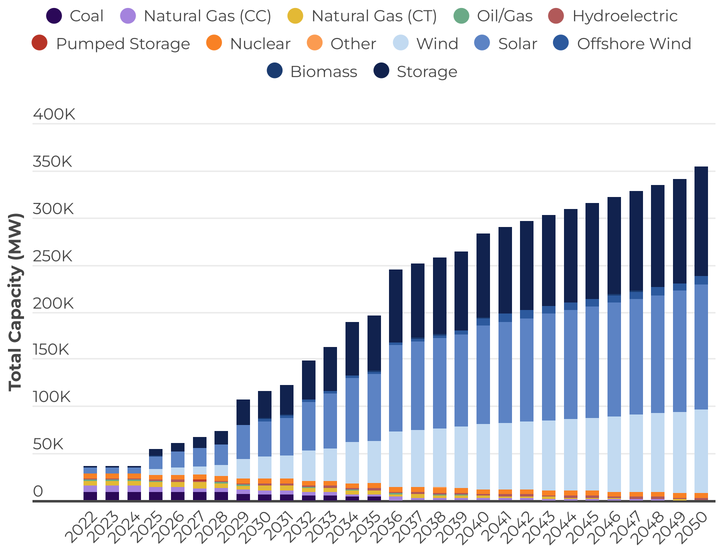


Figure 2.1 The amount of installed capacity on the North Carolina grid would grow from 35,391 MW in 2022 to 353,170 MW in 2050 in this scenario.

Table 2.1 shows that, in order to meet the state's energy needs in this scenario, North Carolina will need to expand its installed capacity of renewable energy and battery backups significantly — in some cases by several hundred orders of magnitude.

TABLE 2.1 NORTH CAROLINA'S ENERGY NEEDS UNDER THE RENEWABLE SCENARIO

	Capacity 2022 (MW)	Capacity 2050 (MW)	Increase in Capacity
Onshore Wind	208	88,643	426 times greater
Offshore Wind	0	8,000	N/A
Solar	6,070	127,347	21 times greater
Battery	36	115,416	3,206 times greater
Coal and Natural Gas	21,343	—	—

Table 2.1 The closure of the state's coal- and natural gas–fired power plants would necessitate 339,406 MW of replacement capacity if intermittent generators and battery storage are used.

In total, the closure of reliable coal and natural gas power plants necessitates a nearly tenfold increase in the total electricity generation capacity installed on the North Carolina grid to meet fluctuations in hourly electricity demand and solar capacity factors, based on historical data obtained from the U.S. Energy Information Administration (EIA).[222]

The massive growth in capacity is needed because North Carolina has a winter-peaking system, with the highest electricity demand occurring during nighttime hours when it is coldest. This demand profile necessitates a large buildout of four-hour battery storage and wind because solar does not operate during the periods of the highest electricity demand.

As a result of the large capacity buildout, 79 percent of North Carolina's electricity would be provided by onshore and offshore wind, solar, and battery storage in 2050 (see Figure 2.2).

FIGURE 2.2 NORTH CAROLINA'S ENERGY MIX IN 2050 UNDER THE RENEWABLE SCENARIO

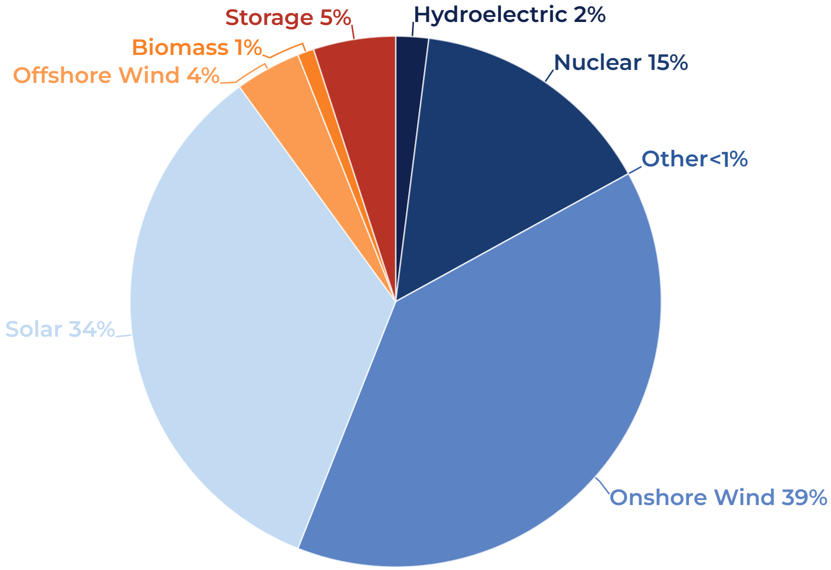


Figure 2.2 Onshore wind would account for 39 percent of electricity generated in North Carolina, solar would account for 34 percent, batteries would supply 5 percent, and offshore wind would supply 4 percent of North Carolina's MWh of electricity in 2050.

Onshore Wind Capacity

Figure 2.3 shows the increase in onshore wind capacity from 2022 through the end of the model run. In 2022, North Carolina had just 208 MW of onshore wind, serving the Dominion Energy system in Virginia, but this total would grow to 88,634 MW of capacity in North Carolina in 2050. For context, this amount is more than twice as much wind capacity as is currently installed in Texas, a state with far more favorable wind resources (see Figure 2.4). It is 426 times more than North Carolina's existing onshore wind capacity.

FIGURE 2.3 INCREASE IN ONSHORE WIND CAPACITY NEEDED UNDER THE RENEWABLE SCENARIO

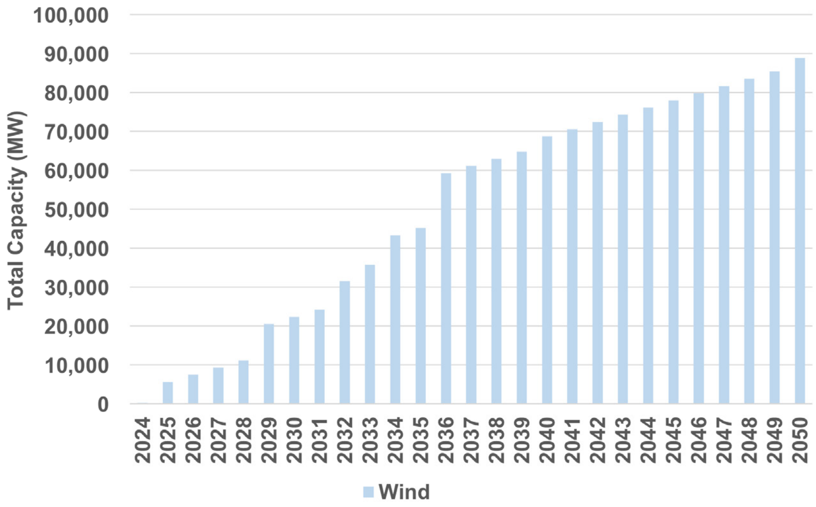


Figure 2.3 From 2022 through 2050, onshore wind capacity would have to grow from 208 MW to 88,634 MW (426 times larger).

FIGURE 2.4 INSTALLED WIND CAPACITY IN NORTH CAROLINA UNDER THE RENEWABLE SCENARIO — COMPARISON WITH TEXAS

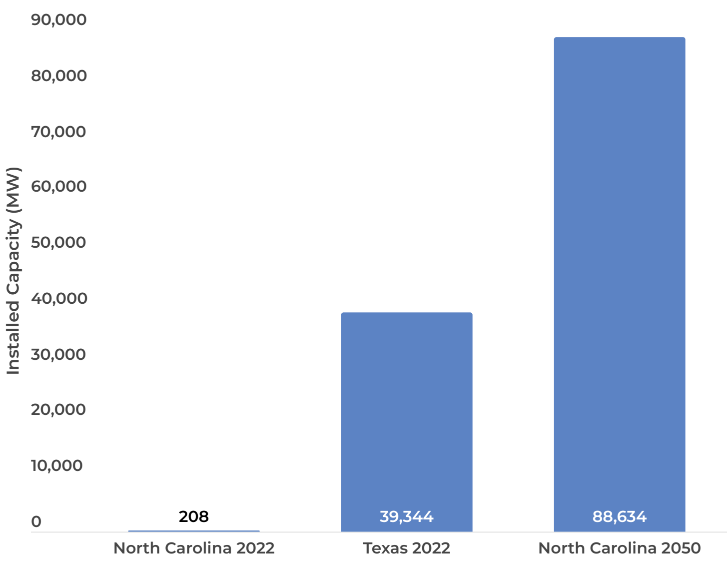
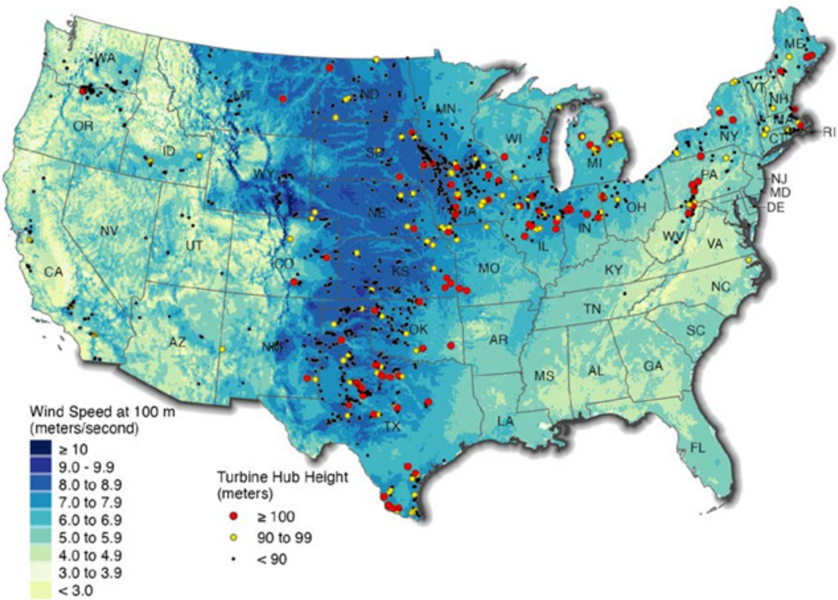


Figure 2.4 (from previous page) Powering North Carolina with a combination of wind, solar, battery storage, and the state's existing nuclear fleet would require a massive buildout of new wind capacity. In fact, North Carolina would require more than double the amount of wind capacity currently installed in Texas.

According the Land-Based Wind Report produced by Lawrence Berkeley National Labs (LBL), the average hub height of land-based wind turbines installed in 2022 was 98 meters, or 321 feet tall.[223] North Carolina, however, has some of the lowest wind speeds in the nation at 100 meters, which will almost certainly necessitate the construction of taller turbines to reach heights with more optimal wind speeds (see Figure 2.5).[224]

FIGURE 2.5 WIND SPEEDS AT 100 METERS IN THE UNITED STATES



Sources: ACP, U.S. Wind Turbine Database, AWS Truepower, Berkeley Lab

Figure 2.5 North Carolina's wind speeds at 100 meters are not suitable for the most common wind turbines installed in the United States in 2022, necessitating larger turbine models.

National Renewable Energy Laboratory (NREL) resources show that North Carolina does have marginally better wind resources at higher hub heights, with the strongest wind resources along the coastline and in portions of the mountains.

Reaching these better wind resources would require taller turbines, ranging in height from 120 meters (393 feet) to 200 meters (656 feet) at the hub of the turbine, which measures the distance from the ground to the top of the tower — not the top of the blades (see Figure 2.6).[225]

FIGURE 2.6 PARTS OF A WIND TURBINE

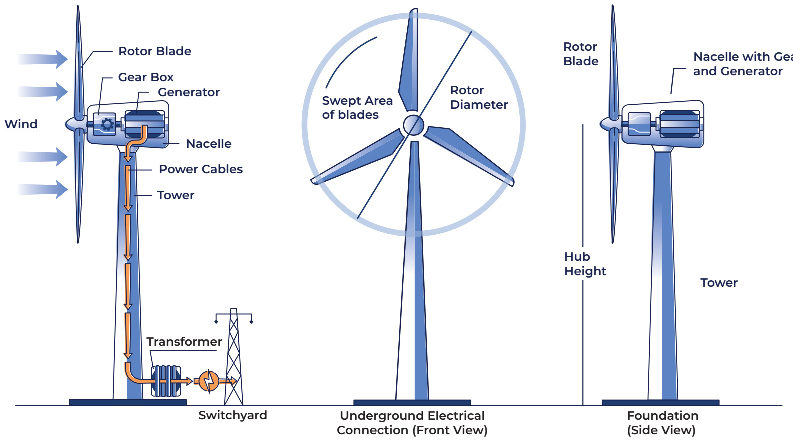


Figure 2.6 The hub is the center of the tower where the blades are attached.

If constructed, these 200-meter wind turbines would be about the same height as Charlotte's Truist Center, the third-tallest building in the state, at its hub. Including the tips of the blades, however, the turbines would measure 935 feet tall, making them the tallest structures in North Carolina.[226] At present, the tallest structure is the Bank of America Corporate Center in Charlotte, which stands at 871 feet tall.[227]

These turbines would likely be sited in the areas with the highest wind speeds, which you can see in the map created by NREL below, which shows wind speeds at 200 meters above surface level (see Figure 2.7).[228]

FIGURE 2.7 WIND SPEEDS IN NORTH AMERICA AT 200 METERS

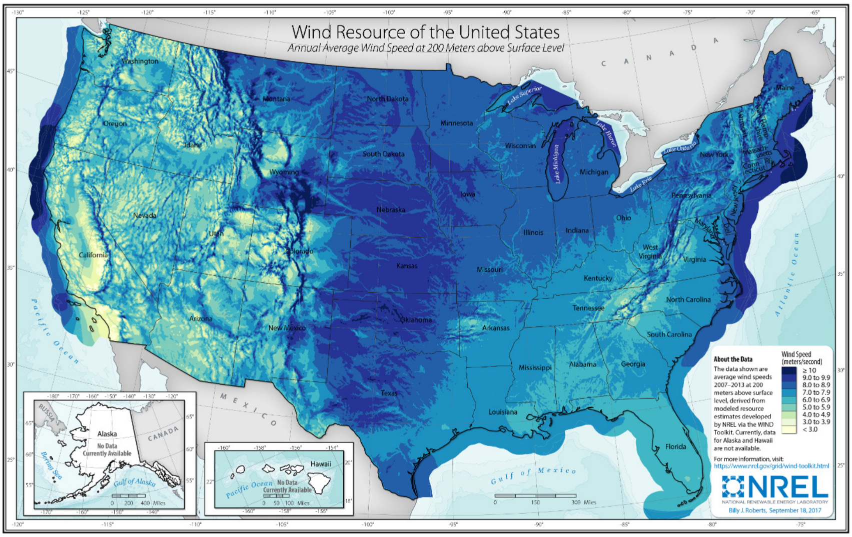


Figure 2.7 Wind speeds are highest in the northeast corner of North Carolina.

In the North Carolina, wind speeds are highest along the coastal regions and in the mountain ranges of Western North Carolina. In these regions, wind speeds could lead to capacity factors of 25 percent to 30 percent or greater.[229]

The Mountain Ridge Protection Act ("Ridge Law") limits the locations in the mountains where companies can build onshore wind. To protect the scenic viewshed of the mountains, the Ridge Law restricts developments on mountain ridges and mountaintops located above 3,000 feet in elevation that are also 500 feet above the adjacent valley floor.

The law also limits construction of buildings by restricting them to be no taller than 40 feet. The Ridge Law applies to 24 counties in the state. Mountain ridges would often be ideal locations for the development of onshore wind, but the likely interpretation of the Ridge Law would make development nearly impossible in the western portion of the state.[230]

Given these geographic and legal limitations, AOER developed wind profiles focused on Eastern North Carolina to be used in our modeling (see Figure 2.8).

FIGURE 2.8 EXISTING AND POTENTIAL AREAS FOR ONSHORE WIND ENERGY FACILITIES IN NORTH CAROLINA

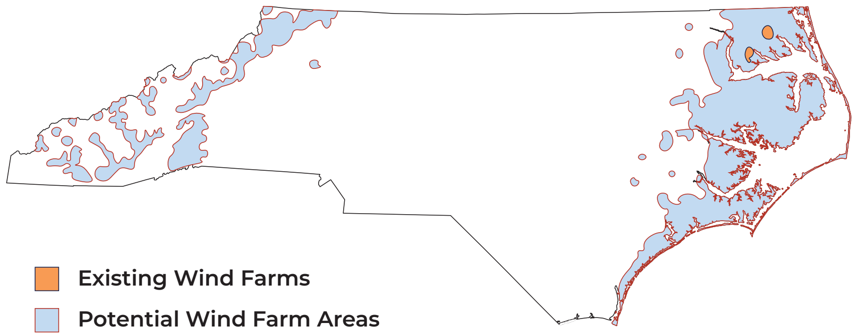


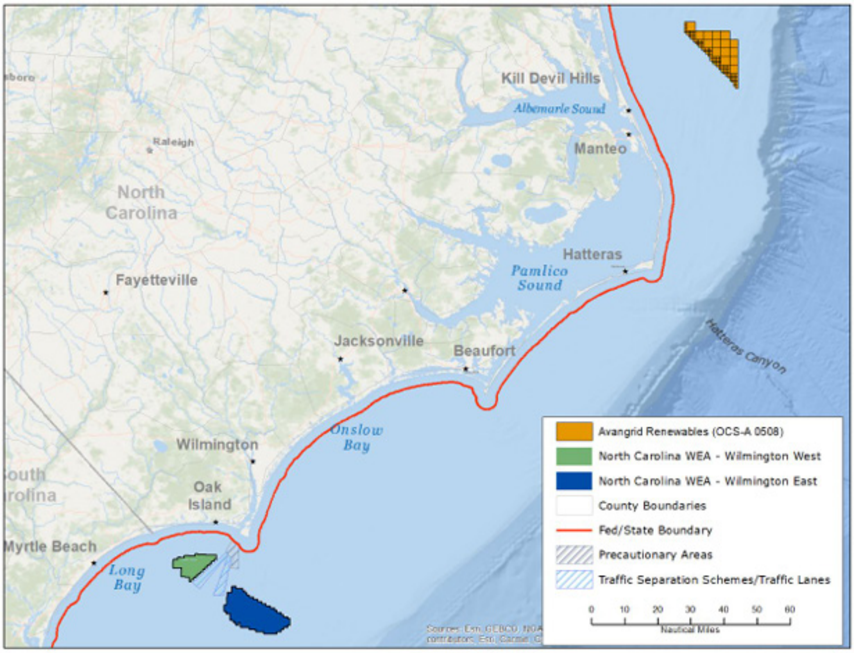
Figure 2.8 Wind development would occur primarily in Eastern North Carolina because the area has the best wind resources in the state that are open to development.

Offshore Wind Capacity

The offshore wind buildouts follow an executive order issued by Gov. Roy Cooper, which called for the 2,800 MW of offshore wind by 2030 and 8,000 MW by 2040.

There are currently two offshore wind projects under consideration: the Kitty Hawk project proposed by Avangrid Renewables, with a rated capacity of up to 3,500 MW, and the Carolina Long Bay project, with a capacity of up to 1,700 MW, which is referenced as Wilmington East and Wilmington West in Figure 2.9 below.[231]

FIGURE 2.9 OFFSHORE WIND ENERGY AREAS UNDER CONSIDERATION OFF THE NORTH CAROLINA COAST



Source: BOEM

Figure 2.9 North Carolina has two locations currently under consideration for offshore wind facilities.

To meet the 8,000 MW of demand in Cooper's executive order, either more turbines will be needed in these leasing areas, or other parts off the North Carolina coast will need to be utilized. Figure 2.10, from NREL, shows wind speeds off the coast of North Carolina that may be suitable hosts for offshore wind developments to achieve the goals of Cooper's executive order.[232]

FIGURE 2.10 WIND SPEEDS OFF THE COAST OF NORTH CAROLINA

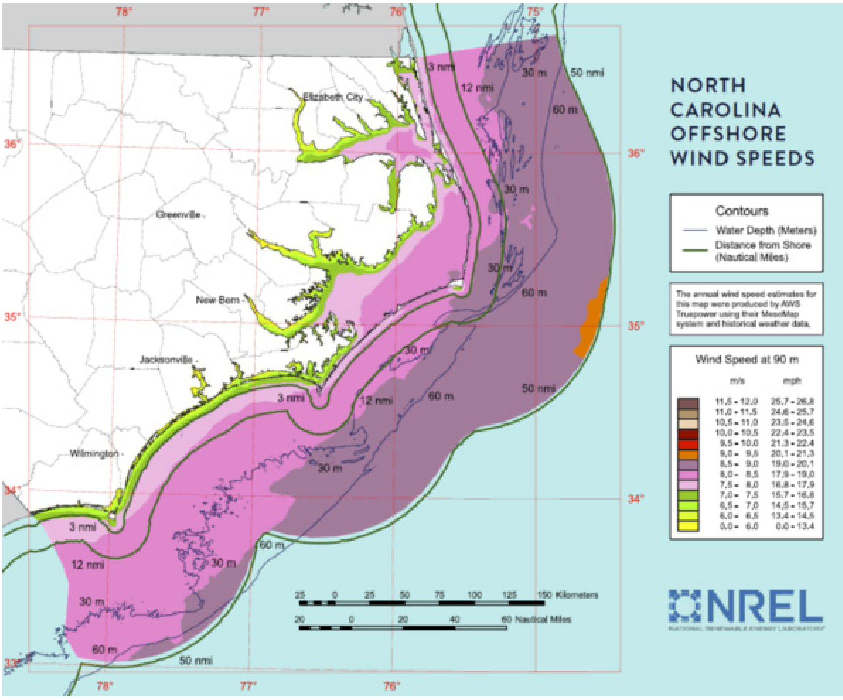


Figure 2.10 Apart from the Kitty Hawk and Carolina Long Bay areas, North Carolina has other areas with wind speeds high enough for potentially hosting offshore wind projects.

SOLAR CAPACITY

In 2022, North Carolina had 6,070 MW of solar capacity, but that number would need to grow to 127,347 MW by 2050. That amount is 1.75 times more solar than was installed in the entire United States in 2022 (see Figure 2.11).

FIGURE 2.11 INSTALLED SOLAR CAPACITY IN NORTH CAROLINA UNDER THE RENEWABLE SCENARIO — COMPARISON WITH THE ENTIRE UNITED STATES

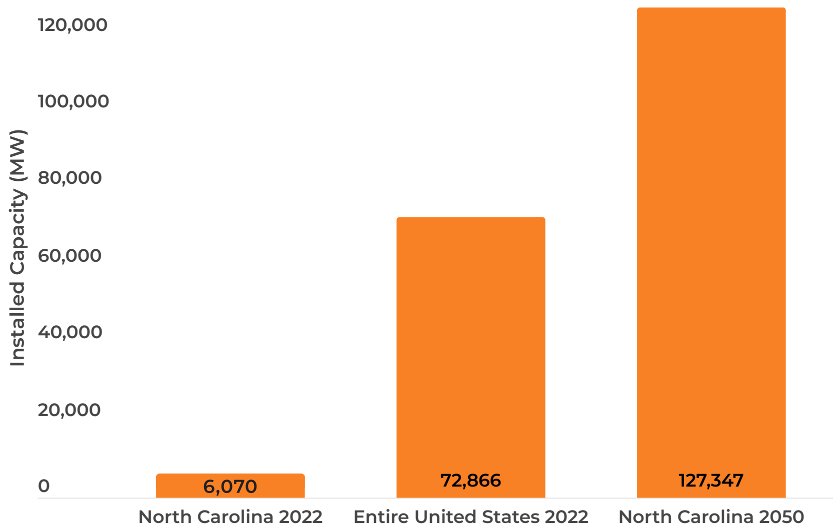


Figure 2.11 North Carolina would require 127,347 MW of solar to meet its electricity demand using primarily solar, wind, battery storage, and existing nuclear and hydroelectric resources. This means North Carolina would require more solar than was installed in the entire U.S. at the end of 2022.

Unlike wind resources, which are highly constrained to the coastal regions of the state, solar resources in North Carolina are more evenly distributed throughout the state, which you can see in the map below (Figure 2.12).

FIGURE 2.12 SOLAR IRRADIANCE ACROSS THE UNITED STATES

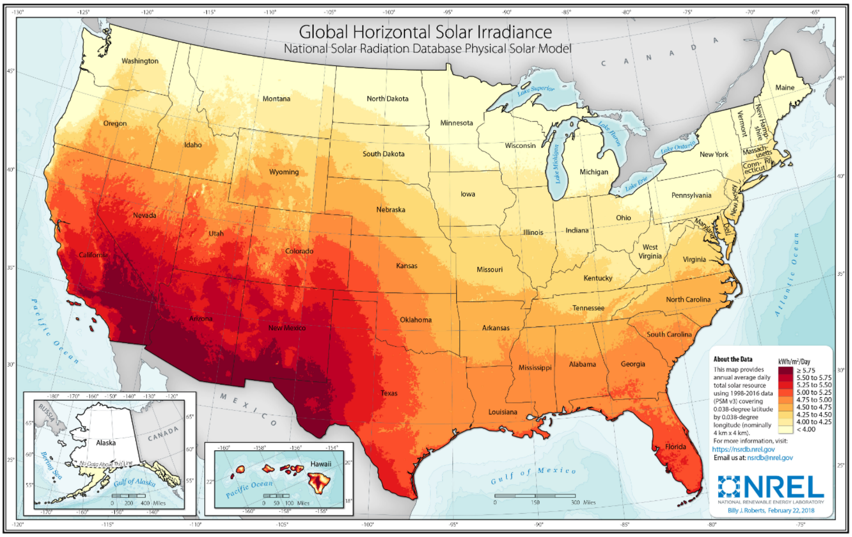


Figure 2.12 North Carolina's solar resources are more evenly distributed than its wind resources, allowing solar to be sited closer to population centers.

This more even distribution of the "fuel" for solar facilities allows for solar facilities to be located closer to major centers of demand than wind facilities, and it also allows solar facilities to be placed near or at retiring coal and natural gas power plants to reuse the existing infrastructure to reduce costs.

Battery Storage Capacity

Powering North Carolina's grid primarily with wind and solar power will require a large increase in the installed battery storage capacity in the state. Our modeling indicated 115,140 MW of four-hour battery storage will be required to maintain reliability during periods of low wind and solar output. That amount is nearly 13 times more than the total battery storage capacity installed in the entire United States in 2022 (see Figure 2.13).

FIGURE 2.13 INSTALLED FOUR-HOUR BATTERY CAPACITY UNDER THE RENEWABLE SCENARIO — COMPARISON WITH THE ENTIRE UNITED STATES

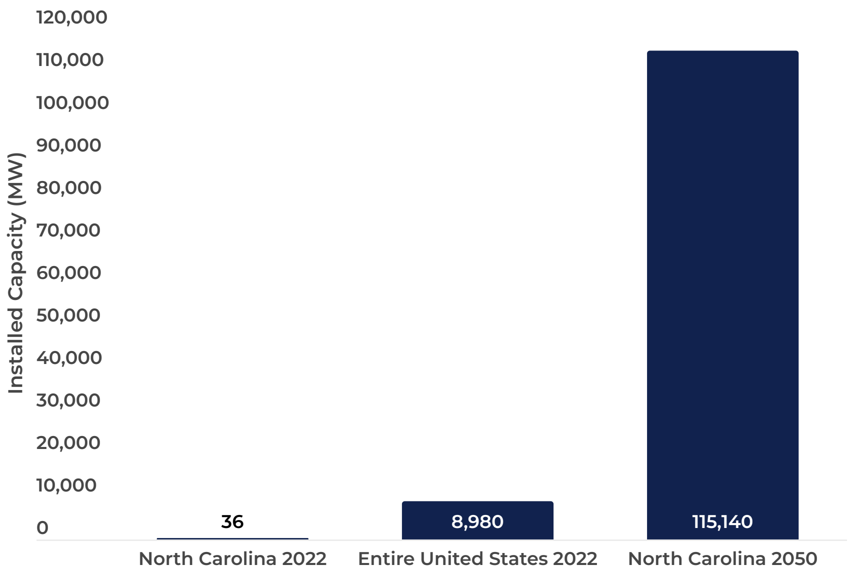


Figure 2.13 This graph shows the amount of four-hour battery storage needed to meet North Carolina's energy needs reliably on a grid consisting of primarily wind, solar, and battery storage resources. For illustrative purposes, it is important to note that this graph assumes all battery storage installed in the U.S. is four hours in duration, even though many storage facilities provide fewer than four hours of duration.

Transmission Lines

The large influx of wind and solar generators would necessitate a build-out of new transmission line capacity.

The "Renewable Electricity Futures Study" published by the NREL shows the amount of transmission required to accommodate more wind and solar increases as they supply ever-greater quantities of electricity. The amount of transmission needed grows exponentially as the wind and solar market share increases beyond 60 percent.[233]

To achieve a grid powered by 80 percent solar and wind in the United States would require the construction of approximately 115 million MW-miles of transmission lines. For context, NREL estimates that there are currently between 150 and 200 million MW-miles of transmission lines in the United States, meaning a grid powered by 80 percent renewable energy would require a 58 to 76 percent increase in transmission infrastructure.[234]

Assuming similar increases in transmission lines would be needed for each state, North Carolina's grid — which would be powered by 79 percent solar, wind, and battery storage, in this scenario — would require the amount of existing transmission lines to increase by 58 to 76 percent to accommodate higher penetrations of intermittent renewable energy.[235] Our analysis used a midpoint of 65 percent to conclude that the state would need to build over 12,500 miles of new transmission lines to accommodate the influx in intermittent power generation (see Table 2.2).

TABLE 2.2 NEW TRANSMISSION LINES NEEDED UNDER THE RENEWABLE SCENARIO

Line Type	Residential/ Rural Power Lines	State Level Transmission	Interstate Transmission Wires
Voltage (KV)	44–69	100–230	500+
Voltage Class	Low–Medium	High	Ultra-High
Duke Energy Carolinas	2,873	9,508	576
Duke Energy Progress	12	5,998	292
Total Lines (Miles)	2,885	15,506	868
Percent Increase Needed	65%	65%	65%
Additional Lines Needed (Miles)	1,875	10,079	564

Table 2.2 More than 12,500 miles of new transmission lines would be needed to accommodate the buildout of wind and solar generators in North Carolina.

Land Use

Wind and solar power plants are frequently touted as zero-emissions sources of electricity that can reduce or obviate coal- and natural gas–fired electricity. But wind and solar farms are not completely resource-free. Wind and solar need huge tracts of land to produce electrons for the grid. It might be technically possible for North Carolina to achieve complete decarbonization using wind and solar power with battery backups, but doing so would use vast quantities of land.

Wind farms and solar arrays have the highest land-use requirements of all electric power sources. Whereas a nuclear power plant uses only a third of an acre per megawatt of nameplate capacity (acres/MW), onshore wind and solar power stations require 208 and 19 times as much land, respectively (Table 2.3). An onshore wind farm will use 71.28 acres/MW of nameplate capacity; a solar array will require 6.58 acres/MW (Table 2.3).

TABLE 2.3 LAND REQUIREMENTS OF DIFFERENT ENERGY RESOURCES[236]

Resource	Onshore Wind	Offshore Wind	Solar	Natural Gas Combustion Turbine	Natural Gas Combined Cycle	Coal	Nuclear
Name	All Utility Wind	All Pending Projects	All Utility Solar	Lincoln Combustion Turbine Station	Asheville Combined Cycle Station	Belews Creek Steam Station[237]	McGuire Nuclear Station
MW	397	3,529	5,786	402	560	2,200	2,316
Acres	28,300	193,524	38,081	746	700	1,050	800
Acres/MW	71.28	54.84	6.58	1.86	1.25	0.48	0.35

Table 2.3 Wind and solar require far more land than coal, natural gas, or nuclear power plants. Figures for Belews Creek include coal ash ponds.

FIGURE 2.14 LAND REQUIREMENTS OF DIFFERENT ENERGY RESOURCES (ACRES PER MW)

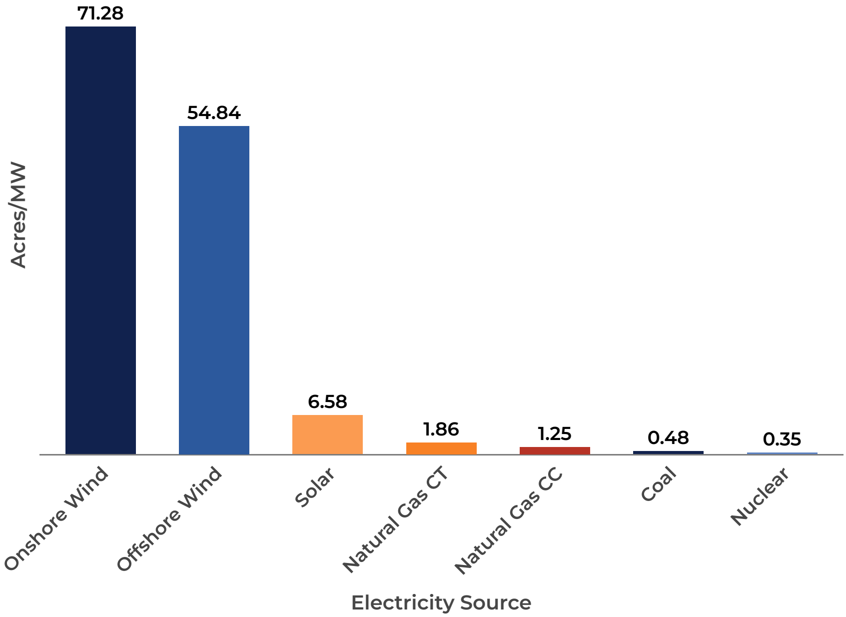


Figure 2.14 Wind and solar require huge tracts of land for each megawatt of installed capacity compared with thermal resources. This calculation uses the entire area of a wind farm, not the amount directly used by the turbines.

Wind and solar power plants also fail to utilize the land they are sited on as efficiently as other electricity sources. To produce 1,000 MW of power, wind projects require 272,576 acres of land, which translates into less than 0.004 MW/acre, whereas land used by nuclear and coal plants will produce 1.5 MW/acre. Land used for nuclear and coal power plants is 425.9 times as efficient at producing energy than land used for wind turbines. Table 2.4 and Figure 2.15 present a detailed breakdown of each primary power source's land-use efficiency.

TABLE 2.4 HOW MUCH LAND DIFFERENT GENERATING SOURCES NEED TO GENERATE 1,000 MW[238]

	MW Nameplate Capacity	Acres Used	MW/Acre
Coal	1,000	640	1.5625
Nuclear	1,000	640	1.5625
Natural Gas	1,000	1,152	0.8681
Solar	1,000	34,688	0.0288
Offshore Wind	1,000	54,839	0.0182
Onshore Wind	1,000	272,576	0.0037

Table 2.4 Wind and solar produce less than 1 MW per acre of land. This calculation uses data obtained from John Locke Foundation's 2024–25 "North Carolina Policy Solutions" report.

FIGURE 2.15 HOW MUCH POWER (MW) DIFFERENT GENERATING SOURCES CAN PRODUCE PER ACRE[239]

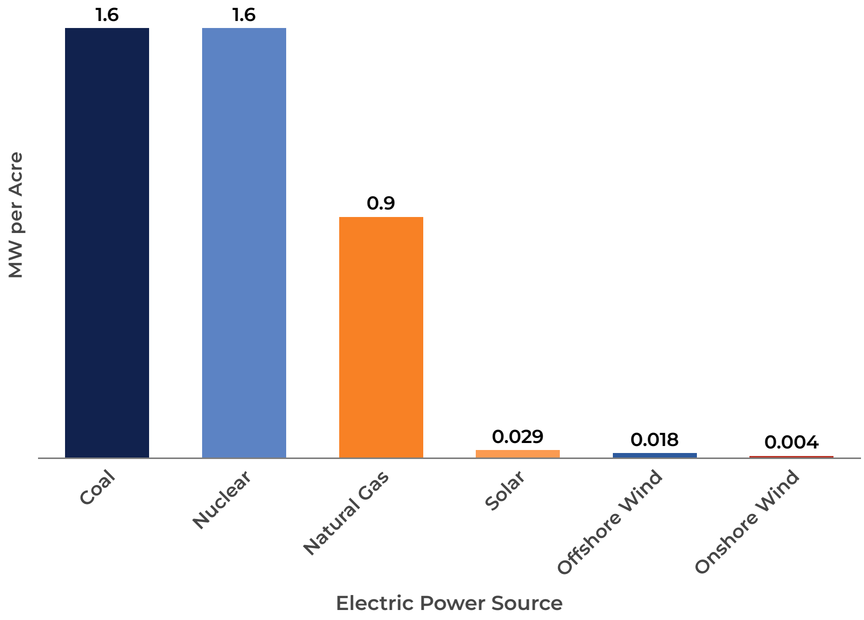


Figure 2.15 (from previous page) Shows how effective different electricity generating resources are at utilizing land. It compares how many MW per acre each source can produce. The data used for Figure 2.15 came from the John Locke Foundation's 2024–25 "North Carolina Policy Solutions" report, which reflects the amount of land needed to produce 1,000 MW of power.

Eliminating coal and natural gas, two of the most energy-dense fuel sources, from North Carolina's energy mix and replacing them with wind and solar power will require millions of acres of land to be set aside for renewable energy projects.

Estimating Land Required to Achieve a Grid Free of Coal and Natural Gas

North Carolina will need to expand existing wind and solar capacity by 88,643 MW and 127,347 MW, respectively. Using data from North Carolina's existing wind and solar generation fleet, we estimated the land required to achieve the modeled decarbonization scenario.

Wind

Desert Wind, North Carolina's first utility-scale wind farm, was built between Elizabeth City and Hertford. Desert Wind began operating in 2017. Timbermill will be North Carolina's second wind farm (Table 2.5). It is located west of Hertford and is expected to begin sending power to the grid by year's end in 2024. Both Desert Wind and Timbermill are situated in North Carolina's Northeastern Coastal Plain. Despite having different tower heights (Figure 2.16 and Figure 2.17), both wind farms will harness the kinetic energy contained in the Coastal Plain's wind channels, which have an average windspeed of 7.0 to 7.9 meters per second (mps).

A higher tower height, coupled with improved generators, will allow Timbermill to utilize land more efficiently than Desert Wind. Desert Wind's 104 turbines are only 93 meters tall (305 feet) with generators with a nameplate capacity of 208 MW. In the seven years since Desert

Wind's completion, turbine technology and design have substantially improved the efficiency of wind turbine systems. Timbermill will be able to achieve a nameplate capacity of 189 MW using half as many turbines, which will decrease total acreage needed for the project by 68 percent.

TABLE 2.5 CHARACTERISTICS OF NORTH CAROLINA'S WIND FARMS[240]

	Desert Wind	Timbermill
Year Operational	2017	2024
Capacity (MW)	208	189
Number of Turbines	104	45
MW per Turbine	2.0	4.2
Acres Displaced by Turbines	200	91
MW/Acre	1	2.1
Area Covered (Acres)	22,000	6,300
Turbine Type	2.0 MW Gamesa G114	Vestas V150 — 4.2 MW
Hub Height (Meters)	93	166
Total Height (Meters)	164	197

Table 2.5 contains a detailed breakdown of Desert Wind and Timbermill's design specifications. Area displaced by turbines refers to the direct land use of a wind facility, which consists of the concrete base of the turbine, and the area covered by turbines refers to the total area that is developed, which includes the blade lengths and project roads.

Nevertheless, assuming North Carolina's future acreage displaced by turbines matches Timbermill's, the 88,643 MW of new wind capacity will require over 42,679 acres of land. And that's just the land occupied by the physical turbines. The visual footprint of the turbines will be considerably larger. If new turbines are spaced similarly to Timbermill's, then wind turbines will sprawl over 3.2 million acres. This area is roughly equal to 5,000 square miles, or a quarter of the land area comprising North Carolina's scenic Coastal Plain.[241]

Because North Carolina's best wind channels are located in the Coastal Plain and Great Smoky Mountains (see Figure 2.17), local opposition to view-spoiling wind turbines will likely be a major impediment to future wind development.

Local opposition has always been a strong force in utility-scale wind projects. In June 1975, the Acting Chief of the Energy Research and Development Administration's Wind Energy Conversion Branch, Louis Divone, observed that the only constraint on the number of wind systems was the public's tolerance for wind turbine sprawl:

> "If we put up one machine, I am sure it is going to be a tourist attraction … but I suspect if we put 100 of them down Skyline Drive, here in Virginia, there is going to be a very serious concern …. [T]he upper limit of how many [turbines that can be built] … is going to be a question of what is acceptable to the public."[242]

Many North Carolinians will likely decry spreading turbines over their state's picturesque geographies and their fragile environments.

FIGURE 2.16 AVERAGE ANNUAL WIND SPEEDS IN THE UNITED STATES AT 100 METERS[243]

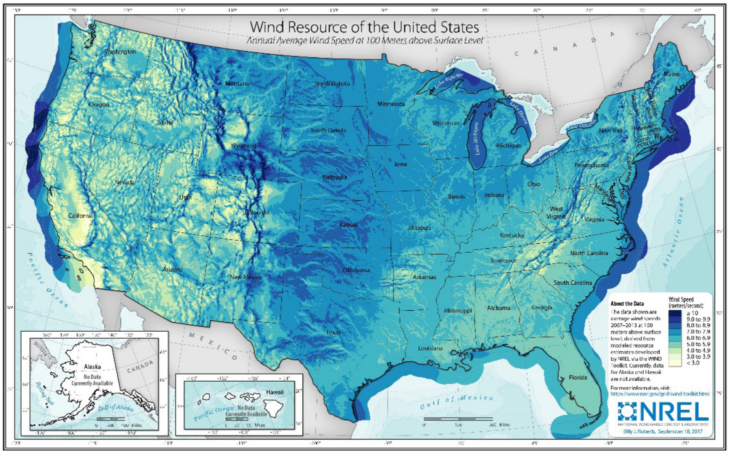


Figure 2.16 shows average annual windspeeds available at 100 meters. Desert Wind's hub height of 93 meters taps into wind channels with an average annual windspeed of between 7.0 and 7.9 meters per second (mps).

FIGURE 2.17 AVERAGE ANNUAL WIND SPEEDS IN THE UNITED STATES AT 160 METERS [244]

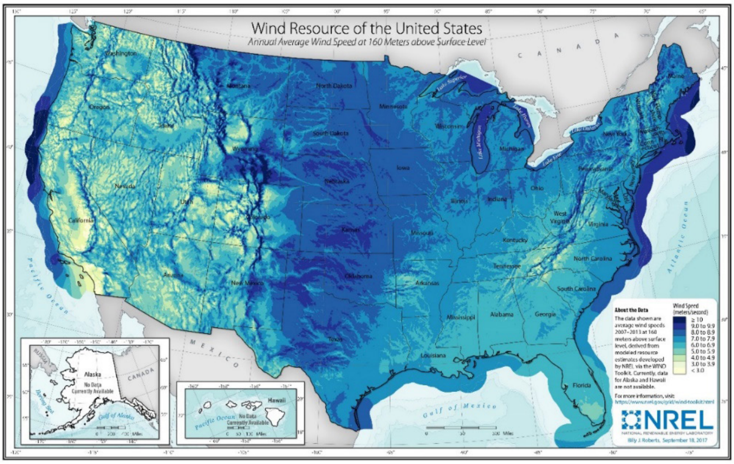


Figure 2.17 shows average annual windspeeds available at 160 meters. The Timbermill Wind project's hub height of 166 meters will tap into wind channels with an average annual windspeed of between 7.0 and 7.9 mps.

FIGURE 2.18 LAND FOOTPRINT OF THE TIMBERMILL WIND PROJECT[245]

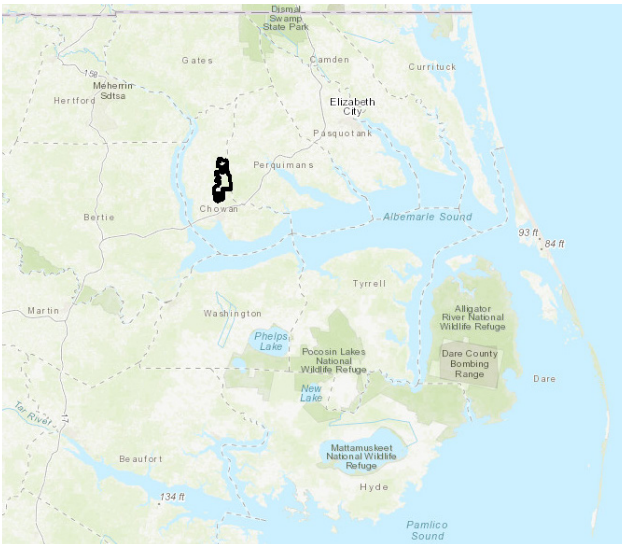


Figure 2.18 shows the Timbermill Wind project's projected 6,300-acre footprint on North Carolina's Northeastern Coastal Plains.[246]

Solar

In 2022, North Carolina's 703 utility-scale solar systems had a combined nameplate capacity of 5,786 MW — earlier figures of 6,069 MW also include rooftop and residential solar — and utilized 38,081 acres of land.[247] Each megawatt of solar power required 6.58 acres of land. Each acre of land used for solar power in North Carolina resulted in only 0.15 MW/acre of nameplate capacity. Installing 127,347 MW of new solar capacity in North Carolina will require 848,980 acres of land — which is nearly 7 percent of North Carolina's arable land.[248]

Most of these new solar farms will likely be placed on existing farmland. Of the 38,081 acres currently used for utility-scale solar projects, over 80 percent are classified as farmland.[249] If siting solar panels on farmland continues at trend, then 679,184 acres of farmland will be covered with solar panels by 2050.

Proponents of rural land for solar use argue that farmland can easily be restored to agricultural conditions. Nevertheless, grading agricultural land for solar development can negatively impact soil drainage and health.[250] Rectifying this damage can take years or decades.

Offshore Wind

Gov. Cooper's Executive Order 218 set an offshore wind development target by 2030 of 2,800 MW.[251] North Carolina's two offshore wind projects, due to be completed by 2030, will hit that target.

Avangrid's Kitty Hawk Wind Project will build 190 offshore wind turbines with a projected 3,500 MW of capacity 27 to 36 miles off the coast of southern Virginia and northern North Carolina.[252] North Carolina's portion of the project, Kitty Hawk South, will contain 121 wind turbines spread over 83,433 acres.[253] North Carolina's share of the power generation is estimated to be 2,229 MW.[254] These offshore wind turbines will provide only 0.027 MW of electricity per acre (see Table 2.6).

TotalEnergies and Duke Energy intend to develop the Carolina Long Bay project. They will build 1,300 MW of offshore wind generation capacity across 110,091 acres of land. Each MW of capacity at Carolina Long Bay requires 84.7 acres.

TABLE 2.6 INDIRECT LAND REQUIREMENTS OF NORTH CAROLINA'S OFFSHORE WIND PROJECTS[255]

	Capacity (MW)	Acres	Acres/MW	MW/Acre
Kitty Hawk South	2,229	83,433	37.4	0.027
Carolina Long Bay	1,300	110,091	84.7	0.012

Table 2.6 shows the indirect land-use requirements for the Kitty Hawk South and Carolina Long Bay offshore wind projects.

Compared to onshore wind's 72.8 acre/MW requirements, offshore wind's lower acreage requirements (58.8 acres/MW) may push some of the needed 88,643 MW of wind capacity out to sea.

Summary

The finite nature of land as a resource begs its husbandry. North Carolina has only so much land it can devote to single-family housing, agriculture, industry, technological development, and energy production. Each one of these competing land uses contributes to economic growth in North Carolina. Ergo, it is paramount that North Carolina's land is used as effectively as possible.

Renewable power's large land requirements and low energy production per acre make it an inefficient use of land in most cases. Furthermore, land used for renewable power generation will not be available for competitive development for 20 to 40 years. More importantly, agricultural land used for solar projects may not be able to be restored to agricultural use at the end of the lease.[256]

Eliminating coal and natural gas from North Carolina's grid will require wind turbines to be placed in North Carolina's fragile coastal environment and solar panels to be installed on Piedmont farmland.

NUCLEAR SCENARIO:

ENERGY INFRASTRUCTURE REQUIRED FOR A CARBON-NEUTRAL GRID

The introduction to the Renewable Scenario explained that how utilities choose to reconcile North Carolina's decarbonization requirements set forth in HB 951 with the state's energy needs will ultimately determine the prices consumers will pay for energy, set the limits for North Carolina's economic growth and development, and influence the amount of infrastructure needed to serve electricity customers reliably.

In this assessment, Always On Energy Research (AOER) has modeled the amount of power plant capacity and associated energy infrastructure needed to meet the requirements of HB 951 using new and existing nuclear and hydroelectric power plants, building upon the recent passage of the federal Advance Act legislation that received broad bipartisan support to bolster nuclear power plant construction in the United States.[257]

This resource mix utilizes the built-in flexibility in HB 951 that allows existing coal and natural gas plants to remain online as needed to ensure reliability and keep electricity prices low as new nuclear power plants are constructed to replace them.

We have determined that this resource portfolio would produce far more electricity with far less energy infrastructure. As a result, it would require fewer new power plants and transmission infrastructure, and it would consume much less land than the all-renewable scenario.

Installed Capacity

Nuclear power plants are highly reliable and productive. For example, in 2022, North Carolina nuclear plants ran at a 94.5 percent capacity factor, which means their electricity production neared their theoretical maximum of 100 percent output. In contrast, solar panels and wind turbines in the state operated at just 21.5 percent and 29.5 percent, respectively.[258]

The high reliability and productivity of nuclear plants means North Carolina will need far less installed capacity to meet its future energy demands with nuclear than if it attempts to do so using a combination of onshore wind, offshore wind, solar panels, and battery storage. Those resources require a great deal of overbuilding capacity to make up for their very low capacity factors.

Figure 3.1 shows the change in electric generating capacity from 2022 through 2050. Coal and natural gas power plants are gradually phased out and replaced with new nuclear power plants. These new nuclear power plants consist of large, APR-1400 power plants and small modular reactors (SMRs). The APR-1400 is a reactor model with a capacity of 1,400 megawatts and a history of being built in a short amount of time relative to the AP-1000 nuclear plants built in Georgia.[259]

In this scenario, North Carolina's existing wind and solar resources are kept online, but no new intermittent resources are added over the model run.

FIGURE 3.1 NORTH CAROLINA'S ANNUAL CAPACITY MIX UNDER THE NUCLEAR SCENARIO

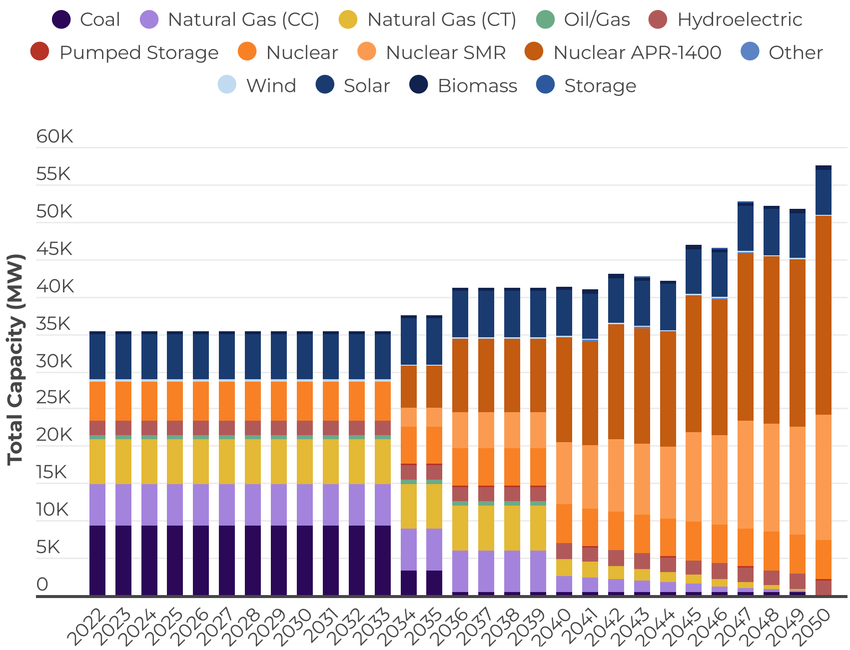


Figure 3.1 The amount of installed capacity on the North Carolina grid would grow from 35,391 MW in 2022 to 57,448 MW in 2050 in this scenario.

To meet the requirements of HB 951, North Carolina will need to expand its installed nuclear power plant capacity significantly, growing from 5,150 MW in 2022 to 48,550 MW, representing a 9.4-fold increase in nuclear power (Table 3.1).

TABLE 3.1 NORTH CAROLINA'S ENERGY NEEDS UNDER THE NUCLEAR SCENARIO

	Capacity 2022	Capacity 2050
Existing Nuclear	5,149.6	5,149.6
APR-1400	0.0	26,600.0
SMR	0.0	16,800.0

Table 3.1 (from previous page) The closure of the state's coal- and natural gas–fired power plants would necessitate 43,400 MW of new nuclear capacity.

In total, the closure of reliable coal and natural gas power plants will necessitate a 22,057-MW increase in the total electricity generation capacity installed on the North Carolina grid (an increase of 62 percent) to meet the projections for rising electricity demand in the Duke Energy Carolinas Resource Plan.[260]

This is a stark contrast to the amount of installed capacity in the Renewable Scenario, where the total installed capacity must reach 353,170 MW, requiring a nearly tenfold increase in total capacity to produce the same amount of electricity reliably (see Figure 3.2).

FIGURE 3.2 NORTH CAROLINA ENERGY INFRASTRUCTURE: RENEWABLE SCENARIO VS. NUCLEAR SCENARIO

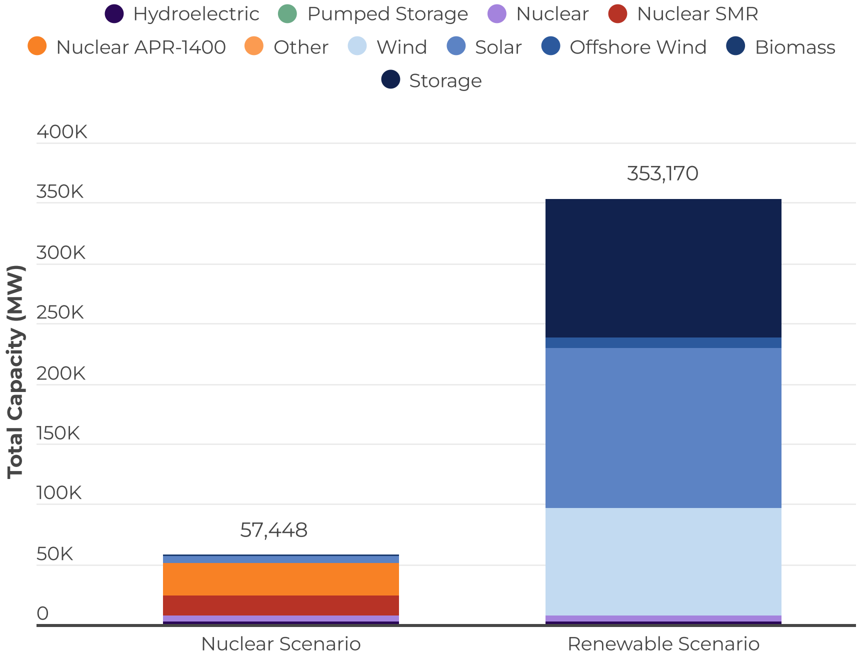


Figure 3.2 The Renewable Scenario would require six times more installed capacity to meet future electricity demand than the Nuclear Scenario.

Onshore Wind Capacity

Unlike the Renewable Scenario, which requires 88,634 MW of onshore wind capacity, the Nuclear Scenario has only the 208 MW of onshore wind capacity currently installed in the state and repowers the facility after it has reached the end of its 20-year lifespan.

Offshore Wind Capacity

In the Nuclear Scenario, no offshore wind is constructed because it is not needed due to the high reliability of nuclear power plants.

Solar Capacity

In 2022, North Carolina had 6,070 MW of solar capacity. This solar capacity remains on the North Carolina system in the Nuclear Scenario, but no new solar installations are constructed because solar does not serve to meet peak demand in North Carolina's winter-peaking system.

Battery Storage Capacity

North Carolina currently has 36 MW of battery storage capacity. In the Nuclear Scenario, no further battery storage is needed because SMRs are able to increase or decrease their output rapidly, allowing them to act as peaking plants on the system.

Energy Mix

Under the Nuclear Scenario, existing nuclear plants would produce 13 percent of the electricity generated in the state, SMRs would provide five percent, APR-1400s 75 percent, existing solar 4 percent, and hydroelectric would serve 2 percent of North Carolina's electricity needs.

FIGURE 3.3 NORTH CAROLINA'S ENERGY MIX IN 2050 UNDER THE NUCLEAR SCENARIO

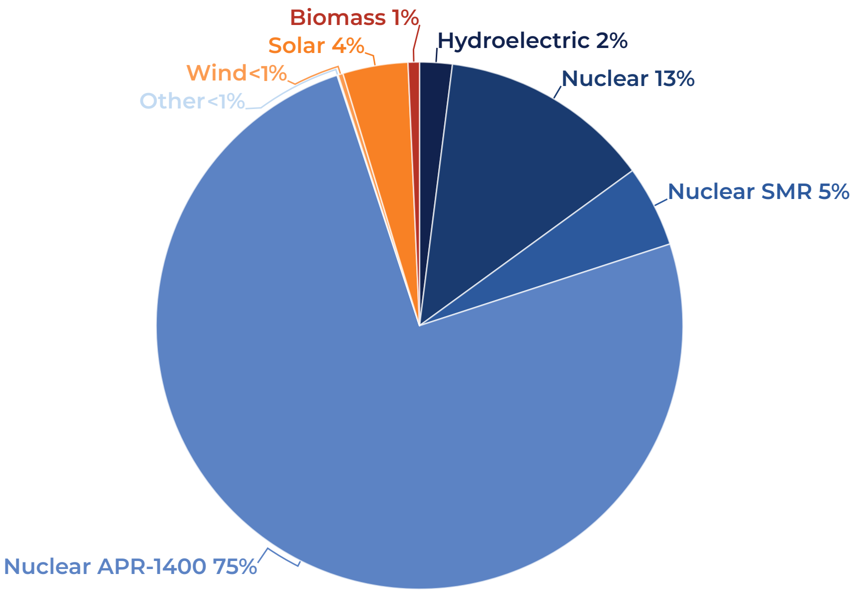


Figure 3.3 Nuclear plants would serve 93 percent of North Carolina's electricity demand in 2050.

Transmission Lines

A large influx of wind and solar generators, as seen in the Renewable Scenario, would necessitate a massive buildout of new transmission line capacity, but because nuclear power plants are dispatchable, there is no need to overbuild the system with hundreds of thousands of MW of wind, solar, and battery storage facilities, greatly reducing the need for new transmission lines.

The most economical way to deploy new nuclear power plants would be to reuse the existing coal and natural gas sites to utilize as much of the existing transmission infrastructure as possible and build new transmission lines to connect new nuclear plants above the current coal and natural gas capacity on North Carolina's grid.

As of 2022, North Carolina had 21,324.6 MW of coal, natural gas, and oil-fired power plants on its system.[261] Additionally, existing nuclear sites in North Carolina have already been proposed as sites for new reactors; e.g., Duke Energy had previously proposed to build two additional 1,100 MW units at the Shearon Harris nuclear plant.[262]

Assuming solar facilities reuse the existing coal and natural gas transmission infrastructure in the Renewable Scenario, that scenario adds an incremental 331,857 MW of capacity to the North Carolina grid in need of new transmission infrastructure. So much new capacity in need of new transmission infrastructure will necessitate a roughly 65 percent increase in the installed transmission line capacity on the grid.

After reusing existing transmission infrastructure at the 21,324.6 MW of coal and natural gas power plants, the Nuclear Scenario adds only 22,057 MW of incremental capacity to meet future electricity demand, meaning it adds only 7 percent of the incremental capacity installed in the Renewable Scenario (Table 3.2). Based on this ratio, we estimate the Nuclear Scenario requires only an additional 1,348 miles of transmission infrastructure — a mere fraction of the more than 12,500 miles needed for the Renewable Scenario.

TABLE 3.2 NEW TRANSMISSION LINES NEEDED UNDER THE NUCLEAR SCENARIO

Line Type	Residential/ Rural Power Lines	State-Level Transmission	Interstate Transmission Wires
Voltage (KV)	44–69	100–230	500+
Voltage Class	Low–Medium	High	Ultra-High
Duke Energy Carolinas	2,873	9,508	576
Duke Energy Progress	12	5,998	292
Total Lines (Miles)	2,885	15,506	868

Line Type	Residential/ Rural Power Lines	State-Level Transmission	Interstate Transmission Wires
Percent Increase Needed	7%	7%	7%
Additional Lines Needed (Miles)	202	1,085	60.76

Reusing existing transmission infrastructure in the Nuclear Scenario has several key advantages because the need for substations, transformers, and transmission line upgrades would be a manageable task, with 230-kilovolt (kV) lines being among the most common voltages for transmission lines carrying electricity from North Carolina power plants to the population centers that consume it (see Figure 3.4).[263]

FIGURE 3.4 POWER LINES FROM THE BRUNSWICK NUCLEAR POWER PLANT

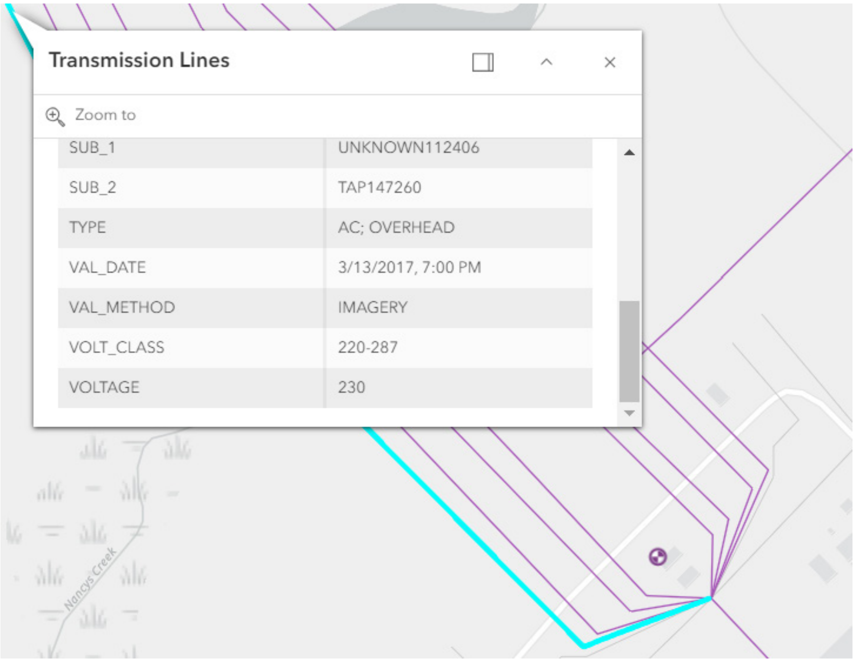


Figure 3.4 The power lines leading from the Brunswick nuclear plant consist of nine 230-kilovolt lines.

Building new nuclear plants at existing sites is also advantageous because the Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) systems are not interconnected. Thus, building new nuclear power plants at the sites of existing coal, natural gas, and nuclear plants within each system reduces the need for expensive transmission buildouts to connect them. As discussed in the first part of this report, Duke Energy has explained that there is "no available import capability" between DEC and DEP with respect to retiring the Roxboro and Mayo coal plants, so "if the Roxboro/Mayo replacement generation is located in DEC and requires import into DEP, then additional, more costly and time-consuming upgrades would be required."[264]

Per the Carbon Plan's decarbonization mandates, every coal- and natural gas–fired power plant will need to be retired and replaced with new generation by 2050. Nuclear power's reliability, minimal land use, and zero-emissions, continously produced power make it the most viable candidate for replacing baseload generation from coal and natural gas with like-in-kind power. While capital costs have always been a hurdle for nuclear plants, siting new nuclear plants on the facilities of the retired coal- and natural gas–fired power plants will reduce costs and help maintain reliability in North Carolina's largely separate service territories.

The cost savings of recycling old infrastructure have not been lost on Duke Energy. Duke Energy is already considering replacing the Belews Creek coal plant with a small modular reactor of 600 MW of capacity.[265]

If every coal and natural gas power plant were replaced like Belews Creek, then North Carolina would be able to recycle transportation infrastructure capable of taking 21,342.6 MW of power. Nevertheless, doing so would provide only 49 percent of the total nuclear power needed to decarbonize North Carolina's electricity sector. An additional 22,057 MW of nuclear power would still be needed to reach homes and businesses.

FIGURE 3.5 LOCATIONS OF COAL, NATURAL GAS, AND NUCLEAR POWER PLANTS IN NORTH CAROLINA[266]

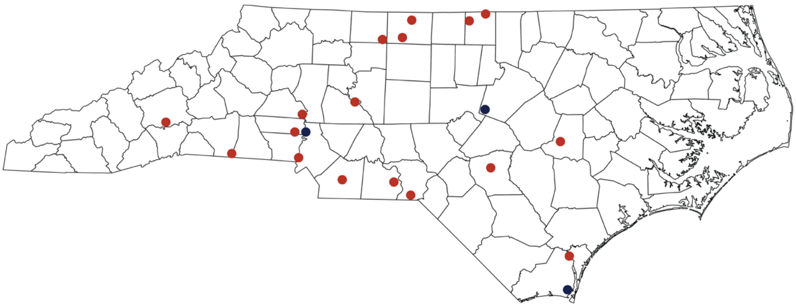


Figure 3.5 This map shows the locations of existing coal, natural gas, and nuclear plants in North Carolina. Nuclear power plants are shown in blue, and coal and natural gas plants are shown in red.

Much of this additional power could be sited alongside North Carolina's existing nuclear power plants. The Harris and McGuire nuclear power plants are located in the heart of North Carolina's Research Triangle and the city of Charlotte, respectively. Following the prudent business advice of "build where you sell," adding reactors at McGuire and Harris would increase the amount of clean power available to the households, data centers, and manufacturers. Adding more reactors at the Harris and McGuire nuclear plants could provide sustantial baseload generation while minimizing transmission upgrades and concomitant passthrough costs accrued to ratepayers.

While large-scale nuclear makes sense for large cities, small modular reactors will play a role in decarbonizing rural and Western North Carolina. By 2050, North Carolina will need 16,800 MW of SMR generation. These plants' small generation capacities make them ideal for replacing Western North Carolina's small coal and natural gas power plants.

Building reliable nuclear power plants results in a large reduction in the additional transmission infrastructure needed to power North Carolina's future electric grid. This strategy allows power plants to be built in the areas that need the power, given that nuclear power plants, unlike wind and solar facilities, are not geographically constrained to areas where they are more consistent.

Land Use

As noted above in discussing the Renewable Scenario, nuclear power plants use far less land than wind and solar facilities do. Figure 2.14 shows that North Carolina's McGuire Nuclear Station uses just 0.35 acres per megawatt (acres/MW) of installed capacity. Conversely, onshore wind requires 71.28 acres/MW, and solar needs 6.58 acres/MW.

The high power density of nuclear power means the Nuclear Scenario will use just a fraction of the land consumed in the Renewable Scenario. Figure 3.6 shows that the Nuclear Scenario would require 15,190 additional acres of land for the new reactors, but this land use requirement could be reduced to 7,720 acres if new nuclear plants reuse existing coal and natural gas power plant sites.

In contrast, the Renewable Scenario requires 7.7 million acres of land, including the indirect land use of wind facilities. It means the Renewable Scenario requires 509 times more land than the Nuclear Scenario.

FIGURE 3.6 LAND USE IN NORTH CAROLINA, RENEWABLE SCENARIO VS. NUCLEAR SCENARIO

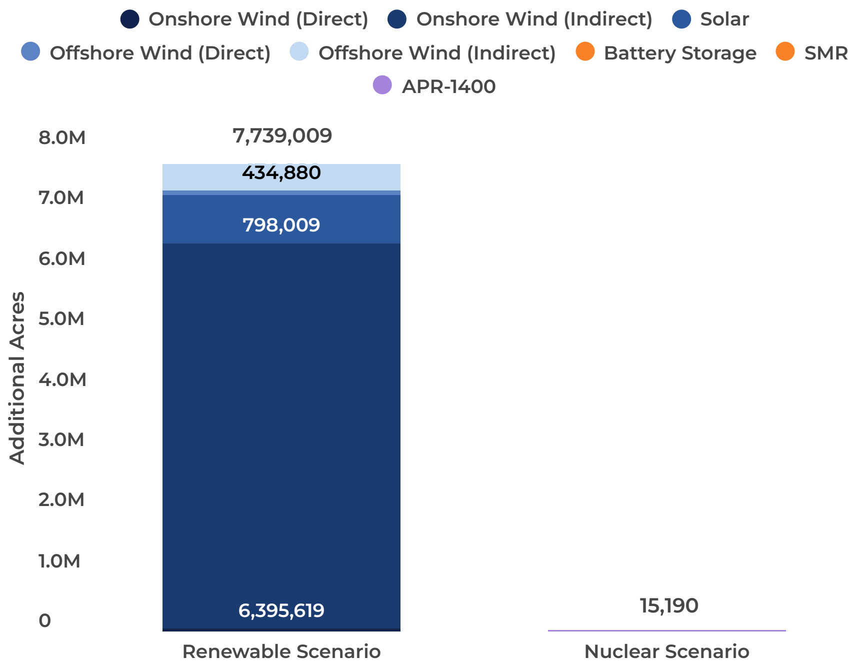


Figure 3.6 The Nuclear Scenario requires an additional 15,190 acres of land, 7,470 acres of which could be mitigated by building nuclear plants at existing coal and natural gas power plant sites. On the other hand, the Renewable Scenario requires an additional 7.7 million acres of land.

For better context, the additional 15,190 acres needed to build new nuclear power plants is less than half of the land that is currently being used to host North Carolina's existing solar capacity of 6,069 MW, which has already consumed 39,938 acres (see Figure 3.7).

FIGURE 3.7 COMPARING THE ACREAGE REQUIRED BY NORTH CAROLINA'S EXISTING SOLAR FACILITIES VS. NEW NUCLEAR POWER PLANTS UNDER THE NUCLEAR SCENARIO

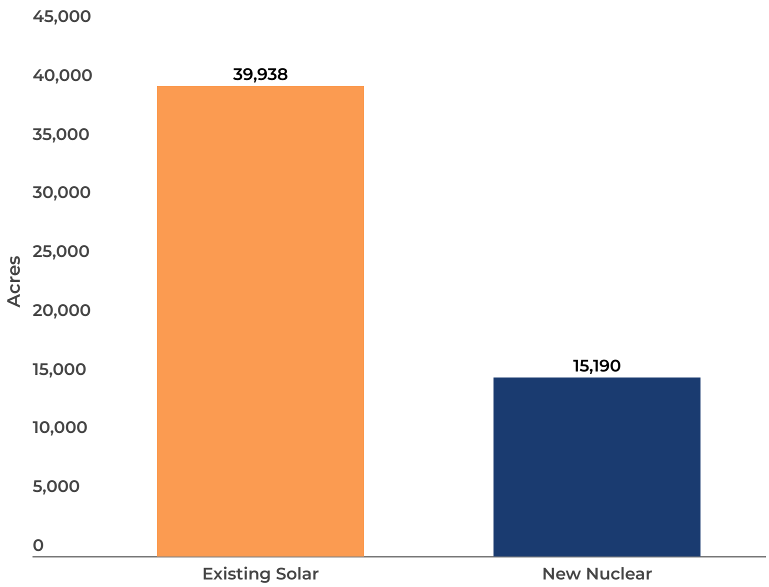


Figure 3.7 North Carolina's existing solar panels consume 2.6 times more land than would be needed to decarbonize the state's grid completely using new nuclear power plants.

Summary

The previous section discussed the importance of conserving North Carolina's finite land for its many competing uses, not just for energy production but also for single-family housing, agriculture, industry, and technological development. Using North Carolina's land as efficiently as possible is responsible stewardship that also allows for the greatest economic growth and prosperity.

Nuclear power's ability to produce large sums of energy on small amounts of land makes it a superior replacement for coal and natural gas plants. Conversely, renewable power's large land requirements and low energy production per acre make it an inefficient use of land in most cases. Furthermore, land used for renewable power generation will not be available for competitive development for 20 to 40 years. And more importantly, agricultural land used for solar projects may not be able to be restored to agricultural use at the end of the lease.[267]

INFRASTRUCTURE REQUIRED FOR THE GOVERNOR'S ZERO-EMISSIONS VEHICLES GOAL

HB 951 committed North Carolina to reducing carbon dioxide (CO_2) emissions from electricity generation with the goal of achieving carbon neutrality in electricity by 2050.[268] Achieving carbon neutrality across the economy, however, would entail modifying every aspect of daily life to generate fewer CO_2 emissions. For the 95 percent of North Carolinians who use their cars and trucks on a daily basis for taking their kids to school, commuting to work, hauling equipment to construction sites, doing general farm tasks, and more,[269] cutting back on emissions from driving would require purchasing an expensive, zero-emissions vehicle (ZEV).

On January 7, 2022, Gov. Roy Cooper signed Executive Order 246, which among other things committed the state of North Carolina to "strive to accomplish" registering 1.25 million ZEVs by 2030.[270] ZEVs include fully electric vehicles (EVs) as well as plug-in hybrid vehicles (PHEVs) and "other forms of zero emissions vehicle."[271] The presumption in the goal is that North Carolinians would replace their conventional, internal combustion engine (ICE) vehicles or never buy such a vehicle in the first place.

Left to their own devices, North Carolinians who do not want EVs can continue to purchase new ICE vehicles as needed. To tip the scales in favor of EV adoption, EO 246 would also have the state strive for half of all new vehicle sales by 2030 to be ZEVs. The state "ZEV Plan" includes mostly financial incentives to reduce the sticker shock of buying new ZEVs and expand the charging network as well as to seek policies, coalitions, and state alliances to lead to more consumer purchases.[272]

North Carolina's financial infrastructure, roads and highways, and electrical infrastructure, however, are not ready for 1.25 million ZEVs.[273] Making North Carolina's roads and households EV-ready will cost between $16.5 billion and $30.5 billion (Table 4.1). This plan would impose significant financial burdens on North Carolina drivers, who would have to spend an extra $17.0 billion to $18.5 billion more to purchase expensive EVs instead of conventional, gasoline-powered cars and diesel trucks over the next seven years (Table 4.1).

TABLE 4.1 TOTAL COST OF EO 246'S 2030 ZEV TARGET AND THE ADDITIONAL INFRASTRUCTURE IT WOULD REQUIRE

Costs Associated with ZEVs	Low-Cost	High-Cost
Electric Vehicle Premium	$17,028,736,979	$18,515,972,222
Household Level 2 Chargers and Circuitry Upgrades	$7,733,950,825	$21,699,042,000
DC Fast Chargers	$883,000,000	
Electricity Transmission Upgrades	$7,938,537,600	
Total	$33,584,225,404	$49,036,551,822

Table 4.1 shows the total cost of a complete EV rollout in North Carolina. Making North Carolina ready for 1.25 million ZEVs will likely cost $25.8 billion to $27.3 billion over the next seven years. Nevertheless, as EV sales continue beyond 2030, additional charging infrastructure will be needed, which will eventually cost North Carolinians $33.6 billion to $49.0 billion.

Trends in the Existing Vehicle Fleet

In a press release issued on March 28, 2024, Cooper's office lauded the public's quick adoption of EVs, reaching — 14 months early — his administration's initial goal of registering 80,000 new ZEVs by 2025.[274] While this growth in EV sales was impressive, it occurred alongside a large uptick in total vehicle registrations. Over the same four-year period, more than half a million new gas-powered and diesel vehicles were registered in North Carolina, dwarfing the 56,000 new EVs added to North Carolina's vehicle fleet. In other words, during this period of rapid growth in EVs, North Carolinians added roughly 10 gas-powered and diesel vehicles for every new EV.[275] In addition, most of these EVs were purchased by North Carolina's top 29 percent of earners, who can afford the high-interest auto loans and green premiums commanded by ZEVs (i.e., how much more a ZEV costs in comparison with a similar conventional ICE car).[276] ZEVs' current share of the auto fleet is almost negligible, and their limited appeal stymies future adoption.

In 2022, there were 8.9 million vehicles registered in North Carolina. Gas-powered and diesel vehicles (ICE vehicles) comprised 88.2 percent of North Carolina's vehicular fleet in 2022 (Figure 4.1).[277] Alternative fuel vehicles (AFVs), which include biodiesel, compressed natural gas, propane, and E85 vehicles, accounted for 9.2 percent. Conventional hybrid electric vehicles powered by gasoline were nearly 2 percent. ZEVs comprised less than 1 percent of North Carolina's vehicle fleet. Breaking ZEVs down by vehicle type, electric vehicles (EVs) accounted for 0.5 percent, and plug-in hybrid electric vehicles (PHEVs) were 0.2 percent (Figure 4.1).

FIGURE 4.1 NORTH CAROLINA'S VEHICULAR FLEET BY FUEL TYPE, 2022[278]

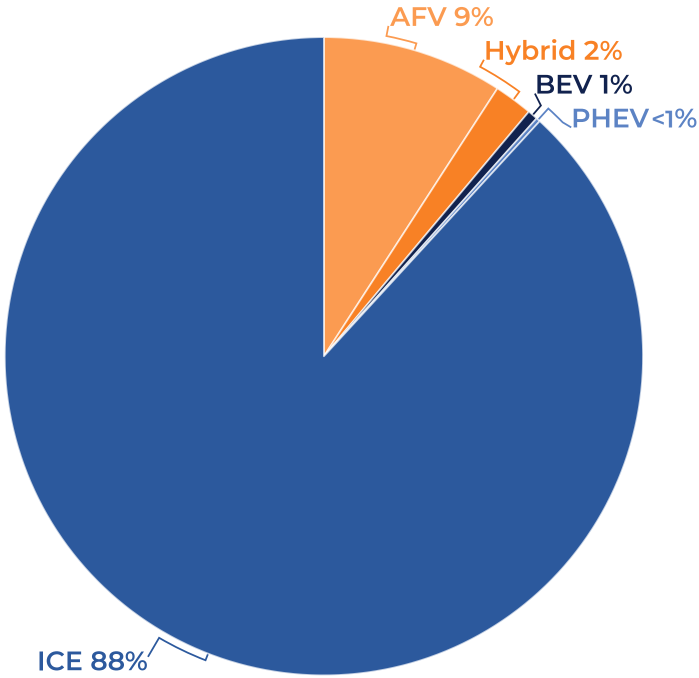


Figure 4.1 shows the composition of North Carolina's vehicular fleet by fuel type in 2022. Despite ZEVs' chain of record-setting year-over-year growth, gas-powered and diesel vehicles (ICE vehicles) accounted for 88.2 percent of all vehicles registered in North Carolina.

If North Carolina were to achieve EO 246's ZEV goal, then ZEVs will comprise 14 percent of the vehicular fleet by 2030 (Figure 4.2). Such an outcome is highly unlikely, however, even before considering the costs. It would require the number of new EVs sold to double every two years, but ZEV registrations have recently been slowing, not increasing. Consumers are balking at ZEVs' high premiums and "range anxiety" (the worry over losing battery power without reaching the destination or finding a charging station).

FIGURE 4.2 NORTH CAROLINA'S VEHICULAR FLEET IN 2030 IF EO 246'S ZEV GOAL WERE MET[279]

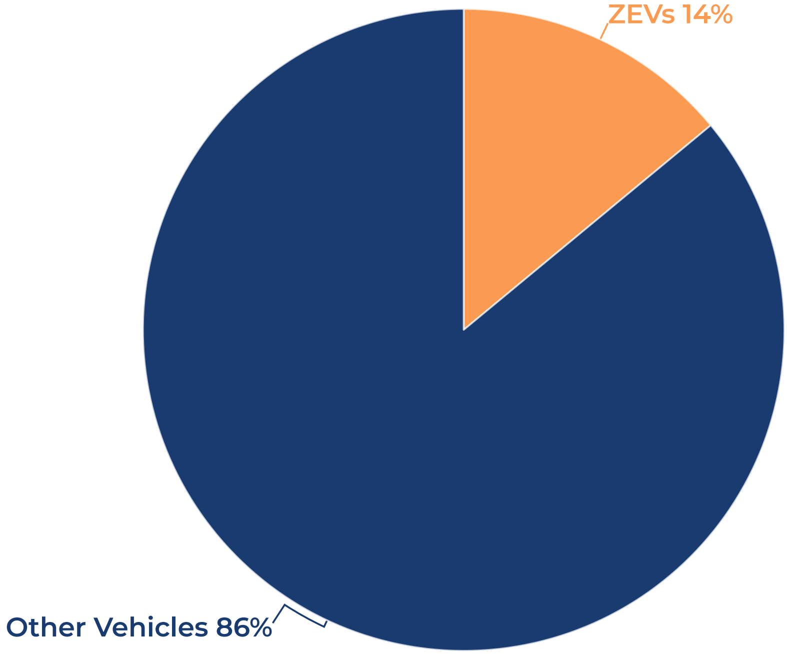


Figure 4.2 shows North Carolina's vehicular fleet in 2030 provided EO 246's target is met. Despite the additional $25.8 million to $27.3 billion that would need to be spent to achieve this goal in the next seven years, ZEVs would still comprise only 14 percent of North Carolina's vehicular fleet. The impact on emissions would be minimal, reducing North Carolina's annual carbon dioxide equivalent (CO_2e) emissions by only 4.1 percent.[280]

TABLE 4.2 NORTH CAROLINA VEHICLE REGISTRATIONS, BY FUEL TYPE AND YEAR, 2016–2022

Year	ICE Vehicles	AFVs	Hybrids	Electric Vehicles	Plug-In Hybrids	Total
2022	7,909,900	820,700	175,300	45,600	18,800	8,970,300
2021	7,895,800	826,700	151,600	25,200	13,500	8,912,800
2020	7,632,900	991,900	133,400	16,200	9,300	8,783,700
2019	7,553,700	963,300	126,600	11,600	8,100	8,663,300
2018	7,435,100	912,600	119,400	7,300	6,500	8,480,900
2017	7,387,200	855,600	114,300	4,400	4,800	8,366,300
2016	7,314,600	777,800	111,000	2,900	3,600	8,206,300

Table 4.2 shows the total number of each vehicle registered per year. These data were used to produce Figure 4.1.

Unrealistic EV Growth Targets

North Carolina's vehicular fleet has been growing by an average of 127,000 vehicles per year,[281] but the majority of this growth is not coming from new ZEVs. Since 2016, 604,600 additional conventional ICE vehicles have been registered in North Carolina, compared with only 67,900 hybrid electric vehicles. And with the sole exception of 2022, far more ICE vehicles have been registered every year in North Carolina than have EV and PHEV vehicles. In 2022, ZEV registrations surpassed those of ICE vehicles (Table 4.3).[282] The surge in ZEV registrations in 2022 was partly driven by the high gasoline prices that resulted from political unrest in Libya and speculative buying of oil in response to the Russia-Ukraine war.[283] That year ZEVs achieved their highest growth ever reported — 40 percent[284] (Figure 4.3).

TABLE 4.3 CHANGE IN NORTH CAROLINA VEHICLE REGISTRATIONS FROM THE PREVIOUS YEAR, BY VEHICLE TYPE AND YEAR, 2017–2022[285]

Year	Hybrid Electric	EV	Plug-In Hybrid	Gasoline	Diesel
2022	23,700	20,400	5,300	14,500	-400
2021	18,200	9,000	4,200	309,200	-46,300
2020	6,800	4,600	1,200	65,500	13,700
2019	7,200	4,300	1,600	105,300	13,300
2018	5,100	2,900	1,700	44,100	3,800
2017	6,900	1,500	1,200	66,000	6,600

Table 4.3 shows the changes in the number of registrations by vehicle type. Despite record adoption rates, ICE and conventional hybrid vehicles are registered in larger quantities than ZEVs.

Preliminary data for 2023 show that, while EV registrations increased by 18,168 vehicles, total registrations declined by 2,300 vehicles. This decline in EV sales caused ZEVs' growth rate to decline from 40 percent per year down to 24 percent, which signals trouble for achieving EO 246's target. Adding 1.25 million ZEVs by 2030 would requires ZEV sales to grow by at least 38 percent per year (Figure 4.4). Putting it in terms of vehicle sales, EV dealers will need to double sales every two years. Figure 4.4 and Table 4.4 show the growth rate and the number of new ZEVs needed per year to achieve EO 246's goal.

FIGURE 4.3 ZEV REGISTRATION GROWTH UP TO 2023[286]

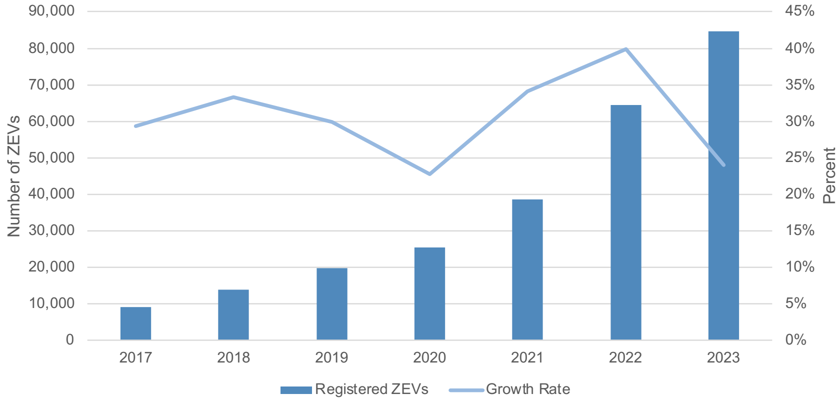


Figure 4.3 shows the total number of ZEVs registered in North Carolina and plots the year-over-year growth rate.

FIGURE 4.4 PROJECTED ZEV SALES GROWTH NEEDED TO REACH EO 246'S GOAL[287]

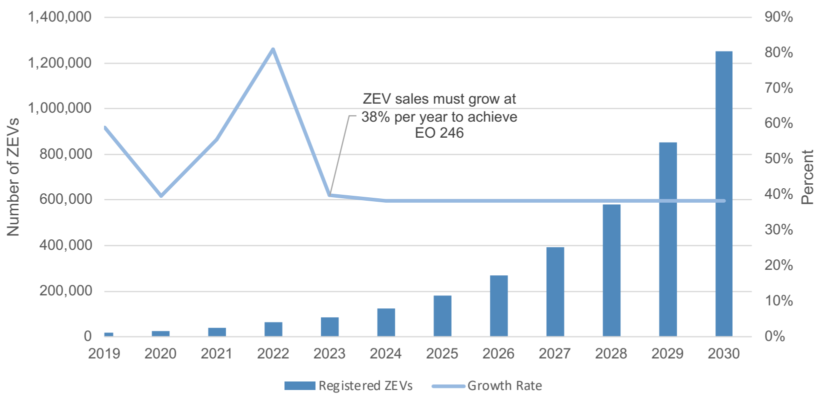


Figure 4.4, based on the data presented in Figure 4.3, extrapolates a path to achieve EO 246's target of 1.25 million ZEVs on the road by 2030.

TABLE 4.4 NEW ZEVS NEEDED PER YEAR TO REACH EO 246'S GOAL[288]

Year	Registered EVs	New EVs per Year	Percent of New ZEVs Added
2024	124,505	39,737	3%
2025	182,869	58,364	5%
2026	268,593	85,724	7%
2027	394,501	125,908	10%
2028	579,431	184,930	15%
2029	851,052	271,620	22%
2030	1,250,000	398,948	32%

Table 4.4 provides the number of ZEVs that would need to be adopted per year to achieve EO 246's target of 1.25 million ZEVs by 2030.

The number of vehicles North Carolinians would need to purchase would be unprecedented. By 2029, North Carolina would be only halfway to reaching EO 246's goal, with 670,568 new EVs remaining to be bought. In 2030, nearly 400,000 new ZEVs would need to be purchased in a single year. Since 2016, no single vehicle class registered over 110,000 automobiles sold in a single year, save for one exception. In 2021, conventional ICE vehicle registrations exceeded 309,000 new vehicles. Registrations likely received a boost that year from the 336,000 people who moved to North Carolina and needed to register their existing vehicle with the state.[289] North Carolina's recent history has not seen anything close to registering 670,568 new vehicles from a single vehicle class in two consecutive years, however.

Furthermore, the massive number of cars that would need to be adopted over the next seven years does not reflect people's actual need for vehicles. According to a survey by S&P Global Mobility, since 2012 the average age of U.S. passenger cars has increased by nearly three years, from 11.2 years in 2012 to 14 years in 2024.[290] With more people keeping their cars longer, fewer North Carolinians will be looking to replace their cars with new EVs. They will either keep their current cars longer or opt to purchase cheaper used vehicles rather than purchase an expensive new ZEV.

ZEV Costs Are Slowing Growth

While ZEVs have seen exponential adoption rates in recent years, interest in purchasing ZEVs is beginning to wane. Consumer concerns about ZEVs' comparatively higher vehicle costs and range anxiety are not only discouraging people from buying ZEVs, but they are also driving ZEV owners to switch back to conventional ICE vehicles. A McKinsey survey published in June 2024 found that 46 percent of America's EV owners were considering switching back to an ICE vehicle.[291] A Gallup poll from April 2024 found that 48 percent of Americans would not purchase an EV at all.[292] The main reasons behind their disinterest is the high premiums EVs command. S&P Global Mobility's survey in 2023 found that EVs were prohibitively expensive for nearly half of respondents.[293] While the federal government offers generous tax credits to cover a portion of ZEVs' cost, the credits are restricted to certain vehicles and fail to offer more choices to buyers at the low end of the spectrum.

The higher cost of purchasing EVs compared with that of otherwise similar ICE vehicles evokes sticker shock in countless potential buyers and prices the rest out. In North Carolina, the average manufacturer's suggested retail price (MSRP) of an EV is $56,475. At an interest rate of 7.15 percent and over a typical payback period of 67 months, the monthly payment for a new EV is $858.68. Using the prudential guidance that car payments should be capped at a maximum of 10 percent of monthly income, the average annual salary needed to afford an EV in North Carolina would be $103,042.[294] This puts most ZEV models well outside the budgets of typical individuals and families in North Carolina, where the median annual income is $41,534 for individuals and $83,448 for families.[295] This immense financial cost essentially restricts EVs to North Carolina's wealthiest households.

Excluding additional interest paid, ZEVs are 67 percent more expensive than their ICE counterparts, which on average cost $33,797.[296] This green premium persists even among "low-cost" entry-level models. Of the 32 EVs available for sale in North Carolina, only six had an MSRP below $40,000.[297] The cheapest among these more affordable vehicles, the Chevy Bolt, carried a 30 percent green premium over its comparable ICE model, the Chevy Trax. Table 4.5 shows the EVs in North Carolina with MSRPs under $40,000.

TABLE 4.5 GREEN PREMIUMS OF NORTH CAROLINA'S LOWEST-COST EVS[298]

Low-Cost EV	Range	EV MSRP	Qualifies for Tax Credit	Comparable ICE Model	ICE Model MSRP	Green Premium
Chevrolet Bolt EUV	247	$27,800	Yes	Chevy Trax	$20,400	36%
Chevrolet Bolt EV	259	$26,500	Yes	Chevy Trax	$20,400	30%
Hyundai Kona Electric	258	$33,550	No	Kona ICE	$25,625	31%
Kia Niro EV	253	$39,550	No	Kia Niro Hybrid	$26,940	47%
Nissan Leaf	212	$28,040	Partial	Kia Soul	$20,290	38%
Volkswagen ID.4	275	$38,995	Yes	Volkswagen Taos	$23,995	63%

Table 4.5 shows the number of EVs for sale in North Carolina with MSRPs below $40,000. High-interest loans have made most EV models unaffordable for North Carolinians. At these relatively affordable prices, families and individuals are limited to several subcompact crossovers.

Like their fully electric counterparts, plug-in hybrids also carry heavy green premiums. Of the nine plug-in hybrids currently for sale in North Carolina, only two have an MSRP below $40,000. The Toyota Prius Prime had the lowest premium across all observed ZEVs at just 15.7 percent. Table 4.6 shows the MSRPs of new PHEVs under $40,000 and compares them with their ICE counterparts.

TABLE 4.6 GREEN PREMIUMS OF THE LOWEST-COST PLUG-IN HYBRIDS IN NORTH CAROLINA (MODEL YEAR 2024)[299]

PHEV	Battery Range (mi.)	PHEV MSRP	ICE Model	ICE Model MSRP	Green Premium
Toyota Prius Prime	44	$32,350	Prius	$27,950	15.7%
Mitsubishi Outlander	38	$39,845	Outlander	$28,395	40.3%

Table 4.6 shows the number of PHEVs for sale in North Carolina with MSRPs below $40,000.

EV proponents claim that the Inflation Reduction Act (IRA)'s $7,500 credit for fully electric vehicles and $4,000 credit for PHEVs reduce or eliminate the EV green premium entirely. Unfortunately, the IRA's credits are available only for ZEVs with batteries made and with final assembly in America. These stipulations have disqualified more affordable EVs, like the Honda Kona and the Kia Niro, from receiving the IRA credit.[300] With the IRA credit, those cars would have cost at most $606 per month, which would make the models accessible to North Carolinian households and individuals earning $72,773 per year. Disqualifying vehicles at the low end of the EV pricing spectrum from the credit forces buyers to take on higher car payments or return to ICE vehicles when looking for desired model types or features. Table 4.7 shows the average cost of EVs and PHEVs with the maximum credit applied alongside the average cost of ICE vehicles (for which the government offers no comparable purchase incentive).

TABLE 4.7 GREEN PREMIUMS OF ZEVS WITH IRA TAX CREDITS APPLIED TO MSRP

ZEV	Average Cost (MSRP)	Maximum Credit	Reduced Price	Green Premium
EV	$56,475	$7,500	$48,975	45%
PHEV	$54,164	$4,000	$50,164	48%
ICE	$35,352	N/A	$35,352	0%

Table 4.7 (from previous page) Deducts the IRA credit from the average MSRP of all EVs in North Carolina. Even if all ZEVs could receive the full amount of the credit — and most of them cannot — removing $7,500 from the MSRP would still fail to make new ZEVs affordable for most North Carolina households.

Using the average costs presented in Table 4.7, the cost of 1.25 million ICE vehicles would be $44 billion. The cost of 1.25 million EVs and PHEVs would be $61 billion and $63 billion, respectively. Therefore, to reach the goal of 1.25 million new ZEVs by 2030, North Carolinians would spend between $17.1 billion and $18.5 billion more on the EVs than on conventional ICE vehicles (Figure 4.5).

FIGURE 4.5 ADDITIONAL COST OF PHEVS AND EVS OVER CONVENTIONAL ICE VEHICLES (COSTS ESTIMATED AFTER APPLYING THE FULL $7,500 IRA TAX CREDIT TO THE ZEVS)

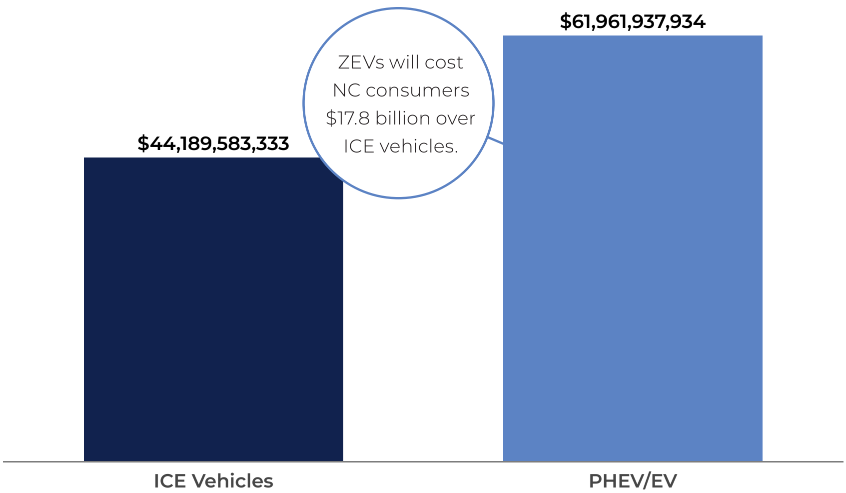


Figure 4.5 compares the cost of purchasing 1.25 million new ICE vehicles versus new EVs and PHEVs. Over the next seven years, North Carolinians would have to pay $17.1 billion to $18.5 billion more in EV premiums.

Proponents of EVs claim that electric vehicles will ultimately save drivers money in the long run (from not needing to buy gasoline). Nevertheless, a study released by Texas Public Policy Foundation found that government favoritism of EVs adds costs that are passed onto conventional ICE vehicle owners — not only from subsidies received by EV manufacturers directly through acts of Congress and indirectly through the National Highway Traffic Safety Administration's Corporate Average Fuel Economy (CAFE) credit multiplier, but also from the effects of EV owners avoiding gas and electricity taxes.[301] While North Carolina's most affluent households can enjoy gas savings from their EVs, middle-class families and blue-collar workers end up subsidizing those choices and paying more for their own ICE vehicles, electricity rates, and fuel taxes.

Current premiums for EVs are pricing out many North Carolinians from making the transition. If high premiums persist over the next seven years, then it is highly unlikely that North Carolina will reach 1.25 million ZEV registrations by 2030. Unfortunately, EO 246's goal to have half of all vehicles sold in the state to be electric by 2030 and the administration's attempts to bring about this goal could limit North Carolinians' mobility and potentially their freedom of vehicular choice. Depending on how the administration regulates EO 246's goal, it could push families to opt for inferior EV models when a comparably priced ICE model would have been better suited for their needs. The governor's order would push North Carolinians to purchase ZEVs at a time when the state's charging infrastructure is woefully unprepared for a rapid rise in EV purchases.[302]

Chargers and Highway Infrastructure

EVs' limited range is a concern for many existing and prospective owners. Range anxiety, especially in rural areas where fuel stations are separated by dozens of miles, has limited EV ownership in rural areas, with adoption rates 40 percent lower than in urban areas.[303] Snow, extreme heat, and other inclement weather challenges not only reduce EV range, but also create adverse road conditions that require increased energy consumption and further reduce vehicle range.[304]

North Carolina ranks second in the nation in miles of state-supported highways.[305] Of the 81,000 miles of road North Carolina maintains, 15,000 miles are interstate and state highways and U.S. routes. Another 65,000 miles are classified as secondary roads.[306] For EV drivers to have similar access to recharging as ICE drivers have to refueling along all 81,000 miles of state-maintained roads in all driving conditions, North Carolina will need a significant expansion of charging infrastructure along highways, at rest stops, and at fueling stations across the state.

Table 4.8 presents data from the U.S. Department of Energy's Alternative Fuels Data Center on North Carolina's existing charging infrastructure. As of this writing, 1,595 fueling stations offer 4,204 publicly available EV chargers, 3,188 of which are Level 2 charging stations and 970 are DC Fast charging stations. Most of the funding for North Carolina's charging infrastructure has come from state programs and federal subsidies. In 2019, North Carolina's Department of Environmental Quality (DEQ) received North Carolina's portion of the Volkswagen Settlement funds.[307] Since receiving control of the settlement funds, DEQ has funded 901 Level 2 and 166 DC Fast charging ports.[308]

"Most of the funding for North Carolina's charging infrastructure has come from state programs and federal subsidies."

The IRA's changes to federal tax credits for charging stations have made it easier for fueling stations to add expensive DC Fast chargers. Prior to 2022, businesses could apply for a $30,000 federal tax credit for electric vehicle infrastructure.[309] In 2022, the IRA raised the value of the credit to $100,000 to spur further development.[310] Raising the tax credit helped expand DC Fast charger access by 50 percent between 2022 and 2023. Additional infrastructure is planned to be built through programs created by the Bipartisan Infrastructure Law (BIL). The BIL doled out $5 billion in taxpayer dollars to states to build 500,000 EV charging stations through the National Electric Vehicle Infrastructure (NEVI) program.[311]

Phase 1 of the NEVI program entails accepting grant applicants to build 37 charging stations with four chargers per station for a total of 148 chargers. This phase will cost $36.3 million. Phase 2 will focus on siting fast chargers in communities and will cost an estimated $76.4 million.[312] The federal government will pay up to 80 percent of construction costs, while the remaining 20 percent will fall on the grant applicant. As of August 2024, no chargers had been built in North Carolina through this program.[313]

TABLE 4.8 EXISTING EV CHARGING INFRASTRUCTURE IN NORTH CAROLINA[314]

Charging Infrastructure	2016	2017	2018	2019	2020	2021	2022	2023
Service Stations with Charging Infrastructure	453	595	666	732	813	1,120	1,166	1,595
Charging Outlets	1,015	1,352	1,488	1,903	2,267	2,789	3,040	4,204
Level 1	67	65	36	28	29	44	37	37
Level 2	812	1,130	1,235	1,592	1,925	2,250	2,312	3,188
DC Fast	136	157	217	283	313	495	691	970

Table 4.8 shows North Carolina's existing EV charging infrastructure. The data were obtained from the Department of Energy's Alternative Fuels Data Center on North Carolina's existing charging infrastructure.[315]

Despite these incentives and pending federal programs, North Carolina would need more infrastructure to support 1.25 million ZEVs.

Long wait times is one of the major issues that additional charging infrastructure needs to address to bring EV charging parity closer to refueling times for ICE vehicles. The lack of sufficient EV infrastructure was made clear in September 2023, when staffers for U.S. Energy Secretary Jennifer Granholm cordoned off several DC Fast chargers with several non-EVs at a service station in Grovetown, Georgia, in order to ensure chargers were available for Granholm's ZEV motorcade. Their actions withheld charging stations from other customers at the service station, forcing them to use slower chargers and delaying their trips.[316] On a fast charger, an EV typically takes up to 30 minutes or so to charge 80 percent.[317] The time it takes an average ICE vehicle to refuel completely is three to six times quicker — just five to 10 minutes for a fuel stop.[318] If no charging stations are available, then an EV's wait time could be extended considerably. North Carolina's NEVI proposal imposes a charge time limit of 45 minutes, up to nine times longer than an ICE vehicle takes to refuel.[319] Nevertheless, siting four chargers per station, coincidently the same number of chargers available during the Granholm debacle,[320] is likely to be woefully insufficient.

Probabilistic modeling from the Energy Policy Research Foundation modeled wait times for EVs based on the number of chargers present and the number of arrivals.[321] Assuming five chargers per station and all ports occupied, a sixth car to arrive at a charging station would spend an expected 32.4 minutes at the station — 5.4 minutes waiting and 27 minutes to charge the vehicle (Table 4.9).

TABLE 4.9 WAIT TIMES BASED ON ARRIVALS OF ELECTRIC VEHICLES AT STATIONS WITH FIVE AVAILABLE CHARGERS[322]

Number of Vehicles Arriving in Previous 27-Minute Period	Expected Wait Times for Charging (in Minutes)
5 or Fewer	27
6	32.4
7	37.8
8	43.2
9	48.6
10	54
11	60+

Table 4.9 presents Energy Policy Research Foundation's calculations that show expected wait times based on the number of chargers available at a charging station and the number of EVs arriving.

Waiting times can be reduced to the time it takes to charge a vehicle by simply adding more charging ports at stations. In *Infrastructure Requirements for Mass Adoption of Electric Vehicles*, Jonathan Lesser assumed 20 charging ports per federal highway stations spaced at 50-mile intervals.[323] In addition to the federal highway stations, DC chargers would need to be provided along North Carolina's 65,000 miles of secondary roads. Installing these chargers at existing service stations would be the best means of ensuring coverage along any road. Currently, 1,595 fuel stations offer chargers. The average number of charging ports available at these service stations is three chargers per station. To ensure charging stations can be accessed along every North Carolina highway and byway, at least three DC Fast chargers need to be added at each of North Carolina's 4,210 charger-less service stations. The total number of EV chargers needed along highways and at service stations would be 17,660. At $50,000 per charger, the total cost of fast-charging infrastructure in North Carolina is expected to be $883 million. Table 4.10 breaks down the number of remaining chargers that need to be installed and their installation costs.

TABLE 4.10 COST OF HIGHWAY INFRASTRUCTURE[324]

<table>
<tr><th>Charging Infra-structure</th><th>Number of Units</th><th>Cost per Unit</th><th>Cost</th></tr>
<tr><td>Existing Fuel Stations</td><td>4,210</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Total Chargers Needed</td><td>17,660</td><td rowspan="3">$50,000</td><td>$883,000,000</td></tr>
<tr><td>Level 3 Retail Chargers</td><td>12,630</td><td>$631,500,000</td></tr>
<tr><td>Highway Chargers</td><td>5,030</td><td>$251,500,000</td></tr>
</table>

Table 4.10 shows the number of chargers that need to be added to charger-less fuel stations and along highways and the total cost of installing these chargers.

Home Improvements

In addition to lack of access to chargers on highways, charging an EV at home has been a major impediment to EV adoption. A June 2024 McKinsey survey found that 24 percent of respondents planned to switch back to ICE vehicles because they could not charge their vehicle at home.[325] North Carolinians who own homes built before 1980 may find themselves in this position. These older homes may require expensive circuitry upgrades costing from $1,500 to $3,000.[326] The cost of installing a Level 2 charger ranges from $1,500 to $3,500.

A Level 2 charger requires a dedicated circuit in a home's electrical box. Level 2 chargers draw current from the breaker at 15 to 80 amps. Houses built prior to 1980 typically have breaker boxes rated at 100 amps. Placing a Level 2 charger in one of these homes would limit the number of appliances that could run while the EV is charging. Running a Level 2 charger simultaneously with a water heater, clothes dryer, dishwasher, or an air conditioner would cause the home's circuitry to draw too much current, overheat a circuit, and blow a fuse. Well over 1.6 million homes in North Carolina may need to upgrade their electric boxes to draw 200 amps of power so as to not overload the breaker or shut off appliances, inconveniencing family members while the EV is charging.[327] To make 1.6 million homes in North Carolina ready for a Level 2 charger would cost between $530 million and $4.9 billion, depending upon how many still need to upgrade. Table 4.11, based on price ranges for a 200-amp installation, presents the estimated costs for making North Carolina's older homes ready to install a Level 2 charger.

TABLE 4.11 ESTIMATED COSTS TO HOMEOWNERS OF UPGRADING ELECTRICAL PANELS IN AGED NORTH CAROLINA HOMES[328]

Percentage of Pre-1980 Housing Stock Needing Upgrade	Houses	Low-Cost	High-Cost
25%	407,415	$529,639,825	$1,222,245,750
50%	814,831	$1,059,279,650	$2,444,491,500
75%	1,222,246	$1,588,919,475	$3,666,737,250
100%	1,629,661	$2,118,559,300	$4,888,983,000

Table 4.11 estimates the total cost of upgrading North Carolina's pre-1980 homes based on the percentage of outstanding homes that still need to shift from 100-amp to 200-amp circuit boxes.

Assuming that North Carolina's existing 85,000 EV owners already have Level 2 charging stations installed, an additional 1,165,000 Level 2 chargers would need to be installed in households across the state. The cost of Level 2 chargers ranges from $300 to $1,000. Installation costs are much higher, ranging between $1,200 to $2,500.[329] EV chargers need to be placed in an area that the owner can access safely and daily.

TABLE 4.12 IN-HOME CHARGER COSTS OVER THE NEXT SEVEN YEARS TO MEET EO 246'S GOAL OF 1.25 MILLION ZEVS IN NORTH CAROLINA[330]

	Low	High
Total Cost	$1,747,848,000	$4,078,312,000

Table 4.12 shows that the cost of installing Level 2 home chargers in North Carolina would range from $1.7 billion to more than $4 billion over the next seven years.

With an average of 2.2 cars per North Carolina household, seeing half of all vehicle sales be electric would inevitably require every household to need an EV charging station for one of their vehicles. If installing an EV charger is not possible, then there would need to be a Level 2 charger set up at frequently visited locations away from home. North Carolina's housing stock can be used to estimate the number of chargers needed across the state. There are over 3.6 million single-family and mobile homes and almost 1.2 million apartment/condo units.[331]

TABLE 4.13 NUMBER OF LEVEL 2 CHARGERS NEEDED FOR THE FULL EQUIPMENT OF NORTH CAROLINA'S HOUSING SUPPLY[332]

Residence	Number of Level 2 Chargers Needed	Low-Cost	High-Cost
Single-Family Homes	3,646,593	$5,469,889,500	$12,763,075,500
Apartment Units	1,156,281	$1,734,421,500	$4,046,983,500
Total	4,802,874	$7,204,311,000	$16,810,059,000

Table 4.13 shows the cost of adding Level 2 chargers proportional to the total residential dwellings in the state.

A report from the National Renewable Energy Laboratory (NREL) observed that apartments and homes without garage parking are unlikely to have Level 2 chargers.[333] Similarly, people living in communities consisting of mobile homes are unlikely to have adequate infrastructure for EV chargers. One solution to this problem proposed by NREL and reiterated by a report from the Energy Policy Research Foundation was for workplaces to install EV Level 2 chargers for their employees.[334] Installing Level 2 chargers on a scale ensuring full access to home charging would cost from $7.2 billion to $16.8 billion (Table 4.13).

Transmission Upgrades

In 2019, the Boston Consulting Group estimated the electricity distribution upgrade costs to achieve 10 percent EV penetration nationally at $5,800 per EV.[335] A report from the National Center for Energy Analytics adjusted the group's estimate for inflation and used $6,800 per EV to estimate the distribution costs at a national level.[336] Applying the $6,800 figure to the approximately 1,165,000 ZEVs still needed to reach Gov. Cooper's goal, the total cost of distribution upgrades would be over $7.2 billion — costs that would be placed on ratepayers. That calculation assumes that by 2030, EVs will make up 10 to 15 percent of North Carolina's vehicle fleet, dependent on growth in competing vehicle registrations, an assumption right at the threshold of the Boston Consulting Group's estimate. Transmission upgrades would likely increase after 2030, however, along with the increasing number in EV sales.

North Carolina's $50 Billion Charging Bill

Assuming that demand for EVs continues to grow to meet the governor's 1.25 million ZEV target in EO 246 and that manufacturers can supply sufficient quantities of EVs, then $25.8 billion to $27.3 billion will be spent on EVs over the next seven years. The costs will not stop there, however. The mandatory minimum sale requirement will increase the number of EVs on the road. Additional charging infrastructure will be needed in homes, along highways, and at roadside fuel stations. The total cost of making North Carolina completely EV-ready ranges from $33.6 billion up to $49.0 billion (see Table 4.1 above).

These estimates, however, very likely understate total costs because they do not adjust for future labor and material cost increases. Many of the metals used in Level 2 chargers are also used in the manufacture of EVs and PHEVs. Copper, for example, is a highly conductive metal integral to ZEVs and charging stations, housing circuitry, and transmission lines. Collins et al. (2024), using their Mines Material Systems Model, estimated that completing this energy transition would require 359.1 percent more copper.[337] Electrical wire requires ultrapure copper, however, so copper mines would need to produce nearly 2.5 million new metric tons of virgin copper ore yearly to satisfy world demand.[338] The increased demand for copper and other materials by utilities, car manufacturers, and renewable power producers will add inflationary pressures on the total cost on North Carolina's transition to ZEVs and clean energy.

Furthermore, this analysis examined only the infrastructure required for electrically powered ZEVs. The cost of infrastructure for hydrogen vehicles, which would also qualify as ZEVs under DEQ's definition, was not examined. Hydrogen vehicles are still an emerging technology, however. Better estimates of hydrogen's cost must wait until testing concludes and hydrogen manufacturing begins at a scale comparable to EVs' current market penetration.

Impact on Emissions

Regarding emissions, this whole effort — spending billions of dollars to make EVs comparable to gas vehicles in the eyes of consumers — would still be only a pyrrhic victory. Assuming that EVs displace only gasoline vehicles and that the size of North Carolina's vehicular fleet stays between 8.5 million and 8.9 million vehicles, then 1.25 million EVs would represent at most 14.7 percent of all registered vehicles in North Carolina. This increase could have only a minor impact on total state emissions. Using data obtained from DEQ's Greenhouse Gas Inventory, passenger cars were responsible for 72 percent of total transportation emissions in 2020, when gas-powered ICE vehicles represented 86 percent of the vehicular fleet.[339]

The types of vehicles replaced by ZEVs could have only a slight impact on total emissions reduced. Replacing ICE SUVs and light trucks with fully electric EVs would have a larger impact on total emissions than replacing ICE hybrids, which already have low emissions. Replacing ICE hybrids with fully electric EVs is more likely, however, given the lack of like-in-kind EV alternatives for SUVs and light trucks. Replacing 1.25 million ICE vehicles with EVs would reduce vehicular emissions by only 5.43 to 5.75 million metric tons (MMT) of carbon dioxide equivalent (CO_2e) emissions.[340] By way of reference, 5.75 MMT CO_2e amounts to about 4 percent of North Carolina's total annual emissions. While proponents of these benefits claim that the emissions-reduction benefits will accrue every year following 2030, in the next few years alone China plans to add 42 times the amount of new coal-fired generation than North Carolina can possibly retire.[341]

Conclusion

While it is dubious that EO 246 will achieve its target of 1.25 million ZEVs in North Carolina by 2030, reaching that goal would result in 14 percent of the state's vehicular fleet being ZEVs. Doing so would require doubling the number of new EVs sold in the state every two years, which is highly unlikely and would also be unprecedented. Most ZEV models are well outside the budgets of most North Carolina families, and even if they weren't, North Carolina lacks the charging and electrical infrastructure to support so many ZEVs. The costs to North Carolinians as consumers, homeowners, and ratepayers to bring about EO 246's target would be massive, running in the tens of billions of dollars. On the other hand, any climate benefits from making just 14 percent of the state's vehicular fleet zero-emissions, bought at such a dear price, would be miniscule, especially in comparison with rapidly increasing emissions from China and most of the rest of the world.

Appendices

Appendix A. North Carolina Energy Jobs

According to the U.S. Department of Energy's 2022 Energy and Employment report, North Carolina's electricity generation and transmission industries employ 43,151 North Carolinians. Figure A1 shows how these jobs are distributed across the electric power generation and energy transmission industries.

TABLE A1 EMPLOYMENT IN THE ENERGY GENERATION AND TRANSMISSION INDUSTRIES IN NORTH CAROLINA[342]

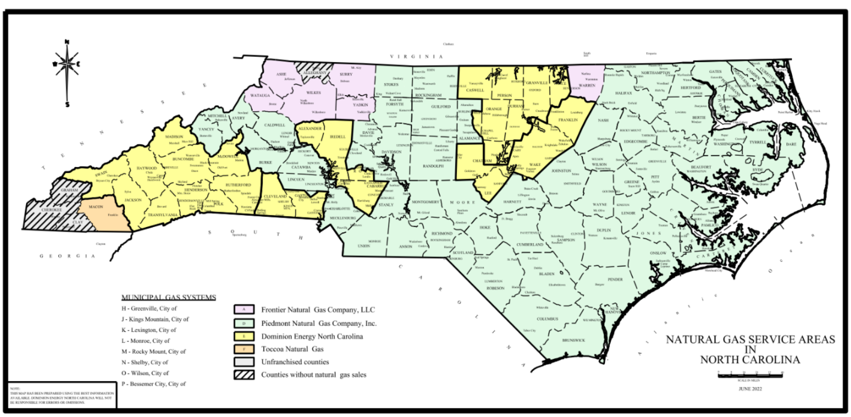
Generation	Jobs
Solar	8,640
Wind	1,179
Hydro	646
Natural Gas	2,654
Coal	1,772
Oil	406
Nuclear	1,459
Other	3,086
Total	19,842

Transmission	Jobs
Utilities	10,694
Construction	7,228
Manufacturing	1,346
Trade	159
Pipelines	992
Professional Services	2,744
Other Services	146
Total	23,309

Appendix B. North Carolina Natural Gas Local Distributors Map

PSNC and Piedmont Natural Gas are North Carolina's largest natural gas service providers, serving 99 percent of all customers in the state. Frontier and Toccoa provide natural gas service to rural counties in the North Carolina mountains. Alleghany, Cherokee, Clay, and Graham counties are not serviced by any LDC, presumably because the cost to run natural gas connections into these mountainous counties is too high to recover through rate-based cost increases.

FIGURE B1 NATURAL GAS SERVICE AREA MAP[343]



Appendix C. North Carolina Storage Facilities

North Carolina's natural gas storage facilities provide additional peak-shaving capacity during winter months. Across North Carolina's five largest storage facilities, the state has an estimated 39 days' worth of peak-shaving capacity.[344] The number of days here is understated, however, since peak-shaving capabilities of each storage facility considerably vary. Pine Needle's draw rate of 0.4 bcf per day is much larger than Piedmont's Robeson County facilities' draw rate. Figure C1 is a map showing the locations of North Carolina's natural gas storage facilities.

Figure C2 is a chart showing North Carolina's daily winter supply of natural gas and peak-shaving capacity.

FIGURE C1 MAP OF NORTH CAROLINA'S NATURAL GAS STORAGE FACILITIES[345]

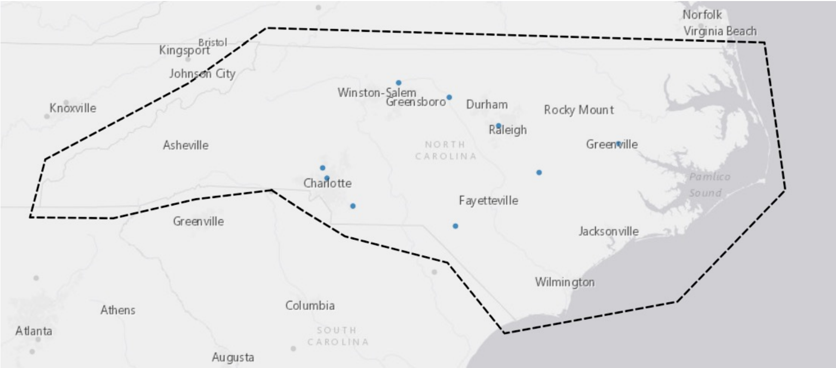
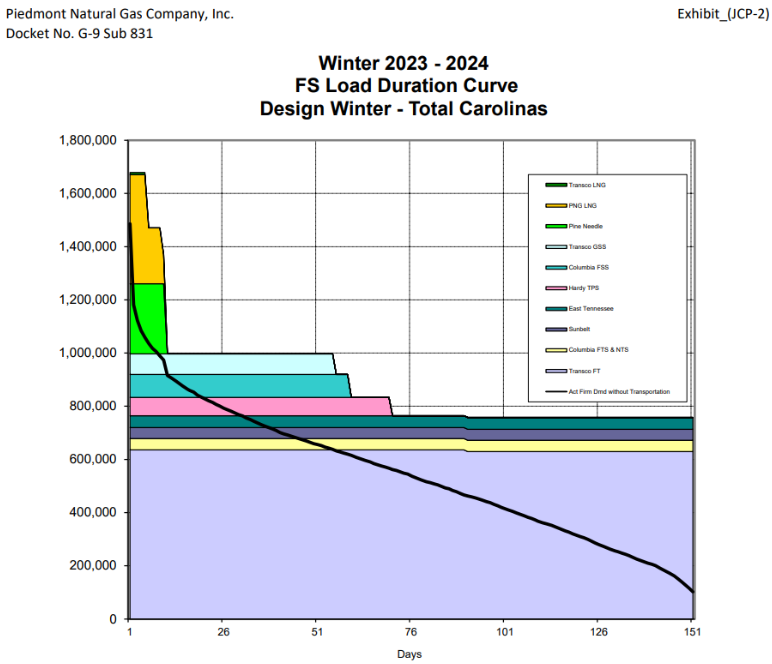


FIGURE C2 WINTER DAILY SUPPLY OF NATURAL GAS AND PEAK-SHAVING CAPACITY OF NORTH CAROLINA'S NATURAL GAS STORAGE FACILITIES[346]



Appendix D. Propane

Owing to a lack of adequate natural gas pipeline infrastructure, propane plays a crucial role for meeting rural North Carolina's energy needs. Unlike natural gas, which needs to be chilled before it can be transported by truck, propane can be stored as a liquid, easily transported by truck, and safely stored at ambient temperature.

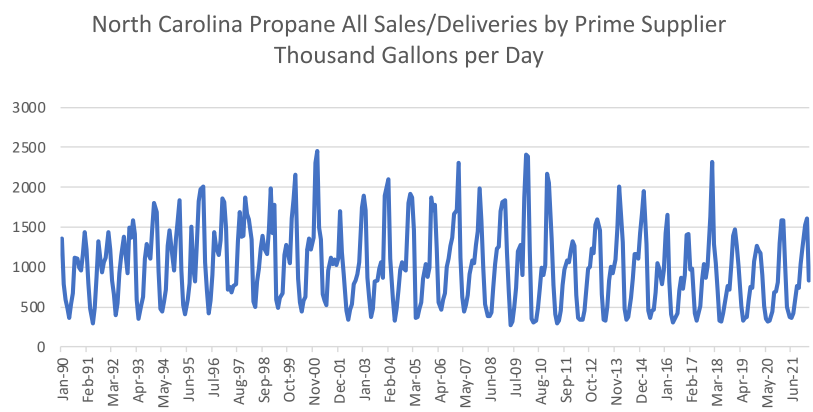
North Carolina's rural households and farmers extensively rely on propane for winter heating and seasonal grain drying. In 2021, North Carolina used more propane than any other state in the mid-Atlantic and Southeastern regions — 375 million gallons. More than a quarter of a million households (263,686) used propane for heating.[347] In 2018, North

Carolina's agricultural industry alone used 71 million gallons of propane for grain drying and other agricultural services.[348]

Functionally all of North Carolina propane is imported from Gulf Coast states via the Dixie LPG pipeline. In 2018, the Dixie Pipeline Company announced an increase in the pipeline's capacity from 58,000 barrels per day (bpd) to 90,000 bpd.[349] The propane is produced at refineries in Texas, Louisiana, and Mississippi and shipped to its terminus in Apex, North Carolina.[350]

Daily propane consumption in North Carolina has fallen since 2009 and has been fluctuating between 320,000 and 1,531,000 gallons per day since 2018 (Figure D1). Natural gas's expanding footprint in the Tar Heel State has displaced some of the demand for propane. Electrification of households and certain appliances may have also contributed to the decline in propane consumption. Propane will remain a cheap primary fuel for home heating and agricultural use in counties where building natural gas infrastructure is too costly and where electricity is a poor substitute.

FIGURE D1 PROPANE CONSUMPTION IN NORTH CAROLINA, 1990–2021 (IN THOUSANDS OF GALLONS PER DAY)



Appendix E

Capacity Additions

This analysis (for the Renewable Scenario) assumes no new CO_2-emitting power plants will be built in North Carolina to meet the standards established by HB 951. In this scenario, North Carolina would add wind, solar, and battery storage capacity to meet the targets established in HB 951.

Hourly Load, Capacity Factors, and Peak Demand Assumptions

Hourly load shapes were determined using real-time hourly load for Duke Energy Progress and Duke Energy Carolinas for the years 2019 to 2023. Load shape data and hourly wind and solar generation were obtained from EIA Form 930.[351] The amount of capacity built is designed to meet demand reliably in each of the past five years, based on historical data.

Hourly solar generation data was divided by installed capacity to get the hourly capacity factor, and onshore wind capacity factors were generated by using hourly PJM production data, divided by the installed capacity. For offshore wind, NREL System Advisor Model (SAM) data were used.[352]

Battery Storage

Battery storage assumes a 5 percent efficiency loss for charging and discharging. Maximum discharge rates for the MISO system model runs were held at the max capacity of the storage fleet, less efficiency losses. Battery storage is assumed to be four-hour storage, while pumped storage is assumed to be eight-hour storage.

Wind and Solar Degradation

According to the Lawrence Berkeley National Laboratory, output from a typical U.S. wind farm shrinks by about 13 percent over 17 years, with most of this decline taking place after the project turns 10 years old. According to NREL, solar panels lose 1 percent of their generation capacity each year and last roughly 25 years, which causes the cost per megawatt hour (MWh) of electricity to increase each year.[353] Our study does not take wind or solar degradation into account, however.

Appendix F

Capacity Additions

This analysis (for the Nuclear Scenario) assumes no new CO_2-emitting power plants will be built in North Carolina to meet the standards established by HB 951. In this scenario, North Carolina would add new nuclear power plants to meet the targets established in HB 951.

Hourly Load, Capacity Factors, and Peak Demand Assumptions

Hourly load shapes were determined using real-time hourly load for Duke Energy Progress and Duke Energy Carolinas for the years 2019 to 2023. The amount of nuclear capacity built is designed to meet demand reliably in each of the past five years, based on historical data.

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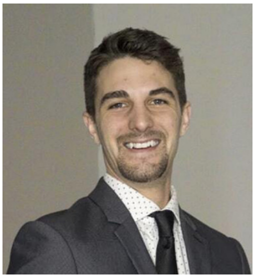

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THE JOHN LOCKE FOUNDATION

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The John Locke Foundation was created in 1990 as an independent, nonprofit think tank that would work "for truth, for freedom, for the future of North Carolina." The Foundation is named for John Locke (1632-1704), an English philosopher whose writings inspired Thomas Jefferson and the other Founders. The John Locke Foundation is a 501(c)(3) research institute and is funded by thousands of individuals, foundations, and corporations. The Foundation does not accept government funds or contributions to influence its work or the outcomes of its research.

Our Vision

Locke envisions a North Carolina in which liberty and limited, constitutional government are the cornerstones of society so that individuals, families, and institutions can freely shape their own destinies.

Our Mission

Locke's mission is to be North Carolina's most influential force driving public policy so North Carolinians flourish in a free and prosperous society.

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