BUILDING FUTURE RESILIENCE TO EXTREME COLD
in the Wake of North Carolina's Rolling Blackouts

ISSUE BRIEF
March 2023

Introduction

As temperatures dipped into the single digits during the early hours of December 24, 2022,[1] Duke Energy cut electricity service to around 500,000 customers across North and South Carolina. Duke noted that these rolling blackouts were required to maintain the balance of their energy grid, preventing wider system failures.[2] However, such compulsory shutoffs have a variety of adverse impacts on those suddenly left without power, particularly vulnerable populations like low-income families, children, and the elderly. The North American Electric Reliability Corporation (NERC) has previously highlighted the risk of energy shortfalls like this one due to large-scale, extreme weather events, as these weather patterns can diminish electricity supply and the availability of energy imports while simultaneously driving up demand for power.[3]

This analysis explores the factors that led to these rolling blackouts and feasible mitigation measures that could help avoid such compulsory shutoffs in the future during extreme weather events. While Duke's service territories span the Carolinas,[4] the measures discussed here focus on North Carolina specifically.[5, 6, 7]

1 Charlotte (the most populous city in North Carolina) experienced temperatures in the single digits. Elsewhere across the state, temperatures ranged from 0 to 20-degrees Fairenheight. In a few mountain locations, temperatures were negative. [NOAA National Weather Service. (n.d). NOWData - NOAA Online Weather Data. **https://www.weather.gov/wrh/Climate?wfo=rah**]

2 Duke Energy. (2022). Duke Energy asks for continued energy conservation as power restoration continues following extreme winter temperatures. **https://news.duke-energy.com/releases/duke-energy-asks-for-continued-energy-conservation-as-power-restoration-continues-following-extreme-winter-temperatures**

3 North American Electric Reliability Corporation. (2021). 2021 Long-Term Reliability Assessment. **https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2021.pdf**

4 Combined, Duke Energy Progress and Duke Energy Carolinas have roughly 3.6 million customers in North Carolina, and 800,000 in South Carolina. [U.S. Energy Information Administration. (2022). Annual Electric Power Industry Report, Form EIA-861 detailed data files. Sales to Ultimate Customers, 2021. **https://www.eia.gov/electricity/data/eia861/**]

5 Where necessary, Duke's North Carolina retail kWh sales and North Carolina peak demand allocation factors are used to scale results that would otherwise apply across the utilities' full Carolinas service territories.

6 Duke Energy Carolinas estimates that 73 percent of their retail kWh sales and 74 percent of their peak demand is from North Carolina. [Docket No. E-7, Sub 1230. (2020). Duke Energy Carolinas, Evans Exhibit 1. Load Impacts and Estimated Revenue Requirements by Program. **https://starw1.ncuc.gov/NCUC/ViewFile.aspx?Id=64dd26b8-2d9e-4080-a279-4b3b44867020**]

7 Duke Energy Progress estimates that 86 percent of retail kWh sales and 87 percent of their peak demand is from North Carolina. [Docket No. E-2, Sub 1252. (2020). Duke Energy Progress, Evans Exhibit 1. Load Impacts and Estimated Revenue Requirements by Program. **https://starw1.ncuc.gov/NCUC/ViewFile.aspx?Id=f547bf5d-6a52-434b-aede-9ad59d56846a**]

PSE

What happened?

Several factors led Duke to initiate blackouts. Despite Duke's cold-weather preparations, equipment at several facilities froze before dawn on the 24th, reducing generation capacity at three gas and two coal plants.[8, 9] Electricity demand also rose faster than expected as temperatures dropped, while power purchased from out of state was unavailable as neighboring regions faced similar challenges and needed that power to keep their own customers warm.[10] Duke's demand forecasts were also 4-10 percent too low, contributing to the lack of available resources (**Figure 1**). Ultimately, the demand for power eclipsed Duke's capacity to provide it.

After an initial effort to lower demand through limited voluntary demand reduction measures,[11, 12] Duke began blackouts just after 6 a.m. (**Figure 1**) By 9 a.m. both Duke Energy Progress and Duke Energy Carolinas were in the

8 NC Policy Watch. (2023). Several crises, malfunctions at Duke Energy led to rolling blackouts on Christmas Eve, utility officials tell state regulators. **https://ncpolicywatch.com/2023/01/04/several-crises-malfunctions-at-duke-energy-led-to-rolling-blackouts-on-christmas-eve-utility-officials-tell-state-regulators/**

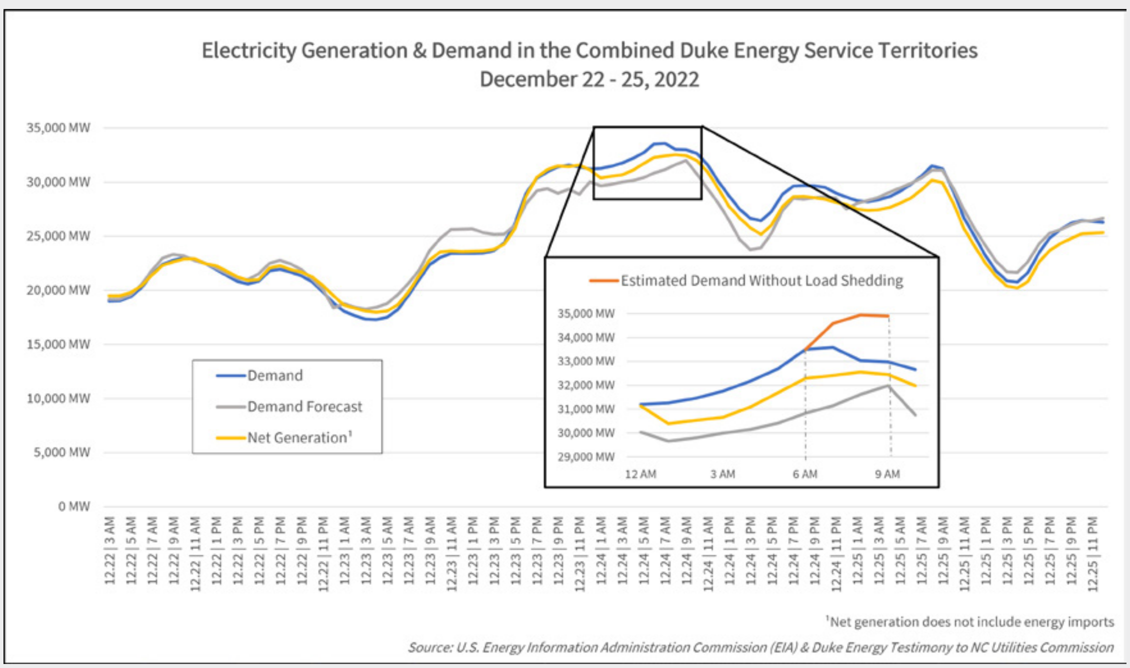
9 North Carolina Utilities Commission. (2023). Staff Conference. **https://www.youtube.com/watch?v=xARPpMFpOA4&t=37s**

10 The Associated Press. (2023). Duke Energy apologizes, explains why they had to do rolling blackouts over holiday. **https://www.wyff4.com/article/duke-energy-apologizes-rolling-blackouts/42393708#**

11 Numerous commercial and industrial customers, and a limited number of residential customers, have contracted with Duke to voluntarily reduce their energy usage when called on to do so. However, when an event is called on short notice–particularly in the early morning hours–there may not be someone available or time to organize a response prior to peak demand hours. [Duke Energy. (2020). Duke Winter Peak Analysis Solution Set. **https://cleanenergy.org/wp-content/uploads/Duke-Winter-Peak-Analysis-Solution-Set-Final-Report.pdf**]

12 Duke Energy Carolinas and Duke Energy Progress used mass media, their website, and interactive voice response telephone systems to communicate about the outages. However, they did not use direct messaging to customers, as that type of communication could take "several hours" due to message crafting and phone carriers. [North Carolina Utilities Commission. (2023). Staff Conference. **https://www.youtube.com/watch?v=xARPpMFpOA4&t=37s. See time marker 51:30 - 54:00**]

Figure 1. The combined electricity demand, forecast, and net generation from Duke Energy Progress and Duke Energy Carolinas between December 22nd and 25th, including a callout for the morning of December 24, 2022. Energy interchanges—the imports/exports that allow Duke to perfectly match net generation with demand—are not pictured.



process of restoring power, but it took until 4 p.m. to finish restoring all impacted circuits.[13] Duke had previously taken steps to insulate its generation equipment against extreme low temperatures, assuring NERC that it was prepared for these conditions.[14, 15] However, the utilities' fossil fuel infrastructure was ultimately less reliable than anticipated.

These rolling blackouts impacted roughly 11 percent of North Carolina residents,[16, 17] distributed across both Duke Energy Carolinas' and Duke Energy Progress' service territories (roughly 15 percent of Duke's total customers;[18] 11 percent of subsidiary customers[19]). While outages did not hit critical facilities like hospitals, Duke acknowledges that medical alert customers—people with medical needs that require power—live on practically every circuit across their service territories.[20] Additionally, more than a third of Duke's customers in North Carolina are low-income, and were less likely to have the financial resources required to find warmer places to stay over the Christmas holiday season (December 24th - December 25th) if left for a significant time without power.

How much power would have kept the lights on?

Across its Carolina service territories, Duke lost around 1,300 megawatts (MW) of generation and 1,800 MW of purchased power, ultimately shedding almost 2,000 MW via rolling blackouts (roughly 5 percent of total demand).[21] With roughly 75 percent of Duke Energy Carolinas and 85 percent of Duke Energy Progress in North Carolina, that's an estimated 1,530 MW in North Carolina alone.

So while it is difficult to know just how high demand might have risen if Duke hadn't called for conservation and begun blackouts, a minimum of 2,000 MW across Duke's territories in the Carolinas would have been required to avoid blackouts.

Before the cascading failures early on the 24th, Duke thought it would have enough energy to meet demand. But actual demand exceeded load forecasts by 8-10 percent in Duke Energy Carolinas and 4-5 percent in Duke Energy Progress,[22] and Duke wasn't able to compensate (**Figure 1**). The grid requires supply and demand to remain balanced. As Duke couldn't increase supply from local generation or imports, it had to reduce demand by cutting people's power.

13 NC Policy Watch. (2023). Several crises, malfunctions at Duke Energy led to rolling blackouts on Christmas Eve, utility officials tell state regulators. **https://ncpolicywatch.com/2023/01/04/several-crises-malfunctions-at-duke-energy-led-to-rolling-blackouts-on-christmas-eve-utility-officials-tell-state-regulators/**

14 North Carolina Utilities Commission. (2023). Staff Conference. **https://www.youtube.com/watch?v=xARPpMFpOA4&t=37s**

15 NC Policy Watch. (2022). Reliability watchdog warns of potential electric shortfalls this winter. **https://pulse.ncpolicywatch.org/2022/12/09/reliability-watchdog-warns-of-potential-electric-shortfalls-this-winter/**

16 A utility customer is typically a household or business. The average household size in North Carolina is 2.5, and the state is home to 10.5 million people. [United States Census Bureau. (n.d.). Quick Facts North Carolina. **https://www.census.gov/quickfacts/NC**]

17 Citizen Times. (2022). Duke Energy to review rolling blackouts after thousands lost power amid bitter cold. **https://www.citizen-times.com/story/news/2022/12/29/duke-energy-to-review-rolling-blackouts-after-winter-power-outages/69760098007/**

18 Duke Energy. (2023). Duke Energy updates North Carolina Utilities Commission on Winter Storm Elliott Emergency Outage Event. h**ttps://news.duke-energy.com/releases/duke-energy-updates-north-carolina-utilities-commission-on-winter-storm-elliott-emergency-outage-event**

19 The Associated Press (2023). Duke Energy apologizes, explains why they had to do rolling blackouts over holiday. **https://www.wyff4.com/article/duke-energy-apologizes-rolling-blackouts/42393708#**

20 North Carolina Utilities Commission. (2023). Staff Conference. **https://www.youtube.com/watch?v=xARPpMFpOA4&t=37s**

21 Total load on Duke's system reached almost 33,600 MW. [U.S. Energy Information Administration. (n.d.). Hourly Electric Grid Monitor. **https://www.eia.gov/electricity/gridmonitor/dashboard/electric_overview/US48/US48. See Duke Energy Carolinas (DUK) Electricity Overview for 12/24/2022 and Duke Energy Progress East (CPLE) Electricity Overview for 12/24/2022**]

22 North Carolina Utilities Commission. (2023). Staff Conference. **https://www.youtube.com/watch?v=xARPpMFpOA4&t=37s**

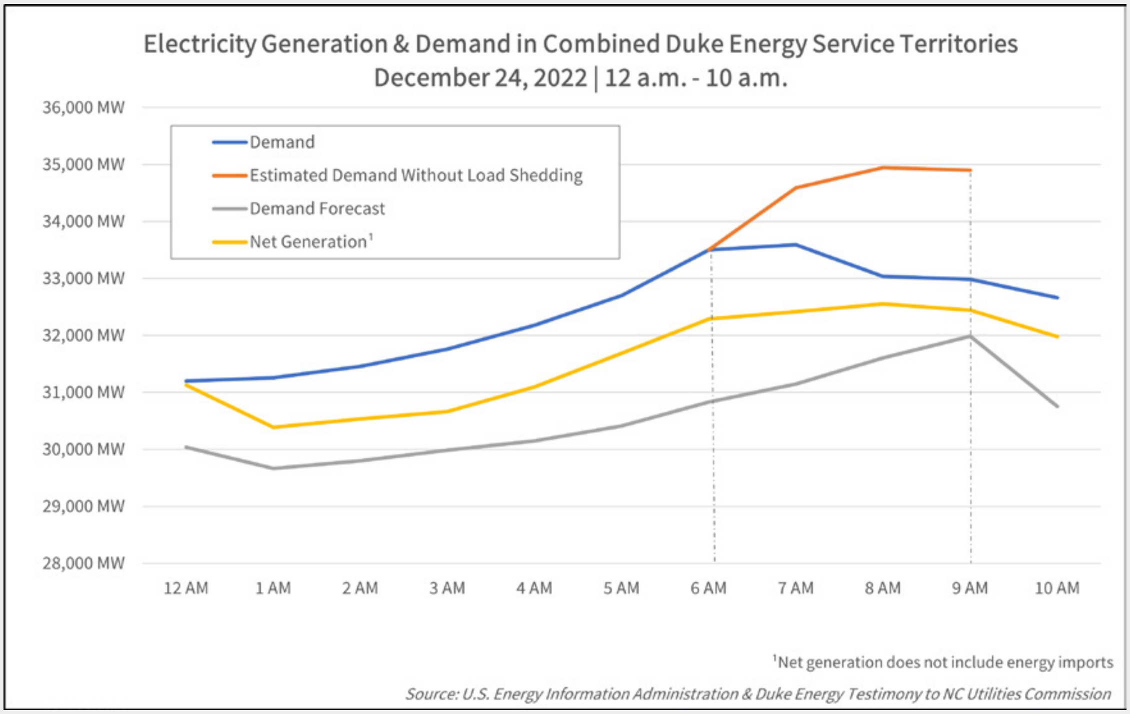


Figure 1a. A zoomed-in snapshot at the critical winter peak time period on December 24, 2022 from **Figure 1**, including the estimated demand without load shedding (e.g., rolling blackouts).

How can we avoid this gap in the future?

There are two ways to avoid this type of supply/demand mismatch. The first is to increase the amount of capacity—energy that can be produced or purchased in time to meet demand—by building new generation and/or transmission infrastructure. The second is to proactively reduce demand using energy efficiency and demand-side management (e.g. shifting around when electricity is used for non-essential services).

Instead of waiting for an emergency and meeting that capacity gap using rolling blackouts, other methods such as targeted investments in weatherization, energy efficient appliances, and demand response programs can keep demand lower and more stable in cold temperatures, and prevent another blackout. More than half of energy demand during winter peak hours—that 6 a.m. to 9 a.m. period marked in **Figure 1a**—came from residential customers.[23] This early morning winter peak is typically driven by widespread heating and appliance use as people start their days, made more intense during winter storm Elliot due to extreme low temperatures. Thus, reducing winter residential energy demand offers significant potential for meeting a potential resource gap.

As an additional benefit, efficiency resources like these are often less expensive per megawatt-hour (MWh) saved than building new generation such as a power plant.[24]

23 Duke Energy. (2020). Duke Energy Winter Peak Targeted DSM Plan. **https://cleanenergy.org/wp-content/uploads/Duke-Energy-Winter-Peak-Targeted-DSM-Plan-Final-Report.pdf**

24 ACEEE. (2021). "The Cost of Saving Electricity for the Largest U.S. Utilities: Ratepayer-Funded Efficiency Programs in 2018." **www.aceee.org/sites/default/files/pdfs/cost_of_saving_electricity_final_6-22-21.pdf**

Weatherization

Weatherizing homes and businesses—insulating them against the elements—reduces the amount of energy required for heating.[25] This would have been especially useful during winter storm Elliot, as energy demand was driven by residential heating. Roughly 65 percent of households in North Carolina use electricity to heat their homes.[26] For these households, roughly 70 percent of their winter peak demand is from electric space heating.[27] Weatherizing these homes would reduce the amount of energy each one of them needs to stay warm, thereby reducing peak demand.

In 2019, almost 11,000 households participated in Duke Energy Carolinas Income Qualified Energy Efficiency and Weatherization Assistance program, saving roughly 9,000 MWh and 1.1 MWs of peak capacity.[28, 29] But fewer than 5 percent of low-income households in North Carolina have participated in a non-behavioral focused energy efficiency or weatherization program.[30] So scaling up this existing program to weatherize the almost 900,000 low-income homes in Duke's service territories that are unlikely to have benefited from a weatherization program could save roughly 750,000 MWh of energy and lower peak demand by nearly 100 MW.[31]

However, this doesn't represent the full potential of energy savings from weatherization. Duke's program only achieves around 6 percent energy savings over the course of the year whereas greater savings are commonly achieved through other programs. For example, the federal Weatherization Assistance Program averaged 10.9 percent net savings in winter electricity consumption for electrically heated single family homes as measured by Oak Ridge National Laboratory.[32]

Weatherizing homes also has major co-benefits. Since it takes less energy to heat and cool a well-insulated home, it can lower energy bills year-round.[33] This is particularly beneficial for low-income households, for whom small changes in an energy bill can be impactful. Additionally, a weatherized home retains its previous temperatures for longer if the power goes out. Not only is this simply more comfortable for residents, it is also safer for those more sensitive to extreme temperatures, such as people with underlying medical conditions, children, and the elderly.

25 North Carolina Utilities Commission. (2023). Staff Conference. **https://www.youtube.com/watch?v=xARPpMFpOA4&t=37s**

26 U.S. Energy Information Administration. (2022). Annual Electric Power Industry Report, Form EIA-861 detailed data files. Sales to Ultimate Customers, 2021. **https://www.eia.gov/electricity/data/eia861/**

27 Duke Energy. (2020). Duke Energy Winter Peak Targeted DSM Plan. **https://cleanenergy.org/wp-content/uploads/Duke-Energy-Winter-Peak-Targeted-DSM-Plan-Final-Report.pdf**

28 Duke Energy. (2020). Evans Exhibit 6; Income-Qualified Energy Efficiency and Weatherization Assistance Program. **https://starw1.ncuc.gov/NCUC/ViewFile.aspx?Id=64dd26b8-2d9e-4080-a279-4b3b44867020**

29 While this 1.1 MW is 2019 peak summer capacity, based on Duke's 2021 estimates for the same program, it would contribute at least this much, if not slightly more, to peak winter capacity.

30 NCUC. (2022). Docket No. E-100, Sub 179. Corrected Attachment A of Appalachian Voices Comments. **https://starw1.ncuc.gov/NCUC/ViewFile.aspx?Id=4d91a66a-6d9b-4b2d-b4a6-3ea72eb950d6**

31 Duke Energy Progress has its own energy efficiency and low-income weatherization program, but it has been significantly less effective. In 2019, Duke Energy Carolinas delivered 234 percent more efficiency savings for low-income customers than Duke Energy Progress, despite only having 50 percent more residential accounts. [NCUC Docket No. E-2, Sub 1252. (2020). Direct Testimony And Exhibits Of Forest Bradley-Wright On Behalf Of The North Carolina Justice Center, North Carolina Housing Coalition, And Southern Alliance For Clean Energy. **https://starw1.ncuc.gov/ncuc/ViewFile.aspx?NET2022&Id=eabde096-a281-4889-b301-5c3acba0d21c**]

32 Oak Ridge National Laboratory. (2015). Evaluation of the Weatherization Assistance Program During Program Years 2009-2011. Table 5.1 **https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2014_582.pdf**

33 U.S. Department of Energy. (2015). Weatherization Assistance Program National Evaluations: Summary of Results. **https://www.energy.gov/sites/default/files/2015/08/f25/WAP_NationalEvaluation_WxWorks_v14_blue_8%205%2015.pdf**

Heat Pumps

Almost a quarter of homes in North Carolina still use furnaces, baseboard heaters, and other forms of electric resistance heating.[34] Assuming roughly 75 percent of these households are served by Duke, that's almost 740,000 homes.[35] If 85 percent of them switched to more efficient heat pumps,[36] technology which may cut electricity use by 50 percent,[37, 38] Duke could see up to 200 MW of winter peak demand reductions.[39, 40, 41]

The benefits of heat pumps aren't only in peak demand reductions. Heat pumps can be used for both heating and cooling, offering both winter and summer efficiency benefits. By lowering the amount of energy required to heat and cool a home, they can also lower energy bills. This is particularly important for the more than 300,000 low-income households[42] in Duke's service territory in North Carolina that heat their homes with electricity. Research has shown that wealthier communities are more likely to have already adopted rooftop solar, battery storage, and efficient appliances.[43] So programs focused on boosting heat pump installations in lower income households will be an important piece of achieving peak demand reductions from efficiency.

Demand Response & Demand-Side Management

Duke was able to call on 400 MW of demand response (200 MW in both Duke Energy Carolinas and Duke Energy Progress) during the December 24th crisis. Demand response is one of a number of demand-side management techniques, such as energy efficiency, that are designed to lower peak load. **Figure 2** shows the current residential demand response programs throughout the state, with most operating around Asheville. For demand response, customers sign up with the utility and allow Duke to remotely adjust their thermostat by up to 4 degrees Fahrenheit.[44] Unlike energy efficiency measures such as weatherization and heat pumps, Duke can actively use demand response to lower energy usage as needed to keep the grid balanced and avoid a crisis.

Despite the fact that more than 60 percent of homes in North Carolina use electricity for heating,[45] only a tiny fraction of peak reductions from demand response comes from residential programs. Of the roughly 700 MW

34 U.S. Energy Information Administration. (2022). 2020 Residential Energy Consumption Survey, State Data. **https://www.eia.gov/consumption/residential/data/2020/index.php?view=state**

35 U.S. Energy Information Administration. (2022). Annual Electric Power Industry Report, Form EIA-861 detailed data files. Sales to Ultimate Customers, 2021. **https://www.eia.gov/electricity/data/eia861/**

36 Modern units can operate efficiently as low as 5°F, with some cold weather units doing so as low as -12°F. [Rocky Mountain Institute. (2019). The Economics of Zero-Energy Homes; Single-Family Insights. **https://rmi.org/insight/economics-of-zero-energy-homes/**]

37 **Energy.gov**. (n.d.). Heat Pump Systems; Energy Saver. **https://www.energy.gov/energysaver/heat-pump-systems**

38 Heat pumps are often accompanied by supplemental heat strips for extreme cold, which have an additional power draw. [Duke Energy. (2020). Winter Peak Targeted DSM Plan. **https://cleanenergy.org/wp-content/uploads/Duke-Energy-Winter-Peak-Targeted-DSM-Plan-Final-Report.pdf**]

39 As detailed data on individual household energy use combined with demographics is not publicly available, we used models based on geographic, demographic, and housing-related variables to approximate household-level electricity and fuel use in residential buildings in North Carolina. For methodology, see: PSE and IEER. (2023) Energy Affordability in Maryland. Appendix A.1.1. **https://www.psehealthyenergy.org/wp-content/uploads/2023/02/Energy-Affordability-in-Maryland-2023_-Fina**

40 This value is based on current home energy use for heating and installing heat pumps rated for cold weather. General practice is to weatherize homes before undertaking other measures. Older heat pump models may also operate less efficiently in extreme cold, but will still offer year-round energy savings.

41 This winter peak demand reduction from heat pump efficiency savings assumes that 6,100 megawatt-hours (MWh) of energy savings from efficiency corresponds to roughly 1 megawatt (MW) of winter peak demand reductions. [NCUC. (2022). Docket No. E-100, Sub 179. Corrected Attachment A of Appalachian Voices Comments. **https://starw1.ncuc.gov/NCUC/ViewFile.aspx?Id=4d91a66a-6d9b-4b2d-b4a6-3ea72eb950d6**]

42 Low income is defined as households living under 200 percent of the Federal Poverty Level.

43 Brown, D. P. (2022). Socioeconomic and demographic disparities in residential battery storage adoption: Evidence from California. Energy Policy, 164, 112877. **https://doi.org/10.1016/j.enpol.2022.112877**

44 Duke Energy. (n.d.). Power Manager Program. **https://www.energywisetstat.com/faqs/energywise-faq/**

45 U.S. Energy Information Administration (2022). 2020 Residential Energy Consumption Survey.

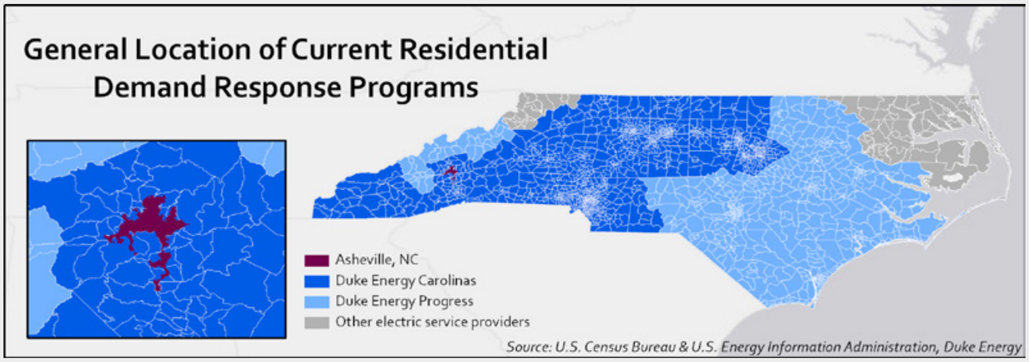


Figure 2. As of 2020, most of Duke's residential demand side management capacity came from programs operating mainly around Asheville.[1]

1 Duke. (2020). Duke Winter Peak Analysis Solution Set. **https://cleanenergy.org/wp-content/uploads/Duke-Winter-Peak-Analysis-Solution-Set-Final-Report.pdf**

of winter demand response in Duke's portfolio, only 32 MW (5 percent) is residential.[46] That indicates that only about 10 percent of residential households are enrolled.[47, 48] Extrapolating from Duke's current residential demand response program, enrolling two qualified devices—for example, an air source heat pump and a heat pump hot water heater—in 30 percent of households or a single device in 60 percent of households could potentially decrease winter peak demand by roughly 100 MW.[49] Enrolling 90 percent of households with two qualified devices could lead to around 300 MW of peak winter demand reduction.[50]

But limiting the utility to existing programs misses significant potential savings. A study on Duke's winter peak demand reduction potential published in 2020 found that the utility could harness roughly 720-970 MW across its service territories of demand reduction from the residential sector by 2030 using new demand-side management programs.[51] This scales to approximately 560-760 MW in North Carolina alone.

The majority of Duke's current winter peak demand reduction capacity—677 MW (98 percent)—comes from the commercial and industrial sector.[52] While nearly all small and medium commercial and industrial (C&I) customers have opted into demand side management measures, most large C&I customers have opted out. These customers account for roughly half of all C&I energy sales. So while Duke estimates that expanding demand-side management programs for C&I customers could add an additional 210-225 MW of winter peak targeted reduction across the Carolinas by 2030, further reductions may be possible if Duke explores new measures or incentives.[53]

46 Duke Energy. (2022). Carolinas Carbon Plan. Appendix G: Grid Edge and Customer Programs. Table G-12. **https://starw1.ncuc.gov/NCUC/ViewFile.aspx?Id=47f81d76-27ff-47fa-b4ed-743047d3f2ec**

47 A single household can enroll multiple devices in the program. This 10 percent assumes 1.5 devices were enrolled per participating household.

48 While these households contribute more than half of demand response savings during peak summer hours, they only account for 2 percent (14 MW) during peak winter events. This is likely because Duke's demand response program focuses on air conditioning units. [Duke. (2020). Duke Winter Peak Analysis Solution Set. **https://cleanenergy.org/wp-content/uploads/Duke-Winter-Peak-Analysis-Solution-Set-Final-Report.pdf**]

49 Duke Energy. (2020). Duke Energy Progress Integrated Resource Plan 2020 Biennial Report. Table: EnergyWise Home. **https://p-scapi.duke-energy.com/-/media/pdfs/our-company/irp/202296/dep-2020-irp-full-plan.pdf**

50 This assumes current energy usage for home heating, which will decrease with the adoption of heat pumps.

51 Duke Energy. (2020). Duke Energy Winter Peak Demand Reduction Potential Assessment. **https://cleanenergy.org/wp-content/uploads/Duke-Winter-Peak-Demand-Reduction-Potential-Assessment-Final-Report.pdf**

52 Duke Energy. (2020). Duke Energy Winter Peak Analysis Solution Set. **https://cleanenergy.org/wp-content/uploads/Duke-Winter-Peak-Analysis-Solution-Set-Final-Report.pdf**

53 Load reduction from large C&I customers relies on process interruptions. Duke's 2020 "Winter Peak Analysis Solution Set" study suggests that, given the way demand response programs are currently arranged, these customers may drop a demand-side management program or opt to pay a fine rather than lower load.

In total, Duke could shave between 925 and 1200 MW across its service territories (or roughly 730-940 MW in North Carolina) of winter peak demand by 2030 using demand-side management techniques like an expanded "Bring-Your-Own-Thermostat" demand response program, time-of-use rates, and changes to peak time rebates.

Wide participation in demand reduction programs also offers benefits beyond the bulk power system. Duke pays customers to participate, which can provide financial assistance to customers including those burdened by their energy bills.[54]

Utility-Scale Renewables & Storage

While fossil fuel plants suffered unexpected mechanical failures on December 24th, solar performed exactly as expected. However, since the crisis occurred before dawn, solar wasn't available. It *was* used later in the day to pump hydroelectric power to meet the following day's electricity needs, though.[55] Pairing intermittent renewable energy like solar or offshore wind with energy storage systems—such as lithium-ion batteries—could diversify the energy supply without having to rely so extensively on fossil fuel generation infrastructure, which proved through this event to be unreliable in winter storms. Solar systems are able to operate efficiently in cold conditions,[56] and are less susceptible to the freezing issues faced by fossil fuel plants in extreme cold.[57] Large energy storage systems are also being designed to withstand freezing temperatures and have successfully operated under winter storm conditions.[58, 59]

A paired solar+storage system with 1,600 MW of solar and 800 MW of 4-hour duration lithium-ion battery storage could contribute 816 MW to winter peak in Duke Energy Progress' territory, while the same solar and storage capacity with a 2-hour duration battery could contribute 736 MW.[60] Duke's Integrated Resource Planning focuses mostly on 4- and 6-hour storage, as 2-hour storage acts more like demand response by only slightly shifting back the peak. However, in the case of winter peaks like the one that caused this blackout, even a 2-hour duration storage system can offer peak load benefits.[61]

Figure 3 illustrates the high solar potential of the Carolinas. As of January 2022, Duke had 4,100 MW of solar installed in North Carolina—enough to power approximately 800,000 homes and businesses at peak output.[62] However, Duke only has about 13 MW of battery energy storage in service. Today, these storage systems are focused on grid services like voltage regulation.[63] But increasing the capacity of energy storage systems will

54 Depending on the program, Duke offers up to $75 a year for participating households and pays non-residential customers based on the amount of load they are able to curtail.

55 North Carolina Utilities Commission. (2023). Staff Conference. **https://www.youtube.com/watch?v=xARPpMFpOA4&t=37s**

56 Mussard, Maxime. (2017). Solar energy under cold climatic conditions: A review. Renewable and Sustainable Energy Reviews, 74: 733-745. **https://doi.org/10.1016/j.rser.2017.03.009**

57 Federal Energy Regulatory Commission and North American Reliability Corporation. (2021). The February 2021 Cold Weather Outages in Texas and the South Central United States. **https://www.ferc.gov/media/february-2021-cold-weather-outages-texas-and-south-central-united-states-ferc-nerc-and**

58 InsideEVs. (2022). Tesla Megapacks Help Alaska's Kenai Peninsula Reduce Its Reliance On Fossil Fuels. **https://insideevs.com/news/572411/tesla-megapacks-alaska-kenai-peninsula/**

59 PowerMag. (n.d.) Prepare Your Renewable Plant for Cold Weather Operations. **https://www.powermag.com/prepare-your-renewable-plant-for-cold-weather-operations/**

60 Duke Energy. (2020). Duke Energy Progress Integrated Resource Plan 2020 Biennial Report. Figure H–7 and H-8. **https://p-scapi.duke-energy.com/-/media/pdfs/our-company/irp/202296/dep-2020-irp-full-plan.pdf**

61 Duke Energy. (2020). Duke Energy Winter Peak Demand Reduction Potential Assessment. **https://cleanenergy.org/wp-content/uploads/Duke-Winter-Peak-Demand-Reduction-Potential-Assessment-Final-Report.pdf**

62 Duke Energy. (2022). Duke Energy's solar portfolio grows in North Carolina with the addition of two new plants. **https://news.duke-energy.com/releases/duke-energys-solar-portfolio-grows-in-north-carolina-with-the-addition-of-two-new-plants**

63 Duke Energy. (2022). Carolina's Carbon Plan. Appendix K: Energy Storage. **https://desitecore10prod-cd.azureedge.net/-/media/pdfs/our-company/carolinas-carbon-plan/supplemental/appendix-k.pdf?rev=6cf8864b9fef4be4a8ab307a8d4643a1**

enable them to provide resilience and emissions-reduction benefits, too. Pairing that battery storage with renewable energy then has the potential to both reduce peak demand and improve public health by hastening the retirement of fossil fuel plants.

Offshore wind is another clean resource that could be used to meet a supply/demand gap. North Carolina has nearly 300,000 MW of offshore wind energy potential,[64] and Duke estimates that offshore wind can provide roughly 55 percent of its nameplate capacity towards meeting winter peak demand.[65] Building just 1,200 MW of offshore wind, in line with one of the scenarios modeled in Duke's 2020 IRP, could offer 660 MW of winter peak capacity by 2030.[66]

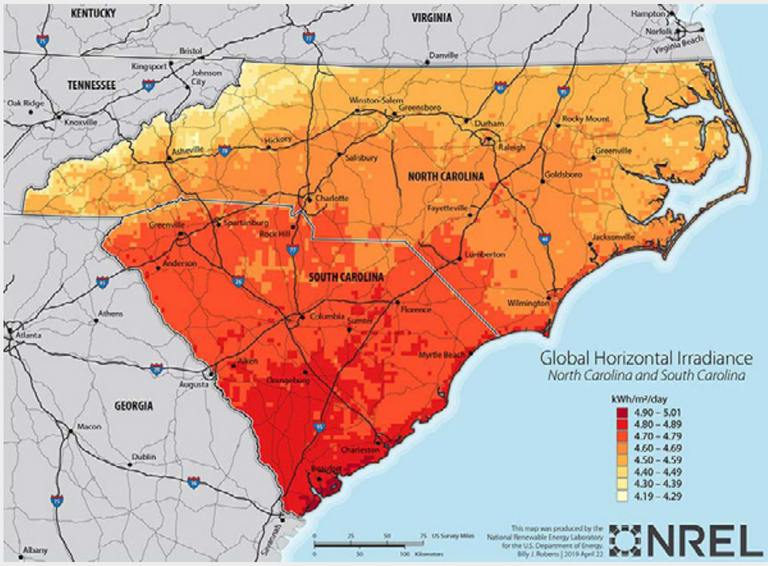


Figure 3. Annual global horizontal irradiance, one measure of solar potential, across the Carolinas.[1, 2]

1 NREL. (2019). Carbon Free Resource Integration Study. **https://www.nrel.gov/grid/carbon-free-integration-study.html**

2 This is an annual average number. Across the continental U.S., solar irradiance in December specifically is sub 4 kWh/m²/day. [NREL. (2018). Global Horizontal Solar Irradiance in December. **https://www.nrel.gov/gis/assets/images/solar-december-ghi-2018-usa-scale-01.jpg**

Distributed Solar + Storage

Distributed generation like solar has historically been confined to homeowners with the financial resources to invest in it, with lower adoption rates for lower-income households and communities of color.[67, 68, 69] This is despite North Carolina having decent solar potential throughout the state (see **Figure 3**). So investing in community solar installations and targeted programs can help increase adoption, particularly given the large percentage of Duke's customers who are low-income.

Installing distributed solar on just 5 percent of rooftops across Duke's territories in North and South Carolina by 2030 would generate more than 6,350 GWh from approximately 4.8 GW.[70] Pairing this distributed solar with batteries sized at 30 percent of solar generation, which Duke estimates can contribute roughly 20 percent to

64 NCUC. (2022). Docket No. E-100, Sub 179. Corrected Attachment A of Appalachian Voices Comments. **https://starw1.ncuc.gov/NCUC/ViewFile.aspx?Id=4d91a66a-6d9b-4b2d-b4a6-3ea72eb950d6**

65 Duke Energy. (2020). Duke Energy Progress Integrated Resource Plan 2020 Biennial Report. **https://p-scapi.duke-energy.com/-/media/pdfs/our-company/irp/202296/dep-2020-irp-full-plan.pdf**

66 Duke Energy. (2020). Duke Energy Progress Integrated Resource Plan 2020 Biennial Report. **https://p-scapi.duke-energy.com/-/media/pdfs/our-company/irp/202296/dep-2020-irp-full-plan.pdf**

67 Sunter, D.A., Castellanos, S., and Kammen, D.M. (2019). Disparities in Rooftop Photovoltaics Deployment in the United States by Race and Ethnicity. *Nature Sustainability*, 2.1, 71-76. **https://doi.org/10.1038/s41893-018-0204-z**

68 Lukanov, B. R., & Krieger, E. M. (2019). Distributed solar and environmental justice: Exploring the demographic and socio-economic trends of residential PV adoption in California. *Energy Policy*, 134, 110935. **https://doi.org/10.1016/j.enpol.2019.110935**

69 Brown, D. P. (2022). Socioeconomic and demographic disparities in residential battery storage adoption: Evidence from California. Energy Policy, 164, 112877. **https://doi.org/10.1016/j.enpol.2022.112877**

70 NCUC. (2022). Docket No. E-100, Sub 179. Corrected Attachment A of Appalachian Voices Comments. **https://starw1.ncuc.gov/NCUC/ViewFile.aspx?Id=4d91a66a-6d9b-4b2d-b4a6-3ea72eb950d6**

winter peak savings for 2-hour duration batteries,[71] could add at least 520 MW of winter peak capacity savings.[72, 73] Research in New England has also indicated that new customer-sited, "behind-the-meter" battery storage is the least cost option for utilities in terms of winter peaking resources.[74]

While installing distributed solar and storage can offer peak capacity savings, it can also be used to bolster resilience for those who need it most. After a blackout, hospital visits from those with home medical devices spike.[75] Locating distributed solar+storage in the homes of those who rely on electricity to power their medical equipment can ensure they don't suffer extreme harm from a winter storm like this one.[76] Additionally, adding solar+storage to trusted community spaces, which can serve as resilience hubs during emergencies, would ensure there are places for vulnerable people in the community to go. These hubs can serve as a lifeline for medically vulnerable residents who rely on power and don't have backup systems at home, as well as for families with children and the elderly who are more vulnerable to winter cold.[77] While this wouldn't contribute peak capacity benefits, it would provide public health and safety benefits if an event like this one happened again.

While utility-scale wind and solar costs have declined by 40 percent and 82 percent respectively, over the past ten years,[78, 79] and battery storage costs have fallen even faster,[80, 81] it is still more economical to reduce energy demand and improve reliability using efficiency measures like weatherization and heat pumps.[82] And since both of those measures enable residents to use less energy to heat their homes, these measures can also make energy demand less volatile to extreme temperatures while simultaneously reducing residential energy bills.[83]

71 Duke Energy. (2020). Duke Energy Progress Integrated Resource Plan 2020 Biennial Report. Figure H-7. **https://p-scapi.duke-energy.com/-/media/pdfs/our-company/irp/202296/dep-2020-irp-full-plan.pdf**

72 Gorman et al. found that a typical commercial battery is sized at 30 percent of average daily PV generation. For residential systems, solar is often sized to generate 100 percent of annual energy consumption with battery sizes ranging from 10 to 30 kWh. [Gorman, W., Barbose, G. L., Carvallo, J. P., Baik, S., Miller, C., White, P., & Prapost, M. (2022). *Evaluating the Capabilities of Behind-the-Meter Solar-plus-Storage for Providing Backup Power during Long-Duration Power Interruptions. Lawrence Berkeley National Laboratory.* **https://emp.lbl.gov/publications/evaluating-capabilities-behind-meter**]

73 This is a conservative estimate, in part because it assumes batteries are operating under fixed dispatch conditions. If the utility implements rates to incentivize charging ahead of winter peak hours or is able to operate some of this storage as utility dispatch, the contribution to winter peak capacity would increase.

74 Applied Economics Clinic & Clean Energy Group. (2021). Energy Storage for Winter Grid Reliability. **https://www.cleanegroup.org/wp-content/uploads/Energy-Storage-for-Winter-Reliability.pdf**

75 Greenwald PW, Rutherford AF, Green RA, Giglio J. (2004). Emergency department visits for home medical device failure during the 2003 North America blackout. *Academic Emergency Medicine*, 11: 786-789. **https://onlinelibrary.wiley.com/doi/abs/10.1197/j.aem.2003.12.032**]

76 As a baseline, there are roughly 105,000 electricity-dependant Medicare beneficiaries in North Carolina. [**HHS.gov**. (n.d.). HHS emPower Map. **https://empowerprogram.hhs.gov/empowermap**]

77 As small battery systems can lose efficiency at below freezing temperatures, those used to address winter energy reliability should be rated for cold weather. This could entail a battery system using temperature-sensitive program settings or installing low temperature lithium batteries. [Altenergymag. (2023). Lithium-Ion Batteries & Cold Weather. **https://www.altenergymag.com/article/2022/12/lithium-ion-batteries-cold-weather/38704**]

78 Wiser, R., M. Bolinger, B. Hoen, D. Millstein, J. Rand, G. Barbose, N. Darghouth, W.l. Gorman, S. Jeong, A. Mills, and B. Paulos. (2021). Land-Based Wind Market Report: 2021 Edition. *Lawrence Berkeley National Laboratory.* **https://www.osti.gov/servlets/purl/1818841/**

79 Feldman, D., V. Ramasamy, R. Fu, A. Ramdas, J. Desai, and R. Margolis. (2021). U.S. Solar Photovoltaic System Cost Benchmark: Q1 2020. National Renewable Energy Laboratory. **https://www.nrel.gov/docs/fy21osti/77324.pdf**

80 National Rural Electric Cooperative Association, National Rural Utilities Cooperative Finance Corporation, CoBank, and NRTC. (2020). Battery Energy Storage Overview. **https://www.cooperative.com/programs-services/bts/Documents/Reports/Battery-Energy-Storage-Overview-Report-Update-May-2020.pdf**

81 BloombergNEF. (2021). Battery Pack Prices Fall to an Average of $132/kWh, But Rising Commodity Prices Start to Bite. **https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite/**

82 This doesn't account for future power plant retirements or reserve capacity changes, which may be influenced by the lower load profile that results from weatherization and increasing home efficiency measures.

83 U.S. Department of Energy. (2018). Weatherization Works! **https://www.energy.gov/sites/prod/files/2018/03/f49/WAP-fact-sheet_final.pdf**

Summary and Key Take-aways

Avoiding future blackouts should start with programs to reduce and manage energy demand. This helps shrink a potential resource gap so the rest can more easily be filled in with solar, wind, and energy storage in line with the State's carbon reduction goals.

Demand-side recommendations:

Increase Weatherization. Expand existing programs, and implement new ones, to weatherize homes. Programs to weatherize homes and switch households to more efficient appliances should start by targeting low-income customers, providing these households affordability benefits along with resilience. Doing so not only boosts winter resilience, but also offers economic and public health co-benefits by reducing pollution, lowering emissions, and shrinking energy bills.

Transition Space Heating Source. Upgrade the approximately 25 percent of households that still use electric resistance heating to high efficiency heat pumps. Programs should prioritize the lowest income households first to improve energy affordability while capturing the greatest number of households that haven't yet transitioned.

Increase Demand Response Participation. Increase participation in residential demand response programs to 60-80 percent of Duke's households in North Carolina by expanding the currently small residential offerings to a wider area while increasing the focus on heating devices. Additionally, incorporate new programs and incentives for large commercial and industrial customers. Doing so will enable Duke to lower demand as needed during an emergency, rather than instituting rolling blackouts or building new fossil fuel plants to meet spikes in winter peak capacity.

Supply-side recommendations:

Increase resiliency with renewables and storage. For **residential** resilience, create incentives to develop distributed solar paired with battery energy storage systems sized for at least 30 percent of average daily PV generation. This can lower peak demand, helping to avoid blackouts. For **local community** benefits, solar+storage can be installed in local community resilience hubs and/or in the homes of electricity-dependent medically vulnerable residents, providing an accessible place for vulnerable populations to reliably access energy. At the **utility scale**, build new utility-scale solar generation paired with significant 4- to 6-hour duration battery energy storage systems. Additionally, support the nearterm development of 1,200 MW of offshore wind, which will provide additional capacity during winter peak hours.

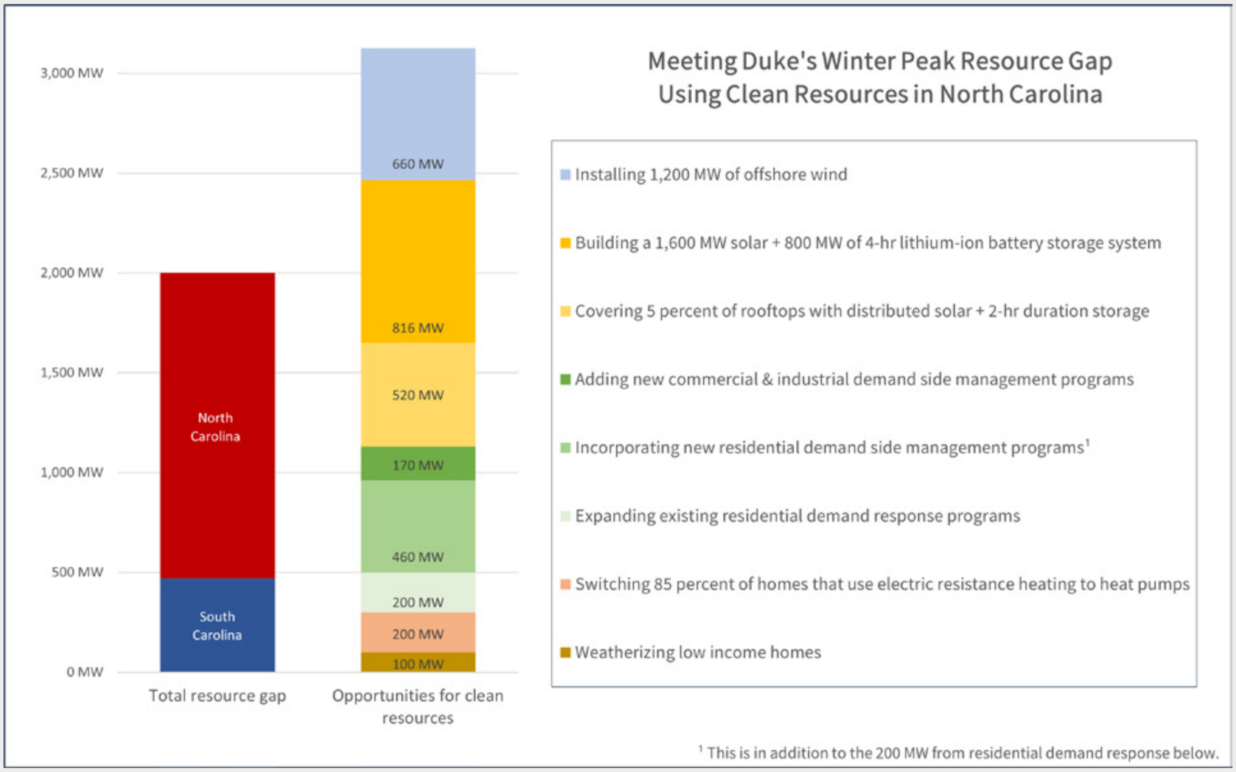


Figure 4: One candidate portfolio of potential winter peak capacity additions from various clean resources in Duke's combined service territories in North Carolina.

If Duke had invested in the above resources, our analysis suggests that the utilities could have kept the lights and heat on for Christmas Eve (**Figure 4**). By law, Duke must reduce carbon emissions by 70 percent by 2030 compared to 2005 levels and reach carbon neutrality by 2050.[84] These kinds of investments can help them do so while also making it easier to avoid the compounding factors—malfunctioning fossil fuel plants, rising peak demand, inaccurate load forecasting, and a lack of power available for purchase on the wider grid—that led to the need for rolling blackouts.

Authorship and Acknowledgements:

This research was conducted by **Bethany Kwoka, MAS** with support from **Jessie Jaeger, MPH, MCP**, **Yunus Kinkhabwala, PhD**, **Patrick Murphy, PhD**, and **Ana McPhail, PhD** of PSE Healthy Energy. We acknowledge and appreciate the financial contribution from the Climate and Clean Energy Fund's Policy Accelerator.

84 General Assembly of North Carolina. (2021). Session Law 2021-165, House Bill 951. **https://www.ncleg.gov/Sessions/2021/Bills/House/PDF/H951v6.pdf**