A PATHWAY TO A CLEANER ENERGY FUTURE IN
NORTH CAROLINA

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EXECUTIVE SUMMARY

The state of North Carolina is at a crossroads regarding its energy future, facing two dramatically different paths. Duke Energy, the main electricity provider in the state, calls for 5,617 MW of new fossil and nuclear capacity between 2018 and 2028 in its preferred resource plans. Under this “Business-As-Usual” (BAU) vision, fossil fuel and nuclear generation are front and center in meeting electricity demand. Although renewable energy and energy efficiency are required to supply 12.5% of the utility’s sales by 2021, Duke Energy does not plan to add any utility-owned solar or wind capacity to the grid; does not plan to meaningfully increase energy efficiency levels (which under Duke’s plans will meet, at most, 0.5% of electricity demand); and plans to utilize only a very small amount of demand response programs.

In dramatic contrast to Duke Energy’s fossil fuel-reliant vision, The Greenlink Group (an energy research firm) has evaluated a cleaner energy pathway, whereby 23% of electricity demand is met by resources such as energy efficiency, distributed and utility-scale solar, wind, hydroelectric power, demand response, and energy storage technologies. In this Cleaner Energy Plan, none of the new fossil and nuclear capacity that Duke Energy has proposed to construct over the next ten years will be needed, and the seven coal plants currently on Duke’s system will be retired between 2018 and 2027 because they are unnecessary to meet system demand. The results of this study suggest that the Cleaner Energy Plan will not only maintain the reliability of the grid and make electricity service more affordable for North Carolinians, it will reduce the environmental impact associated with electricity production.

DESIGNING A CLEAN ENERGY FUTURE

The Cleaner Energy Plan evaluated in this study begins with realistic electricity consumption and peak demand forecasts that align with those of other energy system modeling experts and recent North Carolina history. The results demonstrate that Duke Energy severely overestimated both consumption and demand growth. The realistic growth rates of the Cleaner Energy Plan eliminate some of the utilities’ justification for the construction of new generating assets. Furthermore, the Cleaner Energy Plan introduces cost-effective automated demand response programs and energy efficiency programs, further deepening the reductions in electricity consumption and peak demand. In addition, the Cleaner Energy Plan would also take full advantage of economical renewable and energy storage technologies, lowering the emissions intensity of the electricity supply.

The proposed clean energy measures would fundamentally alter the dynamics of electricity demand and supply in North Carolina. Their substantial impact on Duke Energy’s resource mix manifests in three
The Cleaner Energy Plan will deliver tangible financial benefits to North Carolina electricity ratepayers. The reduction in customer electricity demand due to energy efficiency, demand response, and distributed renewable sources translates to lower overall consumption and lower electricity bills. Despite modest beginnings, the savings ramp up quickly and eventually reach a cumulative savings of $5.4 billion for Duke Energy customers. Relative to the BAU, residential customers will see an average $101 reduction in their annual electricity bill; non-residential customers will experience a $611 annual electricity bill saving.

Jobs, incomes, and GDP are all higher in the Cleaner Energy Plan than in the BAU. Under the Cleaner Energy Plan, employment would increase, ranging from 109,000 to 157,000 job-years between 2018 and 2028. Incomes would experience a net increase of $4.8 billion to $7.7 billion, while North Carolina’s GDP increases by $3.7 billion to $8.2 billion (Figure ES-1). Overall, economic development is accelerated dramatically under the Cleaner Energy Plan.

**THE CLEAN ENERGY FUTURE IS ECONOMICALLY WISER**

The Cleaner Energy Plan will transform the grid in ways. First, under the Cleaner Energy Plan, more-likely consumption and peak demand levels diminish the argument for new fossil and nuclear capacity. Additionally, all existing coal-fired generating capacity can be retired in a 10-year period, reducing system costs without jeopardizing grid reliability. Finally, the machine learning-powered simulation results show that clean energy plays an important role in meeting demand and keep the grid reliable.

In contrast to the diminishing role of fossil generation, clean energy resources experience tremendous growth under the Cleaner Energy Plan, meeting 23% of the total Duke Energy system load in 2028. Solar becomes the largest clean energy source in the Cleaner Energy Plan, producing nearly 16 million MWh of electricity in 2028, more than twice as much as its 2028 contribution.

**THE CLEANER ENERGY PLAN TRANSFORMS THE GRID**

A significant fuel mix change will occur for Duke Energy’s centralized-generating system over the course of the next decade. Compared to the BAU scenario, the Cleaner Energy Plan creates a significant shift away from coal, nuclear, and combined cycle gas generation towards clean energy resources such as solar, wind, and battery storage (Figure ES-2). Coal-fired power plants are phased out entirely by 2027. While combined cycle gas plants play a smaller role under the Cleaner Energy Plan, combustion turbine gas units will generate more electricity under this scenario than under the BAU. Overall gas use, however, is lower under the Cleaner Energy Plan than under the BAU.
in the BAU scenario. New wind capacity in northeastern North Carolina and wind energy purchases from transmission projects make wind the second largest clean energy resource in the State (Figure ES-3). Energy efficiency’s contribution to reducing electricity demand will ramp up from its current level of 0.4% to 4% by 2028, a ten-fold growth. Albeit small in energy terms, demand response programs come at a critical time when power reductions help to maintain operational reliability and cost-effectiveness. The aggressive pursuit of energy efficiency and demand response will also reduce peak load on the Duke Energy system by 18% in 2028. Altogether, clean energy resources become a substantial component of North Carolina’s energy mix, as shown in Figure ES-4.
THE CLEANER ENERGY PLAN BENEFITS THE PUBLIC AND THE ENVIRONMENT

In addition to electricity bill savings, job creation, and GDP growth, the Cleaner Energy Plan also achieves a suite of social and environmental benefits. Emissions of carbon dioxide (CO\(_2\)), sulfur dioxide (SO\(_2\)), nitrogen oxides (NO\(_x\)), particulate matter, ammonia, and volatile organic compounds (VOCs) are lower in the Cleaner Energy Plan than the BAU scenario. Cumulatively, over 160 million metric tons of CO\(_2\) emissions will be avoided between 2018 and 2028, equivalent to the expected emissions of 3.4 million cars over the same period. Similarly, across the other six pollutants, nearly 47% of the emissions will be avoided.

In addition to better air quality, 53 billion gallons of water consumption is avoided due to the retirement of water-intensive coal-plants and the avoided operations of a new nuclear unit.

A cleaner electricity supply leads to a suite of social, environmental, and economic benefits such as better public health, fewer crop failures, and lower extreme-weather-related risks to the economy. The avoided CO\(_2\) emissions alone produce about $3.6 billion social, environmental, and economic benefits globally (valued using the U.S. Interagency Working Group Social Cost of Carbon). Overall, the Cleaner Energy Plan reduces total damages from electricity generation by $21 billion between 2018 and 2028, a 45% decline from the BAU scenario (Figure ES-5).

Because many pollutants travel across state and national borders, the public health benefits due to a cleaner grid in North Carolina can be enjoyed in and beyond the state. Adult mortality declines by 1,200, nearly 900 hospital visits for issues like asthma and cardiovascular disease are avoided, and society benefits from the added productivity of 93,000 missed work days being added back to the economy.

A CLEAN ENERGY FUTURE, A BETTER FUTURE

The Cleaner Energy Plan designed in this study is a much more attractive development pathway for North Carolina. Economic opportunities are greatly expanded, environmental damage is much reduced, and social outcomes are significantly better than under the BAU trajectory. It is also significantly more cost-effective than the BAU case. The cumulative net monetary benefits achieved in the Cleaner Energy Plan associated with the full complement of costs and benefits totals at $59 billion to $100 billion dollars. Overall, these results suggest the Cleaner Energy Plan represents a more desirable and sustainable future for North Carolina, its businesses, and its residents.
CHAPTER 1. NORTH CAROLINA’S ELECTRICITY FUTURE IN A BUSINESS-AS-USUAL WORLD

1.1 HISTORICAL ELECTRICITY GENERATION IN NORTH CAROLINA

The primary electric service provider in North Carolina is Duke Energy, servicing over 70% of North Carolina’s electricity demand. Duke Energy oversees two utility companies in North Carolina: Duke Energy Progress (DEP) and Duke Energy Carolinas (DEC). DEC is the larger of the two companies, with 2.5 million residential, commercial, and industrial customers, while DEP services approximately 1.5 million customers.

Historically, North Carolina has relied on fossil-based and nuclear energy as the primary resources for electricity generation. Coal-fired generation was the single largest generation source in the 1990s, being used to produce 61% of electricity in-state over the decade.1 However, with the economics of natural gas improving over the past decade, the prominence of coal decreased. In 2015, coal was the second largest source of generation, after nuclear power and just ahead of natural gas by 3%, as shown in Figure 1-1.

Renewable energy has seen significant growth in North Carolina since the mid-2000s, due to regulatory dynamics and rapid price reductions. A significant player in both aspects for the North Carolina market was the establishment of the Renewable Energy and Energy Efficiency Portfolio Standard (REPS) in 2007, which requires that by 2021, 12.5% of the prior year’s retail electricity sales from investor-owned electric utilities in the state must be supplied by eligible renewable and energy efficiency sources. Utility-scale solar has led the charge of renewable energy deployment in North Carolina, most of which has been brought onto the grid as qualified facilities (QFs), making the state first in the nation for PURPA-enabled solar capacity, both in percentage and actual megawatt terms.2 In contrast, wind capacity development has been hampered by an unfavorable regulatory environment. Although the state has a strong wind potential in the Appalachian mountain region as well as the coastal region, the Mountain Ridge Protection Act, commonly called the “Ridge Law,” has restricted development of wind turbines on mountain ridges. The consequence of the Ridge Law is that it has effectively banned 75% of the state’s on-shore wind potential from being developed. The only wind farm that currently exists in the state is a 200 MW project in Dominion’s territory along the coast in the northeast corner of the state.

Although energy efficiency is a qualifying resource under the REPS, it has not grown in the resource mix over the past four years relative to demand growth. In 2016, energy efficiency offset 0.5% and 0.4% of the generation in DEC and DEP, respectively. The American Council on an Energy-Efficient Economy (ACEEE) ranks North Carolina 30th in the nation in terms of total-percentage-savings from energy efficiency.3 In addition, both utilities place in the bottom quartile in savings achieved from efficiency and rank 31st and 35th out of 51 in the ACEEE utility efficiency scorecard.4

1.2 ELECTRICITY GENERATION IN DEC AND DEP IN A BUSINESS-AS-USUAL FUTURE

Phase I of this study conducted a modeling exercise to understand the electricity landscape in the State of North Carolina. Using the ATHENIA model, the study developed a forecast of electricity demand and supply in Duke Energy Carolinas and Duke Energy Progress territory between 2017 and 2030 based on both utilities’ 2016 Integrated Resource Plans (IRP), referred to as the business-as-usual (BAU) scenario.

Under the BAU scenario, demand for electricity in North Carolina will experience modest to strong growth in the next 15 years, following DEC and DEP’s Integrated Resource Plans. After considering utility sponsored energy efficiency programs, DEC and DEP anticipate that demand from their customers will grow at 1% and 0.9% annually, respectively. The commercial sector will experience the strongest annual demand growth at 1.3%, followed by the residential sector and industrial sectors.

To meet this demand growth, the Duke utilities call for an expansion in electricity generating capacity to maintain demand-supply balance. As of 2016, 57% of

![Figure 1-1 Electricity Generation by Fuel Type in North Carolina, 2015 Source: EIA Form 923](image-url)
the electricity generation in DEC came from nuclear power plants, followed by 25% from coal-fired power plants; gas accounted for just over 10% of electricity generation. Although still the largest generation source, nuclear accounts for only 39% of DEP generation; gas-fueled plants edge out coal-fired power plants by 2 percentage points to be the second largest electricity generation source in DEP, meeting 28% of demand. Renewable energy accounts for less than 7% for both utilities. More fossil-based generating capacity will be added to the DEC and DEP systems, according to the IRPs. Between 2017 and 2030, DEC plans to add one new gas combustion turbine (NGCT) plant rated at 468 MW, one new gas combined cycle (NGCC) plant rated at 1221 MW, and two 1117 MW-rated nuclear units. Over the same period, DEP plans to add six new NGCT plants rated at 2,158 MW capacity, along with two new NGCC plants that have a combined rated capacity of 1,781 MW.

As a result of the capacity expansion, the utilities plan on gas to play a more important role in meeting Duke’s future electricity demand. The combined generation from NGCT and NGCC plants in 2030 will account for over 27% of system-wide generation, seven percentage points higher than the 2016 contribution. In the meantime, the prominence of coal-fired power plants will decline significantly in the next 13 years; only 14% of the electricity demand in 2030 will be met by coal-fired power plants, down 26 percentage points from 2016 levels. The majority of the fuel switch between coal and gas happens between NGCC and coal-fired plants because they have similar generating profiles.

1.2.1 BILL IMPACTS

Consumers from all sectors in DEC and DEP are expected to experience increases in their electricity bills, due to upward pressure on electricity rates from the planned capacity and grid expenditures, as well as growing consumption levels.

Forecasts conducted in the first phase of this study find that on average, residential customers in DEC will pay $119 per month for their electricity use in 2017, but that will increase by 62% to reach $194 in 2030 (both in nominal dollars). The bill increase is more pronounced in DEP, as the average residential customer is projected to see their monthly bills go up by 85% between 2017 and 2030. Non-residential customers will also see a sizable increase in their electricity bills. In both DEC and DEP, industrial and commercial customers will pay 55% more every month for electricity in 2030 compared to 2017. Although non-residential customers in DEC pay less per kWh, their average electricity consumption is 68% higher than their DEP counterparts. Consequently, the electricity bill for an average non-residential customer in DEC is estimated to reach $1,471 per month in 2030. Average non-residential electricity bills in DEP are approximately 22% lower than in DEC, reaching $1,148 by 2030.

1.2.2 EMISSION IMPACTS

ATHENIA tracks the byproducts of fossil-based electricity generation, including six localized pollutants – SO2, NOx, PM2.5, PM10, VOCs, and NH3 – as well as greenhouse gas emissions of CO2. Previous analysis found that SO2, NOx, PM2.5, and CO2 are the four...
major air pollutants that account for 98% of the total damages associated with electricity generation emissions in North Carolina. Within the localized pollutant family, NOx is the single largest source of emissions in terms of tonnage. However, the public health and the environmental damage caused by a ton of NOx is significantly less than that caused by SO2 and PM2.5, due to the more severe public health consequences related to the latter two. In the projection, SO2 is initially the worst offender, causing more than $470 million in damage in 2016. Coal-fired power plants are the largest emitters of SO2. Fortunately, as the share of electricity generated from coal declines over time, the amount of SO2 and its associated damages also shrinks between 2016 and 2030. However, PM2.5, an air pollutant associated with the combustion of both coal and natural gas, sees a sharp increase between 2022 and 2028, due to the added NGCC and NGCT capacity in both DEC and DEP. The projection finds that it will overtake SO2 in 2023 to be the most damaging air pollutant. In 2028, PM2.5 will cause more than $440 million in public health and environmental damage; the damage value will decline slightly to $360 million by 2030. Large coal plants such as Roxboro, Belews Creek, and Marshall have the largest damages associated with their operations (Figure 1-3).

Accounting for the full, global scope of pollutant impacts, the single largest source of social and economic damage from the Duke fleet is CO2. Again, coal-fired power plants are the largest emitters of CO2 and are therefore responsible for the largest damages. Cumulative emissions across DEC and DEP between 2017 and 2030 are slightly above 820 million metric tons, causing a cumulative damage of over $3 trillion (undiscounted) over the next 14 years.

### 1.3 PEAK DEMAND IN DEC AND DEP IN A BUSINESS-AS-USUAL FUTURE

One key indicator that Duke Energy uses in their resource planning is forecasted system peak demand because they are obligated to build enough resources to reliably meet system demand. According to the BAU forecast conducted in the first phase of this study using Greenlink’s proprietary model, both DEC and DEP’s peak demand will occur in winter time by 2028. The highest electricity demand on the Duke system (DEC and DEP combined) occurs at 8am on a January morning. Close to 34,000 MW of electric power needs to be produced and delivered to the customers at that hour, a value approximately 7% higher than the summer peak demand, which occurs around 5pm in July. Although DEC and DEP experience their system peaks on different days, because DEC’s system load is 40% higher than that of DEP, the total Duke system peak corresponds with DEC’s peak day. The predicted system-wide summer peak hour is around 5pm, which is different from both utilities’ individual peak hours.

In summary, under the business-as-usual scenario, electricity demand in North Carolina will continue to grow between now and 2030; Duke Energy intends to respond to this by adding more electricity generating capacity - the overwhelming majority of which will be
gas. The results of this trajectory are higher system expenditures, higher electricity bills for customers, worse air quality, growing CO2 emissions, and greater stress on water resources, none of which are desirable outcomes for the public.

Fortunately, the business-as-usual scenario is not the only pathway available to North Carolina. The state has significant clean energy resources that can supplement or even displace its current fossil- and nuclear-driven centralized electricity generation model. The remaining sections of this report articulate a cleaner energy vision that ensures the reliability of the grid and reduces environmental externalities, while simultaneously saving North Carolina ratepayers money.

CHAPTER 2. DESIGNING A CLEANER ENERGY FUTURE FOR NORTH CAROLINA

Using the BAU scenario as a baseline, Greenlink evaluated the possibility of a cleaner energy future for the state that does not involve significant spending on building or maintaining fossil-based generating plants. In this Cleaner Energy Plan, a significant portion of the future electricity demand will be met by a diverse set of clean energy resources, including customer-side solutions such as energy efficiency, demand response, and distributed solar, as well as utility-scale technologies such as utility-scale solar, onshore wind, grid-facing energy storage, and more. A more realistic demand growth forecast is also envisioned, derived from the Energy Information Administration (EIA)'s 2017 Annual Energy Outlook. In combination, these resources can be utilized to offset the need for new fossil plants and the continued operation of costly existing fossil plants while still meeting state-wide electricity demand over the next 10 years, i.e. between 2018 and 2028.

2.1 METHODOLOGY OVERVIEW

The Cleaner Energy Plan in this study brings a new approach to electricity supply and demand in North Carolina. It begins with rethinking electricity consumption and peak demand forecasts and asks whether the growth trajectories proposed by the utilities are appropriate. After comparing the utilities’ reported growth rates with historical data and predictions from other reputable sources, it is apparent that the growth rates in the two utilities’ IRP filings are the most optimistic among all reviewed sources. If a more likely growth forecast is adopted, the demand for new generating assets is significantly less than in the BAU scenario. For the purpose of modeling the Cleaner Energy Plan, this study chooses to ground the assumptions about the growth rates on historical data using EIA Form 861 (formerly Form 826) and the assumptions used in Annual Energy Outlook 2017. As a result, electricity consumption and peak demand growth rates are reduced by more than 50% from DEC and DEP forecasts. Lower growth rates relieve some of the pressure on utilities to finance and build many new generating assets to meet demand and meet reliability requirements.

The rest of this chapter and its associated appendices explain the process of avoiding capacity expansions, retiring existing centralized generation, and the approach for adding new clean energy resources. Core to this approach is the retirement of expensive generation as made feasible through other efforts evaluated in the study. Expensive generation is identified as incurring plant-level total operating expenses greater than $20 million in any given year between 2018 and 2028 and costing over $10,000 per MW of capacity annually to maintain. Generation satisfying these criteria are retired, starting with the most-costly, as the reserve margin and loss-of-load-hour analysis permits, to ensure reliability. Overall, this allows for a lower-cost system to come into being in North Carolina.

Lastly, economically feasible energy efficiency and renewable energy resources will be deployed at scale to cost-effectively meet demand as well as to displace marginally more-expensive electricity production coming from the remaining fossil and nuclear fleet in DEC and DEP territory. The overarching goal of this approach is to use economically-viable clean energy resources to replace costly fossil plants while maintaining grid reliability.

2.2 ADJUSTED ELECTRICITY CONSUMPTION AND DEMAND GROWTH AND THEIR IMPACT ON CENTRALIZED GENERATING CAPACITY ADDITIONS

Over the past four years, DEC’s electricity consumption growth has been relatively flat. However, the Company projects annual consumption growth of 1.1% per year (1.0% after accounting for utility energy efficiency programs), with the greatest growth coming from the commercial sector. Like DEC, DEP’s electricity consumption growth has been relatively flat, while the
utility projecting a 1.1% pre-energy efficiency growth rate and a 0.9% post-efficiency growth rate. Both utilities expect their peak demand to grow at a faster rate than electricity consumption, at 1.3% per year.

After considering recent historical patterns and other projections, this study does not use the growth rates from the IRPs, as they project growth increasing imprably rapidly. The primary counterpoint grounding this analysis is the demand projection for the VACAR SERC region (which is dominated by Duke Energy and Dominion), produced by the Energy Information Administration as a part of the Annual Energy Outlook (AEO).6 This report is published and updated annually to incorporate the best information the federal government has on the current state of the entire energy system and projects future demands based on peer-reviewed published methodologies. The model used for the Annual Energy Outlook is the same one used to analyze energy policy proposals for Congress and other interested parties within the federal government.

In the Reference Case of the 2017 AEO, net energy for load in the electric power sector in the VACAR SERC region grows by 0.4% per year from 2017 through 2028. Since AEO does not report peak demand growth, it is calculated by taking the ratio between growth in peak demand and growth in total consumption provided by the utilities in the IRP filings and comparing this to the growth in total consumption. As a result, peak demand is modeled as growing slightly less than 0.6% per year.

Combined with an expansion of renewable energy resources, described in Section 2.4, a slower growth in demand for electricity makes clear that building seven fossil plants and one nuclear unit is not unnecessary (Table 2-1).

### 2.3 AN ECONOMICS-DRIVEN APPROACH TO REDUCE RELIANCE ON EXISTING FOSSIL-BASED PLANTS

Besides avoiding building new fossil- and nuclear-based generating capacity, this study also seeks to understand the ability to cost-effectively reduce North Carolina’s use of fossil-based generating capacity. An evaluation of the operating cost of each coal-fired and gas-fired plant determines which existing plants are the most expensive for North Carolina ratepayers to keep on the system. Operating cost is defined as the total cost required to operate, maintain, and retain environmental compliance for a plant. The maintenance cost for each plant is calculated based on FERC Form 1 data. A list of the cost categories that are included in the calculation can be found in Appendix B.

Using the Coal Asset Valuation Tool (CAVT), this study calculates the environmental compliance costs of the coal plants in DEC and DEP territory.7 Compliance costs center on three areas: cooling water circulation, CCR,8 and effluent discharges. The compliance costs for each plant are first amortized and then added to the annual maintenance costs to derive final operating costs.
$20 million annual in operating costs and maintenance costs of $10,000 per MW are the criteria chosen to define costly fossil plants. Plants requiring greater than these levels of investment to remain functional are usually old plants with pollution control technologies that are in need of upgrades in order to comply with current or upcoming environmental regulations. To continue operating plants of this kind means high system costs that are ultimately passed on to ratepayers. In the Cleaner Energy Plan, they are retired from the generating fleet, which produces ratepayer savings; some of these plants were already slated for retirement, reflecting that this is not a wholly new approach to utility operations. Table 2-2 shows the plants meeting these cost criteria. In the Cleaner Energy Plan, these plants are phased out of the generating mix between 2018 and 2028, after considering system reliability.

### 2.4 Harnessing Economically-Viable Clean Energy

The Cleaner Energy Plan evaluates the economic viability of increased reliance on renewable resources and energy efficiency as compared to the BAU case. These include energy efficiency, demand response, solar photovoltaics, wind (both in-state and out-of-state projects), and energy storage. A brief summary of the methodology for evaluating each of these resources to derive an economic potential follows.

#### 2.4.1 Energy Efficiency Programs

Energy efficiency in electricity use is evaluated sector-by-sector. Estimates for naturally-occurring or federally-driven energy efficiency improvements are derived from the 2017 Energy Information Administration Annual Energy Outlook Reference Case.\(^9\)

Cost-effective efficiency improvements for the demand sectors are identified and modified from studies by the National Renewable Energy Laboratory (NREL) and the American Council for an Energy-Efficient Economy (ACEEE).\(^10,11\) The modeling approach starts with the current annual energy efficiency levels achieved by the utilities, and captures ten percent of the achievable efficiency potential each year, such that these territories have reached their potential by 2026. Afterwards, these efforts are maintained to ensure there is no backslide throughout the remainder of the modeling horizon. For more details, please see Appendix C.

#### 2.4.2 Building Codes

New buildings also present an opportunity to improve energy performance when building codes are adopted and implemented. New building code standards are issued on a consistent three-year basis. Several states have now passed legislation that updates the state building codes when a new standard is issued by the national and international authorities (ASHRAE and IECC). Similar actions in North Carolina would improve...
new building energy efficiency through technology and shell improvements, and are generally considered cost-effective. The energy savings associated with a code advancement vary. In this case, it is assumed that there is 2% annual building turnover, consistent with national averages. The first code update assumes that building codes will provide the average savings of the past two code updates, as assessed by the Department of Energy. Each subsequent update occurs every three years, and is modeled as advancing the code by the lower savings level of the previous two code updates. In total, there are four code updates modeled in this manner.

2.4.3 DEMAND RESPONSE
Demand response programs currently exist within the Duke territory, but do not currently make use of critical peak pricing and technological approaches that are now proven leading programmatic designs to establish price sensitivity and ensuring smart grid integration as a power-saving tool. The vast majority of customers served by Duke have been provided advanced metering infrastructure (more than 90% of residential and commercial customers in both DEC and DEP), but there are no critical peak pricing programs.

Since new technologies must be deployed to take advantage of this potential, the realization of the savings are phased in over a ten-year period, similar to energy efficiency. The cost of direct load control technologies and installations are taken from industry suppliers (such as Cooper Industries) and program and administrative costs reported for other efficiency programs by Duke.

2.4.4 ENHANCED RENEWABLE ENERGY PENETRATION
Many types and configurations of renewable energy are modeled to meet electricity demand in North Carolina in both the Business-As-Usual and the Cleaner Energy Plan. In the Cleaner Energy Plan, solar, wind, and energy storage are added to the system above BAU levels to meet electricity demand in a least-cost fashion, albeit with some technical, economic, and regulatory restrictions on their deployment. The assumptions behind each of these resources and their deployment trajectory follows.

**Solar**
The hourly generation of solar sited in North Carolina is determined using the PVWatts model developed by the National Renewable Energy Laboratory. The lower bound of the generation range produced by the model is used in this study due to experience in comparing PVWatts model outputs to observed generation in Southeastern contexts. This assumption applies for solar in both utility-scale and distributed generation configurations. Panel technical performance is assumed to degrade at 0.5% per year while new panel efficiency improves at 0.25% per year.

Distributed solar capacity is deployed in accordance with the revealed consumer behaviors in North Carolina. The price elasticity of demand for consumers observed over the past several years is used to project future demand in light of projected declines in total installed cost for this customer segment. In addition, a short-lived psychological response to achieving grid-parity, observed in more than a dozen other states, is incorporated into the modeling of distributed generation photovoltaic adoption.

Utility-scale solar deployments in North Carolina have been largely dictated by regulatory and policy decisions. Both Duke utilities are expected to add significantly to their solar portfolios to keep track with the North Carolina Renewable Energy and Energy Efficiency Portfolio Standard requirements. However, instead of stalling after the REPS targets have taken full effect, the Cleaner Energy Plan continues to add to the solar portfolios of both utilities, as the recent Daymark Energy Advisors study has shown is economic. By 2028, Duke Energy Carolinas is anticipated to have roughly 4 gigawatts of solar capacity integrated onto their system, while Duke Energy Progress is modeled as achieving 6.7 gigawatts.

**Wind**
The generation characteristics for wind are derived from the Wind Prospector tool developed by the National Renewable Energy Laboratory (NREL). New wind capacity is modeled both in North Carolina and wheeled in from other states; in North Carolina, wind generation profiles for northeastern coastal North Carolina are utilized, while wheeled power profiles are taken from Stillwater, Oklahoma, and near Lubbock, Texas. Current costs for power purchase agreements are taken from U.S. DOE’s Wind Technologies Market Report, while costs for in-state builds are taken from the 2016 EIA Capital Cost report.

**In-state Development**
New wind capacity is added to the Duke Energy Progress territory, reviewing NREL estimates of cost-effective coastal locations. While there is a cost-effective wind resource in western North Carolina, current regulations limit development prospects and amendments to these regulatory barriers are not
incorporated into the modeling. New wind in Duke Energy Progress is timed to maximize financial benefits, aiming to take advantage of anticipated cost declines while still receiving the maximally-beneficial tax treatment, targeting developments that break ground in the 2018-2019 time frame.

**Delivered Wind**

In addition to the capacity available for development within North Carolina, utilities could also procure wind resources through transmission projects currently underway, intended to deliver Midwestern wind resources to the Southeastern United States. In this case, both utilities are modeled as making significant

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Table 2-3 Duke Energy Carolinas (DEC) Generating Capacity and Reserve Margin under the Cleaner Energy (CE) Plan

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BAU – System Total Capacity (MW)</strong>*</td>
<td>16,892</td>
<td>16,958</td>
<td>16,359</td>
<td>16,404</td>
<td>16,811</td>
<td>16,825</td>
<td>17,021</td>
<td>17,026</td>
<td>17,499</td>
<td>17,502</td>
<td>17,738</td>
</tr>
<tr>
<td><strong>CE – Avoided Plant and Capacity (MW)</strong></td>
<td>1,996</td>
<td>1,080</td>
<td>1,080</td>
<td>1,151</td>
<td>571</td>
<td>571</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marshall Unit 1-4</td>
<td>Belews Creek Unit 1</td>
<td>Belews Creek Unit 2</td>
<td>G.G.Allen Unit 1-5</td>
<td>Cliffside 5</td>
<td>Cliffside 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CE – Total Added Clean Resource Capacity (MW)</strong>**</td>
<td>1,565</td>
<td>2,112</td>
<td>2,926</td>
<td>3,532</td>
<td>4,162</td>
<td>4,821</td>
<td>5,510</td>
<td>6,228</td>
<td>6,975</td>
<td>7,689</td>
<td>6,604^</td>
</tr>
<tr>
<td><strong>CE – Total System Capacity (MW)</strong></td>
<td>20,726</td>
<td>20,739</td>
<td>19,763</td>
<td>18,679</td>
<td>18,701</td>
<td>17,621</td>
<td>17,129</td>
<td>16,555</td>
<td>15,698</td>
<td>15,694</td>
<td>15,694</td>
</tr>
<tr>
<td><strong>CE – Total System Peak Demand (MW)</strong></td>
<td>17,324</td>
<td>16,874</td>
<td>16,158</td>
<td>15,650</td>
<td>15,119</td>
<td>14,559</td>
<td>13,970</td>
<td>13,352</td>
<td>12,706</td>
<td>12,093</td>
<td>13,280</td>
</tr>
<tr>
<td><strong>CE – Reserve Margin</strong></td>
<td>19.6%</td>
<td>22.9%</td>
<td>22.3%</td>
<td>19.3%</td>
<td>23.7%</td>
<td>21.0%</td>
<td>22.6%</td>
<td>24.0%</td>
<td>23.6%</td>
<td>29.8%</td>
<td>18.2%</td>
</tr>
</tbody>
</table>

*Total system capacity according to DEC 2016 IRP
**Clean energy resources include energy efficiency, distributed and utility scale solar, Clean Line wind, and demand response
^ The reduction in total added clean resource capacity in 2028 relative to 2027 is due to the change in the timing of peak demand. Until 2027, DEC system is expected to experience peak demand during summer time, where solar’s contribution to meet the peak is higher compared to a winter peaking system. In 2028, DEC is expected to shift to winter peaking. As a result, solar’s contribution to meeting the peak shrinks, which leads to the drop in the total added clean resource capacity as it counts in the reserve margin analysis.

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Table 2-4 Duke Energy Progress (DEP) Generating Capacity and Reserve Margin under the Cleaner Energy (CE) Plan

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
</tr>
</thead>
<tbody>
<tr>
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<td>16,892</td>
<td>16,958</td>
<td>16,359</td>
<td>16,404</td>
<td>16,811</td>
<td>16,825</td>
<td>17,021</td>
<td>17,026</td>
<td>17,499</td>
<td>17,502</td>
<td>17,738</td>
</tr>
<tr>
<td><strong>CE – Avoided Plant and Capacity (MW)</strong></td>
<td>1,996</td>
<td>1,080</td>
<td>1,080</td>
<td>1,151</td>
<td>571</td>
<td>571</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roxboro Unit 1-4</td>
<td>Roxboro Unit 2</td>
<td>Roxboro Unit 3</td>
<td>Roxboro Unit 4</td>
<td>Mayo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CE – Total Added Clean Resource Capacity (MW)</strong>**</td>
<td>872</td>
<td>1,186</td>
<td>1,671</td>
<td>2,009</td>
<td>2,437</td>
<td>2,796</td>
<td>3,168</td>
<td>3,551</td>
<td>3,946</td>
<td>4,085</td>
<td>4,233</td>
</tr>
<tr>
<td><strong>CE – Total System Capacity (MW)</strong></td>
<td>16,512</td>
<td>15,905</td>
<td>14,608</td>
<td>14,653</td>
<td>13,839</td>
<td>13,385</td>
<td>12,684</td>
<td>12,689</td>
<td>12,694</td>
<td>11,951</td>
<td>11,719</td>
</tr>
<tr>
<td><strong>CE – Total System Peak Demand (MW)</strong></td>
<td>12,361</td>
<td>12,123</td>
<td>11,714</td>
<td>11,453</td>
<td>11,102</td>
<td>10,820</td>
<td>10,526</td>
<td>10,222</td>
<td>9,905</td>
<td>9,845</td>
<td>9,777</td>
</tr>
<tr>
<td><strong>CE – Reserve Margin</strong></td>
<td>33.6%</td>
<td>31.2%</td>
<td>24.7%</td>
<td>27.9%</td>
<td>24.7%</td>
<td>23.7%</td>
<td>20.5%</td>
<td>24.1%</td>
<td>28.2%</td>
<td>21.4%</td>
<td>19.9%</td>
</tr>
</tbody>
</table>

*Total system capacity according to DEP 2016 IRP
**Clean energy resources include energy efficiency, distributed and utility scale solar, coastal wind, Clean Line and Southern Cross wind, grid-facing battery storage, and demand response
investments in wind power delivered by two such transmission projects – the Clean Line Plains and Eastern Line, and the Southern Cross. For Clean Line, hourly generation profiles for mid-Oklahoma are used; with Southern Cross, northern Texas is the benchmark. In the Cleaner Energy Plan, Duke Energy Carolinas is only participating in purchases from Clean Line, contracting for 1500 MW, while Duke Energy Progress contracts for 500 MW from both transmission projects. Ultimate deliveries account for line losses up to and throughout the Duke Energy grid. Line losses are assumed to be substantial for the wheeled power, exceeding 20% for both the Clean Line and Southern Cross transmission projects, with 90% of those losses occurring after leaving the HVDC transmission system.

Storage
Energy storage in the form of lithium ion batteries is also included in the Cleaner Energy Plan. Storage utilization is modeled as displacing more-costly peak generation from NGCTs. Technical specifications for the battery storage systems are taken from Tesla utility-scale installations with four hours of discharge capability. Different usage patterns are in use for winter, shoulder, and summer months, with one full charge/discharge cycle in summer and shoulder months, and two modeled for winter months. Batteries are assumed to experience a 2% loss in performance year-to-year. This may represent a negative view of the technology, as the only performance improvements modeled are anticipated cost-reductions, not improvements in technical performance, which could increase the value of storage to the system. Duke Energy Progress is the only utility to make use of energy storage resources through 2028 in the Cleaner Energy Plan. In the Business-As-Usual Case, neither utility utilizes energy storage as a means of meeting electricity demand, although several projects exist to provide ancillary service such as voltage and frequency control. In its 2016 IRP, Duke Energy Progress committed to a 15 MW solar and 5 MW storage project as part of its Western Carolina Modernization Project. The project is currently at its initial planning stage; details about siting and timing of the deployment are yet to be seen.

2.5 BUILDING A LEAN, CLEAN AND RELIABLE GRID UNDER THE CLEANER ENERGY PLAN
In the Cleaner Energy Plan, the consumption of electricity grows at a realistic rate while the major grids that supply electricity to consumers become lean, clean and reliable through increased efficiency and market signals, fewer emissions, and no decrease in system reliability. Table 2-3 and Table 2-4 provide a view of DEC and DEP’s system capacity planning between 2018 and 2028 under the Cleaner Energy Plan. The rapid ramp up of economically viable energy efficiency, renewables, and energy storage technologies can meet system demands that Duke Energy planned to meet with fossil and nuclear generation. Under the Cleaner Energy Plan, both DEC and DEP are able to maintain an above-17% reserve margin between 2018 and 2028 and pass loss-of-load-hour and loss-of-load-event tests consistent with NERC standards.

2.6 ATHENIA OVERVIEW
ATHENIA is a scenario analysis model developed by The Greenlink Group. ATHENIA is comprised of several modules that solve the problem of electricity supply and demand on an hourly basis, then determine the impacts of that solution, as shown in Figure 2-2. A fully-integrated ATHENIA run will have detailed characterizations of demand and supply, and when used to compare between scenarios, a full suite of economic results, including employment effects, impacts on regional economies, net benefits (benefits minus costs), and benefit-cost ratios of various approaches to meeting electricity needs. Descriptions of each module within ATHENIA can be found in Appendix A.
This chapter explores the differences in the generation mix under the Cleaner Energy Plan from Duke Energy’s BAU case in order to understand the impact of the clean energy approach. In general, both DEC and DEP will experience a significant shift away from nuclear and fossil fuel electricity generation, especially from coal. The gap left by retiring existing coal plants and the avoidance of new fossil-fueled capacity is mostly replaced by renewable generating capacity, energy efficiency, demand response, and battery storage. NGCTs will also see some increase in their total contribution to grid demands, although at a much lower level than clean energy resources. The result is an electricity system that does not rely on the continuous expansion of centralized thermal plants to meet growing demand. Rather, clean energy resources and load management approaches create a grid that is lean (i.e. more efficient and responsive to market signals), clean, and reliable in providing electricity service. The remaining sections of this chapter examine in detail the new patterns of electricity generation under the Cleaner Energy Plan.

3.1 A NEW ELECTRICITY PRODUCTION PARADIGM IN NORTH CAROLINA

3.1.1 A GRID WITHOUT COAL

The Cleaner Energy Plan demonstrates how Duke could operate a coal-free electricity grid by the year 2028 with the right investments. This calls for a significant departure from Duke Energy’s proposed pathway. In this case, the demand for electricity grows at a slower pace, as shown in Figure 3-1. In contrast, Duke projects electricity demand will grow more than 13% during the same period in the BAU scenario. In the year 2028 alone, the Cleaner Energy Plan shows a 45 million MWh reduction in electricity generation needs, saving fuel costs for the utilities as well as creating economic and environmental benefits for the state.

One of the most noticeable trends under the Cleaner Energy Plan is the disappearance of coal-fired generation over time. According to the economic criteria, all seven coal plants on Duke Energy’s North Carolina system are defined as costly. Compared to resources such as solar and wind, which have no operating cost and low maintenance costs, coal-fired power plants are uneconomical. Even in relationship to other fossil fuel power plants such as NGCC and NCGT, coal plants are more expensive to operate and to maintain. As a result, they are phased out over a ten-year period. Tables 2-3 and 2-4 show the timing of the retirement events; the more expensive a coal plant is, the earlier it will be retired. The impact of the retirement is illustrated in Figure 3-1 as coal’s share in North Carolina’s electricity generation mix declines over time and eventually disappears by 2028.

3.1.2 GENERATION SHIFTS BETWEEN GAS TECHNOLOGIES

Within the fossil fuel family, the importance of gas fired generating capacity will also decline under the Cleaner Energy Plan relative to the BAU scenario, resulting in 5.3 million MWh less electricity generation from NGCCs and NGCTs as a whole in 2028. NGCC generation sees the most significant reduction, decreasing from 40.8 million MWh in 2028 in the BAU scenario to 20.6 million MWh in the Cleaner Energy Plan. The decline in production is largely due to the avoided addition of 2 new NGCC plants in DEC and DEP territories, totaling 2,442 MW generating capacity. In addition, lower electricity demand from consumers also leads to slightly lower utilization rates of existing NGCC plants.

In comparison, the NGCT fleet will experience an increase in production of 140% in 2028 in the Cleaner Energy Plan relative to the BAU scenario. In the same way that the Cleaner Energy Plan avoids the need for NGCC capacity expansion, it also avoids 2,058 MW of additional new NGCT capacity. However, unlike NGCCs, where all the avoided capacity would have come on line by 2023, over 70% of the avoided NGCT capacity would have come online between 2024 to 2028. Partially as a result, existing NGCT plants show an increase in their generation levels. Under the BAU scenario, NGCT plants in DEC and DEP are only used 4% of the time on average, which means that they have room to increase their electricity production, a fact that is exploited in the Cleaner Energy Plan.

As shown in Figures 3-1 and 3-2, NGCT plants become the second largest source of electricity generation in 2024, overtaking both coal and NGCCs. By the end of 2028, NGCTs will generate about 26.8 million MWh of electricity, accounting for over a quarter of the electricity generated from centralized power plants in Duke Energy’s system in the Cleaner Energy Plan. Overall, this still represents less gas generation than in the BAU scenario.
3.1.3 THE RISING RELATIVE IMPORTANCE OF NUCLEAR POWER

Nuclear power plants remain a stable source of electricity production under the Cleaner Energy Plan, although their electricity generation level shrinks over time due to slower demand growth. One new additional nuclear unit, rated at 1,117 MW capacity and scheduled to start generating electricity in 2027, is avoided in this scenario, making the reduction in nuclear electricity generation relative to BAU even bigger in the final two years of the study horizon. By 2028, nuclear power will produce 68 million MWh of electricity in the Cleaner Energy Plan, 20% lower than BAU levels. Nevertheless, Duke Energy will become more reliant on nuclear over time, as its energy contribution to Duke’s conventional power plant fleet rises from 47% in 2028 under the BAU scenario to 70% in the Cleaner Energy Plan. A majority of Duke Energy’s centralized generation could become carbon free since as early as 2020 (Figure 3-2).

3.1.4 TRIPLING THE CLEAN ENERGY CONTRIBUTION IN A DECADE

By 2028, clean energy resources’ contributions to the grid will grow three times as large as in 2018 under the Cleaner Energy Plan, doubling the BAU level electricity production (or savings, as is the case with energy efficiency) by as early as 2026. By the end of 2028, clean energy resources, including energy efficiency, distributed and utility-scale solar, in-state wind development as well as wind purchases from the Clean Line and Southern Cross projects, demand response, grid-facing battery storage, hydroelectric power, and pumped storage, will account for 23% of the total electricity generation on Duke Energy’s system, making clean energy the second largest source of electricity production, after nuclear power.

Figure 3-3 shows the progression of the clean energy resources as they penetrate Duke Energy’s system. Solar is the largest resource under both scenarios, yet the Cleaner Energy Plan doubles the amount of solar electricity generation in the BAU scenario by 2028, reaching 16 million MWh, representing over 10% of the total electricity generated on the Duke Energy system.

Wind is the second largest clean energy resource, after solar. Even without any new wind capacity in the mountain region due to the limitations imposed by the Ridge Law, wind provides about 5% of North Carolina’s total electricity generation by 2028, one sixth of which comes from in-state coastal wind projects.

Energy efficiency’s growing contribution to system demand reductions is also a key part of the Cleaner Energy Plan. Cumulatively, it will reduce electricity generation by 36 million MWh, leading to lower utility costs and customer bills.
Although the MWh contributions of demand response and battery storage are small in the Figure 3-3, they make critical contributions when the grid experiences stress. With these two types of resources, Duke Energy’s system operators will be able to control its peak demand, add flexibility to the system, manage voltage, and maintain reliability. Figure 3-4 highlights the Cleaner Energy Plan’s drastic departure from the BAU scenario in resource mix. The elimination of coal and the growth of clean energy resources are two most significant changes.

With the combination of all the above-mentioned clean energy resources as well as conventional hydropower and pumped storage, whose generation remains constant, the Cleaner Energy Plan enables the electric grid in North Carolina to be lean, clean, and reliable at the same time. A reserve margin test and a Loss of Load Hour (LOLH) test find the resource mix under the Cleaner Energy Plan can allow both DEC and DEP to maintain a reliable grid and quality service to their customers while retiring all seven coal plants early and avoiding the financing and construction of new NGCC, NGCT, and nuclear capacities between 2018 and 2028. One of the key components in the Cleaner Energy Plan is the concerted effort to reduce electricity demand in peak hours, discussed in the next section in detail.

### 3.2 Peak Demand in North Carolina

The Cleaner Energy Plan has a number of measures that focus on saving customers’ money while providing the same services and comforts from electricity, including an aggressive pursuit of energy efficiency, utilizing cost-effective distributed solar, and automated technology-enabled demand response programs. Together, these cost saving measures produce significant reductions on system load and peak load for Duke Energy.

With the clean energy measures, the North Carolina Duke Energy system will experience its peak demand in the summer, as opposed to winter under the BAU scenario. The automated demand response programs introduced in this study do most of the heavy lifting in terms of reducing winter and summer peaks. Distributed solar and utility-scale solar are crucial in reducing late afternoon and early evening peak demands in both summer and winter days. As a result of the combination of multiple clean energy measures, the peak demand on Duke Energy’s overall system is projected to be just above 26,000 MW in 2028, compared to over 32,000 MW under the BAU scenario, representing a reduction of approximately 18%. Moreover, this summer peak occurs during early evening hours on a late summer day as opposed to mid-summer days in the BAU. This is helpful in terms of
avoiding situations like the “duck curve” where utilities experience large swings between peak hours and low-demand hours due to daily electricity demand patterns and the contribution of clean energy, primarily solar energy, during the peak hours.

Winter peak demand under the Cleaner Energy Plan is 25,000 MW, about 1,000 MW lower than the summer peak demand. The individual utilities experience peak demand at different times. For DEC, peak demand occurs during the early morning in winter, whereas for DEP the highest demand happens in early evening in mid-summer.
CHAPTER 4: ECONOMIC BENEFITS TO NORTH CAROLINA RATEPAYERS AND THE STATE ECONOMY

4.1 ELECTRICITY BILL SAVINGS
The Cleaner Energy Plan allows market forces to drive distributed solar adoption and ramps up energy efficiency and demand response programs significantly to reduce customers’ electricity consumption. As a result, residential and non-residential customers experience overall savings in their energy bills. Despite humble beginnings, they ramp up quickly and eventually produce a cumulative savings of $5.4 billion for DEC and DEP customers (Figure 4-1). The average customer in both DEC and DEP territories will begin to experience reductions in electricity bills from 2020 onward. By 2028, residential customers will see an average $101 reduction in their annual electricity bills relative to the BAU; non-residential customers (commercial and industrial customers) will experience a $611 dollar annual electricity bill saving.

Customers in DEP will experience slightly higher bills in 2018 and 2019. This is due to the retirement of over 2 GW of coal capacity in these two years; if allowed, the retirement costs incurred by the utility will be passed on to the customers through rate adjustments, leading to higher electricity bills. The electricity savings achieved by DEP customers in those two years are not big enough to offset the rate increase, leading to higher average electricity bills. Nevertheless, in the following years, the higher electricity rates will be more than offset by demand savings. Given the overall savings achieved by the Cleaner Energy Plan, the costs from the early retirements could be spread over more years to provide savings in all years of the projection.

4.2 ECONOMIC GROWTH AND JOB CREATION
Investment pathways are significantly modified by the introduction of the Cleaner Energy Plan. Because of these changes, the overall economic picture for North Carolina faces some substantial deviations. For example, retiring power plants, building new ones, and pursuing energy efficiency drive increased work opportunities in construction and technical support fields, while cancelled power plants and reduced utility bills reduce overall labor needs in the utility sector. There’s also an impact in the broader economy; when less money is taken from ratepayers to fund utility investments, North Carolinians have increased disposable income that can be spent elsewhere in the economy, inducing job creation in other sectors. These investment pathways do more than simply impact job creation in North Carolina; there are also implications for the incomes of North Carolinians and the overall GDP of the state.

Figure 4-1 Electricity Bill Savings in DEC and DEP, BAU vs. Cleaner Energy Plan
A range of economic development impacts is presented as a High and Low case, representing variations in the economic dimensions of induced investments. In the High case, the induced economic activity occurs entirely within North Carolina, while in the Low case, only 50% of the impact of induced activity takes place in state. These are presented as high and low bounds, with reality likely falling somewhere in the middle.

4.2.1 EMPLOYMENT
Employment is measured in job-years, the amount of work expected to be completed by one full-time employee in one year. All clean energy sectors see a net increase in employment from the Cleaner Energy Plan, relative to the BAU case. Solar job creation leads these sectors, averaging a 4,000-employee increase over the decade with a 2021 peak. Efficiency is the second-largest driver, with the largest impacts in 2018 and 2026-2028. Utility jobs generally see a decrease, averaging a decline of about 1,500 jobs per year. Exceptions occur in 2018 and 2028; in 2018, jobs related to the retirement of specific plants provide a net gain of employment, and in 2028, utility-scale energy storage needs produce net job gains for the sector. Induced employment effects represent the single-largest source of jobs, seeing an average increase of 4,800-9,600 jobs, with 2020-2022 representing the largest job gains. In total, there is a gain of 125,000 to 173,000 job-years in clean energy and induced sectors, while the utility sector sees a loss of 16,000 job-years. The resulting net impact from the Cleaner Energy Plan is an increase in employment in North Carolina, ranging from 109,000 to 157,000 job-years through 2028.

4.2.2 INCOME
Not all jobs are created equal; an increase in employment could coincide with a decline in incomes if the new jobs are low paying. This turns out not to be the case in the comparison between the Cleaner Energy Plan and BAU. Peak-year income impacts for individual sectors align with their peak employment years. Solar again leads, with incomes increasing by nearly $2.5 billion over the modeled horizon. Energy efficiency adds another $1.4 billion, while the utility-sector-dependent incomes decline by $1.8 billion. As with jobs, induced income effects are the single largest contributor, adding $2.6 billion to $5.2 billion. Average net income impacts are $88 million to $135 million, resulting in a net increase in incomes of $4.8 billion to $7.7 billion through 2028.

4.2.3 GDP
The Cleaner Energy Plan will also have an impact on North Carolina’s GDP. For clean energy sectors, solar again leads, contributing an additional $3.5 billion to state GDP; efficiency adds another $2.2 billion. In 2019, wind energy development is the leading clean energy GDP producer, adding $142 million to the pie. However, unlike the jobs and income categories, there are no years where the net effect of the Cleaner Energy Plan is positive for the utility sector. The reduction is strongest in 2026, where investments in retiring Cliffside 6 are
offset by lost bill revenues and a nearly $750 million avoided investment in the construction of new natural gas combustion turbines and nuclear power. Induced effects again lead all sectors, adding $4.5 billion to $8.9 billion to state GDP through 2028. In total, GDP increases in the Cleaner Energy Plan by $3.7 billion to $8.2 billion.

Looking across all sectors, the Cleaner Energy Plan represents a significant net gain to North Carolina’s economic development trajectory for the next decade (Figure 4-2). While there is year-to-year variation, each year shows a positive effect on job creation, incomes, and GDP, and this conclusion holds across the projected range of likely outcomes.

CHAPTER 5. ENVIRONMENTAL, SOCIAL, AND ECONOMIC BENEFITS OF NORTH CAROLINA’S CLEANER ELECTRICITY FUTURE

A lean and clean electricity grid in North Carolina leads to efficiency in meeting electricity demand while also reducing CO2 and other air pollutant emissions, leading to a cleaner environment, better public health, less crop failures, and lower extreme-weather-related risks to the economy. Less generation from centralized fossil and nuclear plants also means lower levels of water consumption and withdrawals. This chapter articulates the environmental, social and economic benefits achieved in the Cleaner Energy Plan.

5.1 EMISSIONS REDUCTIONS

The Cleaner Energy Plan phases out all seven coal plants in Duke Energy’s North Carolina system. The impact of this change on air pollution is striking. The most significant non-CO2 pollutant emission reductions come from SO2, PM2.5 and PM10 (Figure 5-1), which are the primary pollutants associated with coal-fired power generation. With the phasing out of coal plants, cumulative SO2 emissions are 46% lower in the Cleaner Energy Plan than in the BAU scenario. Figure 5-2 further breaks down total SO2 emissions by generating technology. Coal plants are the biggest contributor of SO2, and their cumulative emissions are cut by almost half with the clean energy measures.

PM2.5 and PM10 emissions follow similar patterns, as shown in Figure 5-2. Coal-fired power plants and gas-fired plants are both major sources of particulate matter emissions. Under the Cleaner Energy Plan, the emissions of both pollutants decline significantly across technology types. Cumulative PM2.5 and PM10 emissions from coal plants shrink by more than two-thirds, although the largest reduction comes from
NGCC plants due to avoided new capacity and lower utilization of existing plants. As a result, in the Cleaner Energy Plan, PM2.5 emissions are slightly over 31,000 tons, only a quarter of the levels in the BAU. PM10 has a deeper reduction in percentage terms, achieving an 80% reduction under the Cleaner Energy Plan.

NOx emissions are reduced by 9% in the Cleaner Energy Plan relative to the baseline (Figure 5-1). However, its pattern of emission reduction is different from most other pollutants (Figure 5-2). NOx emissions from coal plants are cut nearly by half in the Cleaner Energy Plan, but ATHENIA shows emissions from NGCT plants increasing noticeably due to their increased utilization rate against the backdrop of coal-fired power plants retirement. Since NGCT plants are likely to have a high NOx emission rate (measured in tons of emission per MWh of electricity generated), this increased generation level leads to an increase in NOx emissions.

CO2 emissions are reduced across coal-fired plants and NGCC plants but increase among NGCT plants, changes that are all commensurate to the generation change discussed in Chapter 3. Section 5.3 will provide more details about the CO2 emissions pattern.

5.2 AVOIDED SOCIAL AND ECONOMIC DAMAGES

The link between air pollutant emissions and a suite of social and economic damages is well established. For non-carbon air emissions, this study relies on the Air Pollution Emission Experiments and Policy Analysis Model (AP2) to articulate the damages associated with emissions’ adverse effects on human health, yields of agricultural crops and timber, visibility, and enhanced depreciation of man-made materials, as well as damages due to lost recreation services. In terms of CO2 emissions, the social damages are calculated using the Technical Update to the US Federal Government’s Interagency Working Group Social Cost of Carbon 3% Average case. Social cost of carbon accounts for changes to agricultural productivity, sea level rise, rainfall changes, extreme weather and risks to human health. Appendix D describes in detail the methodology and analytical model used to calculate the monetary value of the damages. This section presents the social and economic welfare benefits resulting from the Cleaner Energy Plan.

Figure 5-3 compares the total damages associated with all seven pollutants tracked by ATHENIA over time under the two scenarios modeled in this study. Overall, the Cleaner Energy Plan reduces the total social and economic damages associated with electricity generation by a total of $21 billion between 2018 and 2028, a 45% decline from the BAU scenario. This means that the changes to the resource-mix in North Carolina is going to create positive outcomes for North Carolinians and residents in neighboring states, allowing them to enjoy better health, a cleaner environment and fewer crop failures.

Among all benefit categories, public health is one area that benefits significantly with cleaner electricity supply. It has long been understood that emissions have an impact on public health. Table 5-1 shows the impact of the Cleaner Energy Plan on public health outcomes nationwide. Across all categories, outcomes improve. Through 2028, adult mortality declines by more than 1,000, non-fatal heart attacks drop by more than 400, visits to the emergency room prompted by asthma decline by more than 400, and the national economy experiences 93,000 fewer lost work days due to sickness. On average, North Carolina is the direct recipient of 24% of the benefits across all categories.

From a generating technology perspective, the phasing-out of coal plays a significant role in improving social and economic outcomes. Among the $2.5 billion of avoided damages in 2028 under the Cleaner Energy Plan, the majority are derived from avoided CO2 and SO2 emissions, both of which are linked primarily to coal-fired generation (Figure 5-4).

Eliminating the need for new NGCC capacity additions beyond 2018 under the Cleaner Energy Plan also contributes to reducing social and economic damages resulting from the burning of gas. In 2028 alone, the value reaches $800 million. Cumulatively, the avoided damages from reduced NGCC operations adds up to $8 billion by 2028.

A portion of the social and economic benefit resulting from less coal and NGCC generation is offset by the increased use of NGCTs. As previously discussed, NGCT plants show an increase in generation from 2022 onward. Most noticeably, CO2, NOx, SO2, and VOCs emission levels are higher from NGCT sources in the Cleaner Energy Plan than in the BAU scenario. As a direct result, NGCT-related damages are higher in the Cleaner Energy Plan each year between 2022 and 2028, except for 2023. By 2028, damages related to electricity production from NGCT are $0.5 billion higher. Although the social and economic damages associated with NGCTs are lower in the Cleaner Energy Plan in five of the eleven years studied, the cumulative impact is $1.4 billion higher than the BAU Scenario.
From a generating technology perspective, the phasing-out of coal plays a significant role in improving social and economic outcomes. Among the $2.5 billion of avoided damages in 2028...

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**Figure 5-3 Damages from All Pollutant Emissions, BAU vs. Cleaner Energy Plan**

**Table 5-1 Avoided Medical Events**

<table>
<thead>
<tr>
<th>Medical Events</th>
<th>Adult Mortality</th>
<th>Infant Morality</th>
<th>Non-fatal Heart Attacks</th>
<th>Respiratory Hospital Admission</th>
<th>CVD* Hospital Admission</th>
<th>Acute Bronchitis</th>
<th>Upper Res Symptoms</th>
<th>Lower Res Symptoms</th>
<th>Asthma ER Visits</th>
<th>MRAD**</th>
<th>Work Loss Days</th>
<th>Asthma Exacerbations</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Avoided events</td>
<td>1,212</td>
<td>2</td>
<td>463</td>
<td>210</td>
<td>264</td>
<td>1,065</td>
<td>19,404</td>
<td>13,578</td>
<td>410</td>
<td>556,371</td>
<td>93,262</td>
<td>20,560</td>
</tr>
</tbody>
</table>

*Cardiovascular Disease

**Minor Restricted Activity Days

Table 5-1 Avoided Medical Events
In summary, the Cleaner Energy Plan will create a cleaner environment, better public health outcomes, result in fewer crop failures, and lessen chances for extreme weather events for the state of North Carolina and beyond. It is worth noticing that the majority of the emissions reductions and the social and economic benefits come from CO2 emission reductions (Figure 5-4). The next section zooms in to the plant level to examine the changing pattern in CO2 emissions.

5.3 REDUCTION IN CO2 EMISSIONS AND THE ASSOCIATED SOCIAL AND ECONOMIC BENEFITS

With the Cleaner Energy Plan’s shift in electricity generation to clean resources, there are significant reductions in CO2 emissions and avoided public health damages. Figures 5-5 and 5-6 provide a comparison of social and economic damages associated with CO2 emissions at the plant level between the BAU Scenario and the Cleaner Energy Plan in 2028. Each color represents a unique technology type and the size of the bubble reflects the level of social and economic damage. The most noticeable difference between the two scenarios is in the steam coal category. Following the retirement schedule introduced in the Methodology section, the last coal-fired unit will be retired in 2027, making 2028 the first coal-free year under the Cleaner Energy Plan. As a result, 34.5 million metric tons of CO2 emissions from coal plants in the BAU scenario will be eliminated under the Cleaner Energy Plan, creating a $2 billion benefit.

Another significant change is the use of clean energy to avoid the financing and construction of new gas capacity. Without building new NGCC and NGCT plants, 1.6 million metric tons of CO2 emissions will be avoided in 2028 alone. Cumulatively, 37.5 million metric tons of CO2 emissions will be avoided between 2018 and 2028, producing a $3.6 billion benefit.

Finally, CO2 emissions from NGCT plants increase as their generation level rises in the Cleaner Energy Plan. Cumulative CO2 emissions and damages more than double between 2018 and 2028 relative to the BAU scenario. However, the increase from NGCT plants is small in comparison to the decline of coal- and NGCC-related emissions.

5.4 SAVINGS IN WATER CONSUMPTION AND WITHDRAWALS

The Cleaner Energy Plan also creates benefits to North Carolina’s bodies of water. Reducing electricity generation from the centralized power generation system significantly lowers the amount of water required to providing cooling services to the thermal plants.
Figure 5-5 CO2 Emission Damages in 2028 (2015-$), BAU
Note: The locations of the new NGCC and NGCT plants in DEC and DEP are placeholders. Actual locations are not yet known.

Figure 5-6 CO2 Emission Damages in 2028 (2015-$), Cleaner Energy Plan
Note: The locations of the new NGCC and NGCT plants in DEC and DEP are placeholders. Actual locations are not yet known.
Coal-fired power plants and nuclear plants are particularly “thirsty” when it comes cooling water needs. The early retirement of coal plants (beginning in 2018) leads to significant reductions in cooling water withdrawals throughout the modeling horizon of this study. In 2018, the withdrawal of approximately 1.9 trillion gallons of water will be avoided due to the retirement of Marshall Units 1-4 and Roxboro Unit 1, which combined represent over 2.4 GW of coal-fired capacity. This water withdrawal saving represents a 41% reduction from the BAU scenario, and continues to grow over the following decade, eventually exceeding 2.8 trillion gallons in 2028, a 62% reduction from the baseline. Figure 5-7 shows the comparison between the two scenarios.

It is important to notice that most of the coal plants and nuclear plants in Duke Energy’s system use once-through cooling technology. An overwhelming majority of the water withdrawn to cool these plants will eventually be returned to the waterbody (although the temperature may be higher than that of the normal waterbody), making the actual water consumption only a small fraction of the total water withdrawals - usually less than one percent. For example, in 2028 under the Cleaner Energy Plan, water consumption is projected at 13.5 billion gallons, compared to 1.7 trillion gallons of water withdrawal. Like the change in water withdrawals, water consumption declines remarkably with the expansion of clean energy. Water consumption in the Cleaner Energy Plan is less than half of that in the BAU. Cumulatively, 53 billion gallons of water consumption are avoided under the Cleaner Energy Plan relative to BAU.
Chapter 6. Overall Benefit-Cost Analysis

Previous portions of this report have evaluated the various impacts that accelerating the transition to clean energy would have for North Carolina in areas like reliability, the environment, public health, and economic development. The final remaining question is whether this approach is cost-effective policy – that is, does it provide net benefits? Results from all other sections are pulled together and evaluated in this section to tally the benefits and the costs of this policy scenario relative to the Business-As-Usual case to determine overall cost-effectiveness. Values are presented at both 3% and 7% discount rates to provide a range of results. Each number discussed in the text reflects this range; in general, the 3% discount rate shows a higher dollar value. Transfer payments, where one party’s benefit is another party’s cost, are not included in this section of the analysis; while these may be of interest from a distributional and equity point-of-view, they have no bearing on the overall cost-effectiveness of the policy. Please see the other sections of this report where such costs and benefits are presented in detail. Costs and benefits are assessed through 2045 to recognize that social, technological, and economic decisions have multiyear impacts in this space and to capture the expected lifetime impacts of deviations from one scenario to another.

6.1 Benefits

There are two major streams that emerge as net benefits in the Cleaner Energy Plan – avoided social and economic damages from emissions reductions and reduced utility operating costs.

Damages associated with emissions are lower in every year relative to the Business-As-Usual case, averaging an improvement of $1.1 billion - $1.4 billion per year through 2028. 2025 provides the single greatest savings, at $1.4 billion - $2 billion in that year. By 2020, the cumulative avoided social and economic damages are worth $2.5 billion - $2.8 billion, growing to $14.1 billion - $19.5 billion in 2030 and $23.5 billion - $40.5 billion through 2045.

Utility operating costs (both fixed and variable) are also consistently lower in the Cleaner Energy Plan. Through 2028, they average savings of $1.8 billion - $2.3 billion per year, peaking in 2023 at $1.9 billion - $2.5 billion. In 2020, the cumulative value of these savings is worth $5.2 billion - $5.9 billion, growing to $22.5 billion - $30.7 billion by 2030, and reaching $35.7 billion - $59.9 billion over the entire period.

The combination of these values represents the net set of benefits provided by the Cleaner Energy Plan relative to the Business-As-Usual case. Table 6-1 shows the cumulative results for all types of benefits as well as the total, which by the end of the analysis period reach $59.2 billion - $100.5 billion.

6.2 Costs

There is also one major cost category in the Cleaner Energy Plan. This is the net impact on investments, including any associated administrative and program costs, regardless of the system participant making the investment (for example, this category includes the cost incurred of installing and interconnecting distributed generation at a home by a homeowner as well as the cost of retiring existing power plants borne by utilities). This category generally covers investments made in equipment and operating programs across all stakeholders. Variations in the cost metrics are substantial, ranging from costs of $550 million - $720 million to $400 million - $490 million in savings, due to the change in the schedule of investments and the elimination of new capacity additions that occur in the Business-As-Usual case. In the average year, the present value of investments ranges from -$114 million - $92 million, suggesting this cost category may be providing benefits, depending on the discount rate used. In any case, there are early substantial cost savings, as shown in Table 6-2 below.

Overall, the Cleaner Energy Plan is significantly more cost-effective than the BAU case. In total, the state of North Carolina is expected to see billions of dollars in net benefits from the Cleaner Energy Plan. When the full impact of the scenario is tallied up and benefits and costs are compared, the cumulative net gain ranges from $59 billion - $100 billion, as shown in Table 6-3.
A Pathway to a Cleaner Energy Future in North Carolina

CHAPTER 7. MOVING TOWARDS A CLEAN ENERGY FUTURE

7.1 A LEAN, CLEAN, AND RELIABLE ELECTRIC GRID IS WITHIN REACH IN NORTH CAROLINA

North Carolina is standing at a crossroads regarding its energy future. It could continue its current fossil fuel and nuclear-centric path, or it could choose a cleaner energy future where a large portion of its electricity demand is met by resources such as energy efficiency, distributed and utility-scale solar, wind, hydro-electric power, demand response, and energy storage technologies. Both approaches can maintain the reliability of the grid. This study designs a Cleaner Energy Plan that allows the state to develop the resources needed to realize a cleaner energy vision and the benefits it creates.

Under the Cleaner Energy Plan, North Carolina will see the retirement of all seven coal plants on Duke Energy Carolinas and Duke Energy Progress’ system between 2018 and 2027. The decision to retire the coal plants is rooted in economic analysis: their high operating costs render them expensive options to serve North Carolinians in the long term.

Furthermore, the Scenario introduces aggressive automated demand response programs and energy efficiency programs that allow customers in the state to harness economically-viable demand reduction and energy efficiency potentials. The combination of the two approaches leads to lower peak demand during critical hours and lower electricity consumption in general relative to the business-as-usual case, both of which are impactful in shaping the resource mix and capacity needs of the Duke Energy system.

On top of demand-side approaches, electric utilities and their customers in North Carolina also take advantage of cost-effective renewable and energy storage technologies under the Cleaner Energy Plan. As the costs of renewable and storage technologies fall overtime, more capacity will be added to the system year-over-year. Combined with demand response and
energy efficiency, this further reduces peak loads and electricity demands faced by Duke Energy's centralized generation system.

The result of adding the clean energy resources is profound. Lower peak demand means that the two Duke utilities can avoid building new NGCT plants, whose primary purpose is to serve peak load. In the meantime, the growth of overall electricity demand is also slower, which makes the NGCC and nuclear capacity additions proposed in DEC and DEP's 2016 IRPs unnecessary. Reserve margin and Lost of Load Hour (LOLH) tests conducted for this study found that DEC and DEP can maintain a reliable grid with quality service to their customers, retire all seven coal plants, and avoid building new NGCC, NGCT, and nuclear plants between 2018 and 2028, if they recognize and pursue the potential of clean energy resources.

7.2 HARNESSING THE ENERGY, ENVIRONMENTAL, AND SOCIAL BENEFIT OF A CLEAN ENERGY FUTURE

The impact of the Cleaner Energy Plan is significant and long-lasting. The aggressive pursuit of energy efficiency and demand response reduces the peak load faced by the Duke Energy system by 18% in 2028. With a realistic outlook of future demand and consumption growth that is grounded in historical data, the Cleaner Energy Plan will see more than 20% of the electricity demand in North Carolina met by clean energy resources in 2028 (Figure 3-1).

A significant fuel mix change will also occur for Duke Energy's centralized system with the Cleaner Energy Plan. In general, both DEC and DEP experience a significant shift away from coal, nuclear and NGCC generation to clean energy resources such as solar, wind, and battery storage (Figure 3-1). Within the fossil fuel family, coal-fired power plants are phased out entirely by 2028. NGCT plants will generate more electricity under this scenario compared to the baseline. (Figure 3-2).

In contrast to the diminishing role of fossil generation, clean energy resources experience tremendous growth under the Cleaner Energy Plan, responsible for meeting 23% of the total Duke Energy system load in 2028. Solar becomes the largest clean energy resource in the scenario, producing nearly 16 million MWh of electricity in 2028, more than twice as much as its contribution in the BAU scenario. The new wind capacity in northeast North Carolina and wind energy purchases from the Clean Line and Southern Cross projects make wind the second largest clean energy resource in the state (Figure 3-3). Energy efficiency's contribution to reducing electricity demand will ramp up from its current level of 0.4% to 4% by 2028, a remarkable ten-fold growth. Albeit small in energy terms, demand response programs are critical for managing peak demands, when the grid benefits from power reductions for maintaining its reliability and cost-effectiveness. Altogether, clean energy resources become a substantial component of North Carolina's energy mix.

As the electric grid becomes leaner and cleaner, a suite of environmental, social, and economic benefits appears. From an environmental perspective, the emission levels of all six non- CO2 pollutants are lower under the Cleaner Energy Plan than the BAU scenario (Figure 4-2). Cumulatively and across pollutant types, nearly 47% of emissions will be avoided. Similarly, over 160 million metric tons of CO2 emissions will be avoided between 2018 and 2028.

Cleaner electricity supply is also associated with better public health, less damages to agriculture products and infrastructure due to extreme weather events. Because airsheds cross borders, the social and economic benefits due to a cleaner grid in North Carolina will produce better outcomes in the state and beyond. The largest contributor of improved social and economic welfare is avoided CO2 emissions, which create about $3.6 billion in benefits. Overall, the Cleaner Energy Plan reduces total social and economic damages associated with electricity generation by a total of $21 billion between 2018 and 2028, a 45% decline from the BAU scenario (Figure 5-3).

With the retirement of water-intensive coal-plants and the avoided construction of a new nuclear unit, water consumption is 53 billion gallons less in the Cleaner Energy Plan than the BAU scenario. Watershed withdrawals drop by trillions of gallons.

Jobs, incomes, and GDP are all higher in the Cleaner Energy Plan than in the BAU. Due to variations in how much induced economic development will occur within state borders, the results show a range of probable outcomes. The net impact on employment with the Cleaner Energy Plan is an increase, ranging from 109,000 to 157,000 job-years through 2028. Incomes would experience a net increase of $4.8 billion to $7.7 billion, while North Carolina's GDP increases by $3.7 billion to $8.2 billion. Overall, economic development is accelerated by the Cleaner Energy Plan.

In addition to cleaner air, a better economy, and improved public health and welfare, North Carolina electricity ratepayers also enjoy a tangible benefit
on their electricity bills. The reduction in electricity demand due to energy efficiency, demand response, and distributed renewable resources means that they will purchase less electricity and therefore, pay less on their monthly electricity bills. The savings ramp up quickly after a modest start in 2018 and 2019, and eventually reach a cumulative savings of $5.4 billion for DEC and DEP customers.

Lastly, the Cleaner Energy Plan is significantly more cost-effective than the BAU case. The results are sensitive to the choice of discount rate. When the full impact of the scenario is tallied up and benefits and costs are compared, the cumulative net gain to the state ranges from $59 billion to $100 billion dollars. From a societal perspective, this is highly suggestive that the Cleaner Energy Plan would be a better pathway for North Carolina than the BAU.

Given the full suite of results produced by ATHENIA in comparing the BAU and the Cleaner Energy Plan, it appears that the Cleaner Energy Plan is a much more attractive development pathway for North Carolina. Economic opportunities are greatly expanded, environmental damage is much-reduced, and social outcomes are significantly better than under the BAU trajectory. Overall, these results suggest the Cleaner Energy Plan represents a more desirable and sustainable future for North Carolina, its businesses, and its residents.

APPENDIX A. DESCRIPTION OF ATHENIA MODULES

DEMAND-SIDE MODULE
Sector-specific electricity demand profiles are constructed using the widely-adopted Department of Energy E+ model, specified to the median characteristics of buildings of a specific age, type and quantity in the region under study, as reported in the 2012 Commercial Building Energy Consumption Survey and the 2009 Residential Energy Consumption Survey. In total, 85 E+ model building profiles are used to replicate the hourly demands of the residential and commercial sectors, representing over 400 specific end-use profiles. These profiles are then aggregated based on weights produced to represent each building type’s presence as a percent of the overall sectoral demand, then fitted to the reported annual demand from the sector for each utility to generate hourly estimates of demand from each sector using historical data.

Demand-side efforts serve as an adjustment to the signal. Electricity consumption reductions achieved through energy efficiency programs are taken from historical values. Anticipated growth in on-site renewable energy deployment is also captured by using a price elasticity of demand relationship for the state of North Carolina, calculated from historical prices and quantity-deployed values (these values come from several industry publications, including groups such as the Solar Energy Industry Association, Green Tech Media, the Energy Information Administration, and others).

Photovoltaic (PV) performance values are derived from the National Renewable Energy Laboratory’s PVWatts. After these anticipated demand-side efforts are accounted for, an adjusted demand signal is produced. Hourly historical total demand data is reported to FERC; the difference between the residential and commercial demands and the total represents industrial demand and wholesale power transfers in each hour. Summing the residential, commercial, industrial and wholesale data thus reproduces the historical FERC data. Future demand is then calculated per the growth rates reported in the IRPs or the Annual Energy Outlook, as appropriate.

SUPPLY-SIDE MODULE
Historical data on plant and unit operations is collected from the US Environmental Protection Agency, the US Energy Information Administration, the Federal Energy Regulatory Commission, SNL Financial, and Bloomberg LP. A profile is constructed for each electricity-generating unit, covering aspects from generation and capacity to emissions, water usage, and financial operating data. Roughly 35,000 data points are collected for each electricity generating unit and processed through ATHENIA’s machine learning algorithms, which produce information on unit availability (a simulation of each unit’s probability of an outage and the probable duration of an outage for a specific unit) and unit behavior (how a unit responds to a shift in demand as well as a shift in the other resources that are available to meet demand in the system). This information is trained on historical data until each unit is correctly predicted with under 1% error in each hour of hindcast. The algorithms then feed the validated and calibrated system hourly demand...
signals from the demand modules, and dispatch units accordingly to meet demand. Power purchases can meet demand during shortfall periods or to take advantage of market conditions to reduce overall costs; the quantity of power purchases is established from reported historical values. Transmission and distribution losses on the grid are calculated using information reported to the US EIA regarding electricity disposition and total losses; these values are state-specific.

Utility-scale renewable assets are handled differently. Pumped storage is dispatched in accordance with historical patterns, predominantly at peak demand times to reduce the cost of operating the system. Conventional hydroelectric facilities hourly data is estimated using the monthly generation values reported to EIA. PVWatts and Wind Prospector, both NREL tools, are used to estimate the hourly generation from solar and wind resources, respectively. The contribution of renewables to demand is subtracted from the overall demand signal (after accounting for T&D losses), as they reduce the quantity of power required to come from the other centralized generating resources available to the system.
**DISPATCH MODULE**

ATHENIA marries supply resources and demand through the dispatch module, which evaluates the calibrated availability of supply-side resources and demand levels hour-by-hour, determining the means of meeting demand in 50 MW blocks. This layering process is continued until hourly demand has been met. In this study, this process is completed over 28,000,000 times to fill demand requirements throughout the next 15 years. Following this dispatch process, a loss-of-load hour and loss-of-load event analysis is performed, following NERC procedures, to ensure that sufficient resources were available to meet anticipated demand levels. This serves as a more sophisticated check on the reserve margin and resource adequacy analysis performed during the Supply Module solution. A failure at this step may require the addition of new resources (in either the Supply or Demand Modules) to ensure reliable electricity service. The procedure for BAU and Scenarios through the Dispatch Module is identical.

**UTILITY FINANCIALS MODULE**

The UFM is a highly-modified version of the GT-CPP and GT-DSM2 models, open-source utility financials models co-developed by The Greenlink Group and the Georgia Institute of Technology’s Climate and Energy Policy Laboratory. UFM is laid out in sectors to allow for analysis of the impact of changes in supply and demand on the financial cash flows associated with the operation of utilities. The Customer Sector breaks out impacts to residential and commercial/industrial customers, determining the rate and bill impacts of a scenario relative to the BAU. The Utility Sector emphasizes the financial structure of the utility, evaluating costs, revenues, and expected rates of return, as applicable. The UFM is a powerful advancement over many other similar tools in its ability to assess the impacts to specific customer classes as well as spillover effects between customer classes. The full benefits of the UFM require a point-of-comparison in the form of an alternative scenario, although key indicators about utility financial expectations into the future can be derived from a BAU-only configuration.

**ECONOMIC DEVELOPMENT INDICATORS MODULE**

The EDI evaluates several macroeconomic indicators of a scenario. It collects the investments of all flows related to the electricity ecosystem, for example, investments in new electricity generating units, energy efficiency, and new renewables development. The industry-standard MIG IMPLAN model is used to develop employment, labor income, and gross regional product coefficients for each investment stream, which are returned as [impact]/$-million. By taking the difference in investments between the BAU and Scenarios and applying the appropriate coefficients, EDI produces the change in employment, incomes, and GRP in the scenario.

**ENVIRONMENTAL MODULE**

The environmental module makes use the characterization of units produced by the Supply Module to establish emission rates for CO2, SO2, NOx, PM2.5, PM10, VOCs, and NH3. The Environmental Module combines these rates with the outputs of the Dispatch Module to estimate the total emissions in each year from each electricity generating unit on the system. The Environmental Module then establishes the social damage that results from these pollutant emissions. For CO2, the US Government’s Social Cost of Carbon 3% Central trajectory cost values are to monetize the damage; the damage per ton increases over time for this pollutant. For all other pollutants, the appropriate outputs of the AP2 model are used. AP2 assesses the economic damage caused by various pollutants emitted at various heights in every county of the United States through a complex Monte Carlo evaluation process. The Environmental Module matches the correct AP2 outputs to the total emissions from each unit on the system and derives an annual damage for each pollutant as new outputs. This process can be performed on the BAU case alone to assess the magnitude of economic damages caused by electricity generation, and the comparison of these values for the BAU and Scenario case also allows for a differential analysis. Additionally, the epidemiological impacts on public health are produced by linking ATHENIA to the USEPA COBRA model, which calculates the differences in scenarios at a county-by-county level for PM2.5, NOx, SO2, NH3, and VOCs. In total, 12 epidemiological outputs are produced, including results for impacts on adult mortality, infant mortality, non-fatal heart attacks, respiratory hospital admissions, cardiovascular disease hospital admissions, acute bronchitis, upper respiratory symptoms, lower respiratory symptoms, asthma emergency room visits, minor restricted activity days, work loss days, and asthma exacerbations.

**COST-BENEFIT MODULE**

The CBA Module collects all the policy analysis-relevant information and performs a cost-benefit analysis, ultimately resulting in a calculation of net benefits and the benefit-cost ratio of the Scenario relative to the BAU. Any category can be a cost or a benefit, including: net emissions impact, change in utility fixed
and variable costs, net investment costs, net fees and charges (including integration costs), and net utility program costs. While the CBA Module also collects data on several other financial flows (such as energy bill savings and lost revenues), ultimately all other financial flows are transfer payments between one party and another and not relevant to the benefit-cost analysis. Once all relevant values are tabulated, they are discounted. The default discount rate for analysis in ATHENIA is 3%, based on guidance from OMB Circular A-4, but this value can be modified for sensitivity analysis.

APPENDIX B. COSTS INCLUDED IN THE ECONOMIC ANALYSIS OF COSTS TO OPERATE POWER PLANTS

Operating cost is defined as the total cost required to operate, maintain, and retain environmental compliance for a plant. It includes costs related to the following items:

- Maintenance of electric plant
- Maintenance of boiler (or reactor) plant
- Maintenance of structures
- Maintenance of miscellaneous steam plant, and
- Maintenance supervision and engineering

Environmental compliance cost includes the expenses incurred to comply with regulations that concern the following areas:

- NOx
- SO2
- PM2.5 and PM10
- Hg
- Cooling water circulation
- Coal combustion residuals (CCR)
- Effluent

APPENDIX C. EXPANDED ENERGY EFFICIENCY AND CONSERVATION MODELING DETAILS

Cost-effective efficiency improvements for the demand sectors are identified and modified from the National Renewable Energy Laboratory (NREL) and the American Council for an Energy-Efficient Economy (ACEEE).23,24 The modeling approach starts with the current annual energy efficiency levels achieved by the utilities, and captures ten percent of the achievable efficiency potential each year, such that these territories have reached their potential by 2026. Afterwards, these efforts are maintained to ensure there is no backslide throughout the remainder of the modeling horizon.

The NREL study assesses the current level of economic energy efficiency potential in single-family detached homes in each state in the United States through an intensive computational procedure, evaluating many variations in building and technology configurations as informed by survey data and compared to more-efficient means to meet service demands. Opportunities to improve energy performance with short paybacks and attractive project economics survive the cut. For the portion of North Carolina residential demand that comes from single-family detached housing, the NREL estimates of current potential are used. This likely a conservative approach because it does not account for technological progress, only for a decade-long phasing in of approaching the current economically-feasible electricity potential within the single-family detached segment of the residential sector. The final step of this analysis is to determine the demand with and without action to increase the adoption of the cost-effective measures identified by the study, if the cost-effective measures were adopted within a ten-year time window. A compound annual growth rate for energy savings in the single-family detached housing segment is then calculated between these two potentials, based on the Annual Energy Outlook projection of residential demand growth between 2017 and 2028, and the difference if the cost-effective potential were taken up by consumers.

For non-single-family detached residential demands, the ACEEE study is referenced, which studied the potential for more than a dozen socio-technological policy measures to improve energy efficiency nationally. The national potential identified by ACEEE is scaled to North Carolina by accounting for differences in technological deployment and reliance on various
fueled and means of meeting energy demand, after accounting for site-to-source losses. These estimates do incorporate some technological progress, as evaluated by the Energy Information Administration in the Annual Energy Outlook. However, this assessment is less-comprehensive than the NREL study, so it is also likely a conservative representation of the energy efficiency potential. The compound annual growth rate achievable from this assessment is calculated in much the same way as the NREL study.

To get a residential-sector-wide compound annual growth rate for energy efficiency savings, a value is calculated by weighting the savings potentials by the percentage of North Carolina residential electricity demand from single-family detached homes as reported in the 2009 Residential Energy Consumption Survey.

For the commercial sector, the same ACEEE study is used to benchmark the potential for cost-effective energy efficiency improvements. Procedurally, the percentage of commercial delivered energy consumption that electricity represents is calculated, as reported in the Annual Energy Outlook. The quotient of delivered electricity and total delivered energy for the South Atlantic census division is divided by electricity’s national percentage of delivered energy to calculate the regional adjustment factor for commercial electricity consumption. Once this is determined, the commercial savings potential within the census division can be calculated, as shown below.

\[
\text{Savings Potential} = \frac{Q_{S}}{Q_{T}} \times \frac{Q_{S}^{c}}{Q_{S}^{n}} \times \frac{Q_{Ed}}{Q_{Ed-SA}} \times \frac{Q_{Ed-SA}}{Q_{ET-SA}} \times \frac{Q_{ET-SA}}{Q_{ET}}
\]

Where:

- \(Q_{S}^{c}\) is the quads saved nationally in 2040 from ACEEE
- \(Q_{S}\) is the quads of delivered electricity to the commercial sector in 2017 from AEO 2017
- \(Q_{T}\) is the quads of total energy delivered to the commercial sector in 2017 from AEO 2017
- \(Q_{S}^{n}\) is the quads saved in the commercial sector in 2040 from ACEEE
- \(Q_{Ed}\) is the quads of electricity delivered to the commercial sector in 2017 from AEO 2017
- \(Q_{Ed-SA}\) is the quads of electricity delivered to the commercial sector in the South Atlantic census division in 2017 from AEO 2017
- \(Q_{ET}\) is the total delivered energy to the commercial sector in the South Atlantic census division in 2017 from AEO 2017

The final result is the commercial savings potential in 2040 (in quads), if the cost-effective measures identified by ACEEE were adopted and the characteristics of the South Atlantic census division were incorporated. The savings potential is then subtracted from the commercial sector projection in 2040 from AEO 2017, providing the 2040 commercial energy consumption in 2040 with an increased level of energy efficiency. Dividing this value by the AEO 2017 commercial sector electricity consumption and raising it to the 1/23 power produces the compound annual growth rate for demand with increased efficiency. Subtracting by 1 produces the compound annual growth rate for savings for this region, which can then be scaled to the electricity sales of the particular demand in question to provide an estimate of cost-effective annual savings potential.

Industrial sector savings potentials are calculated in the same fashion as the commercial sector.

The cost to achieve energy savings from energy efficiency programs and building codes are calculated based on the sector-specific end-uses targeted and scaling existing program designs within utility territories, as reported in Form EIA-861 and NCUC regulatory filings. Each utility and sector shows some variation reflecting differences in resources, opportunities, and program designs, and this methodology takes these variations into account. Industrial programmatic costs are assessed using the commercial sector values, which may overestimate the costs, given the results from federal programs such as the Industrial Assessment Centers. However, industrial savings comprise less than 5% of the total, so the bias introduced by this conservative assumption is likely small.

For demand response, reviewing the results of roughly 120 studies and eight different program classes, critical peak pricing programs with direct load control have demonstrated the greatest ability to provide a large demand response capacity value while maintaining customer satisfaction and program participation.\(^{25,26}\) The median value of demand savings were taken
from this study-set and used to assess the potential for residential, commercial, and industrial customers. Customers already utilizing time-of-use rates were accounted for by taking the difference between median observed savings for customers in time-of-use programs and the median observed savings for those in critical peak pricing with direct load control technologies and weighting their contribution as a percent of the whole. In this way, the power savings from this type of dynamic pricing and demand response program are not overestimated. Overall, these sector-specific savings contributions are scaled to utility seasonal peak demand to derive the final estimate of current demand response potential.

**APPENDIX D. METHODOLOGY FOR DETERMINING SOCIAL DAMAGES ASSOCIATED WITH EMISSIONS AND THEIR MONETIZATION**

The monetization of the non-carbon air pollutant emissions (SO2, NOx, PM2.5, PM10, VOCs, and NH3) takes a careful, spatially-specific procedure. The Environmental Module of the ATHENIA model relies on the outputs of the AP2 model, originally developed by Muller and Mendelsohn, and continually developed by Muller; for a detailed description of the model, see their technical appendix.27

In summary, the AP2 model uses the environmental and public health economics literatures to generate damages estimates for emissions of particular pollutants at various heights, informing the model with several detailed EPA, Census, and industry datasets to establish emissions inventories, populations, and emission point-sources. It then utilizes a Gaussian plume air pollution dispersion model to establish the likely damage of a particular pollutant emitted in an individual county at a specific height, taking economic, environmental, and demographic factors into account. This process is repeated through a Monte Carlo statistical procedure over 10,000 times for each pollutant at each height in each county to generate a probabilistic result which can be reliably used to inform research and analysis.

The Environmental Module takes these county-by-county outputs and matches the pollutant damages produced by the AP2 model to the emissions of a particular emissions-producing unit. Damages include adverse effects on human health, reduced yields of agricultural crops and timber, reductions in visibility, enhanced depreciation of man-made materials, and damages due to lost recreation services.

The Environmental Module assumes that these emissions occur at the highest height available in the AP2 outputs, generally over an effective emissions height of 250 meters, with a lower economic damage assessment associated with each pollutant than at any other height.

\[ D_{UP} = E_{AP} \times I_{PC} \]

Where,

\[ D_{UP} \] represents the monetary value of the social damages of a particular pollutant from a particular unit,

\[ E_{AP} \] represents the emission level, and

\[ I_{PC} \] represents the monetary value of the social damage of a particular pollutant with an effective emissions height exceeding 250 meters from a specific county in the United States.

With power purchases from sellers that are not directly modeled, the determination of social damages is dependent on the use of Mode 1 or Mode 2. In Mode 1, the generation-weighted damages of the purchaser’s generation profile are used to determine the average damage profile of power purchases. In Mode 2, the generation-weighted damages of the seller’s generation profile are used to determine the average damage profile of power purchases.

For CO2, the social damages are calculated using the Technical Update to the US Federal Government’s Interagency Working Group Social Cost of Carbon 3% Average case.28 Social cost of carbon accounts for changes to agricultural productivity, sea level rise, rainfall changes, extreme weather and risks to human health, to varying extents.
The calculation is the same as in equation 1, with the only difference being that there is no geographic variation in the damage assessed for a ton of CO2 from different units because CO2 is a well-mixed pollutant that does not have particularly local effects.

The final step in the analysis is to calculate aggregate economic damages from all pollutants tracked in the environmental module. This involves summing all damages calculated individually.

\[
(2) \quad D_S = \sum D_{U,P}
\]

This step is repeated annually to provide the annual economic damages from pollution related to the production of electricity within the chosen geography.
ENDNOTES


8. CCR includes only the control costs, not the cost to decommission the facilities.


16. Calculation based on the following dataset. Lawrence Berkeley National Laboratory, Tracking the Sun IX. https://emp.lbl.gov/publications/tracking-sun-ix-installed-price


19. Technical Appendix to The Air Pollution Emission Experiments and Policy Analysis Model (APEEP, also knowns as AP2) Technical Appendix https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxuaWNrbXVsbGVyc2hbVWVwYWdlIjJkMzk0YjjiMjBjNyZmU


22. Impacts calculated based on emission reductions in SO2, NOx, PM2.5, NH3, and VOC.


