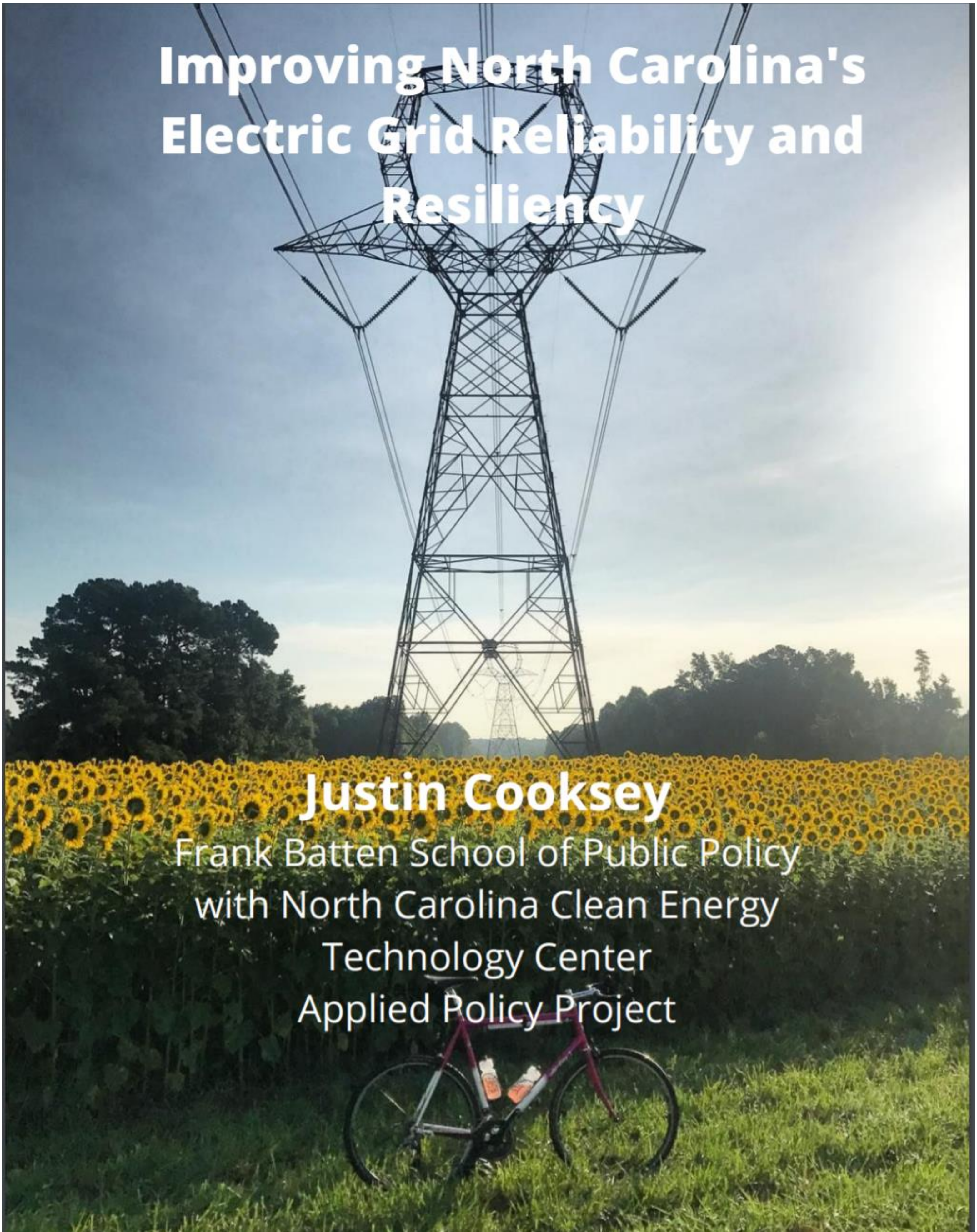

Improving North Carolina's Electric Grid Reliability and Resiliency

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Disclaimer

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other agency.

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Honor Statement

On my honor, as a student, I have neither given nor received unauthorized aid on this assignment.

Dustin Cooksey

Key Terms and Acronyms:

CIP – Critical Infrastructure Plan

DER – Distributed Energy Resource

DOE – Department of Energy

EIA – Energy Information Administration

FERC – Federal Energy Regulatory Committee

IOU – Investor-Owned Utility

MED – Major Event Day

NCUC – North Carolina Utilities Commission

NERC – North American Electric Reliability Corporation

RTO – Regional Transmission Organization

SAIDI – System Average Interruption Duration Index

SAIFI – System Average Interruption Frequency Index

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Executive Summary

North Carolina is one of the most vulnerable states in the nation to damage to its electric grid from hurricanes and other major weather events, in large part due to its coastal geography. These major weather events cause massive outages and represent massive challenges to the reliability and resiliency of the grid. Past efforts by various stakeholders to address these concerns have proven to be ineffective, as displayed by massive statewide outages in recent years caused by damage from hurricanes. With roughly 2.3 million North Carolina electricity customers experiencing a power outage in 2018 due to severe weather episodes, the need for further action on this policy issue is clear.

This report examines five solutions to address North Carolina's grid reliability and resiliency challenges:

1. Join the PJM Interconnection
2. Continue Current Hardening Expenditures
3. Implement a 100% RPS by 2045
4. Increase Hardening Expenditures
5. Subsidize Residential Battery Storage Devices

Each of the five alternatives is evaluated using five criteria: cost-effectiveness, political feasibility, environmental sustainability, ease of implementation, and administrative sustainability.

This report concludes that subsidizing the purchase of residential battery storage devices while ensuring that the current levels of hardening expenditures are continued represents the best option to address the reliability and resiliency issues facing the North Carolina electric grid.

Problem Statement:

In 2018, roughly 2.3 million North Carolina electricity customers experienced a power outage due to a severe weather episode[1].

Problem Definition:

In 2018, there were a total of 2,558,712 outages caused by severe weather that affected utilities that generate power in North and South Carolina. Both Duke Energy Carolinas and Duke Energy Progress represent the two largest electric utilities in North Carolina, both of which are controlled by the broader Duke Energy company. These utilities produce electricity for customers in North and South Carolina, but don't publicly aggregate their customers by state, instead publishing a total. From this total, a proportion of customers served in North Carolina was generated and then used to produce an estimate of the total number of outages in North Carolina, which was 2,288,103.

North Carolina is uniquely susceptible to electric grid damage from hurricanes and severe storms due to its location on the coast. North Carolina ranks only behind Florida as the state with the most landfalls from tropical cyclones, described as hurricanes, tropical storms, or tropical depressions[2]. This is underscored by the prevalence of hurricanes in recent years which have impacted North Carolina. In 2017, Hurricane Maria and Hurricane Irma impacted coastal regions in northern portions of North Carolina. Additionally, in 2018, Hurricane Florence made direct landfall in Wrightsville Beach, North Carolina, greatly impacting both coastal and inland regions of the state. In 2019, North Carolina was significantly impacted by Hurricane Dorian, with a state of emergency and mandatory coastal evacuations being implemented. Additionally, recent research suggests that the trend of global warming is helping to contribute to an increase in the proportion of the strongest hurricanes, classified as category four and five hurricanes[3]. This propensity for hurricanes to impact North Carolina, as well as the increasing power of these storms suggests that North Carolina will be dealing with the impacts of severe weather patterns on its electric grid for years to come.

To underscore the effects that hurricanes have on the North Carolina electric grid, the damage caused by the direct impact of Hurricane Florence is examined below. As previously mentioned, this storm impacted the entirety of the state, not just the coastal regions like some

[1] *Electric Power Monthly with data for November 2019*. EIA (2020). 282. https://www.eia.gov/electricity/monthly/current_month/epm.pdf

[2] *North Carolina—State Energy Profile Analysis—U.S. Energy Information Administration (EIA)*. (n.d.). Retrieved February 23, 2020, from https://www.eia.gov/state/analysis.php?sid=NC

[3] Holland, G., & Bruyère, C. L. (2014). Recent intense hurricane response to global climate change. *Climate Dynamics*, *42*(3), 617–627. https://doi.org/10.1007/s00382-013-1713-0

hurricanes. Duke Energy Carolinas, the main provider for inland North Carolina, reported an outage that affected roughly 38,000 customers. Duke Energy Progress, the main provider for coastal North Carolina, reported an outage that affected nearly 1.3 million customers, with an electric cooperative reporting another 325,000 customers being affected by an outage[4]. In total, this means that Hurricane Florence caused a power outage for at least 1.7 million residents in North Carolina. Additionally, the longest of these outages, under the jurisdiction of Duke Energy Progress, lasted for 166 hours and 4 minutes, or roughly a week. The scale and length of these outages serve to emphasize the need for a long-term comprehensive plan to try to address the issues which major weather events pose for the North Carolina electric grid. Table 1 below displays all of the major energy disturbances which were caused by severe weather in 2018 in North Carolina, displaying the extent to which these weather-related outages affect citizens of North Carolina.

Table 1: 2018 Major Energy Disturbances from Severe Weather

Utility	State Affected	NC and SC Customers Affected	Projected NC Customers Affected
Duke Energy Carolinas	North Carolina, South Carolina	78,100	59,637
NC EI Member Corporation	North Carolina	325,000	325,000
Duke Energy Progress	North Carolina, South Carolina	1,457,583	1,293,362
Duke Energy Carolinas	North Carolina, South Carolina	50,000	38,180
Duke Energy Carolinas	North Carolina, South Carolina	240,807	183,880
Duke Energy Progress	North Carolina, South Carolina	170,222	151,043
NC EI Member Corporation	North Carolina	117,000	117,000
Duke Energy Carolinas	North Carolina	50,000	50,000
Duke Energy Progress	North Carolina	70,000	70,000

[4] *Electric Power Monthly with data for November 2019*. EIA (2020). 282. https://www.eia.gov/electricity/monthly/current_month/epm.pdf

Costs to Society

Costs of Power Outages

Loss of power drastically affects a host of different parties and can cause economic and social hardship. Loss of power frequently requires a suspension of business activity, which can cause huge losses for businesses. For Instance, a report by the Council of Economic Advisors suggested that "weather-related outages are estimated to have cost the U.S. economy an inflation-adjusted annual average of $18 billion to $33 billion, with more significant events like 2012's Hurricane Sandy having an estimated $27 billion to $52 billion economic impact". The majority of these losses stem from businesses shutting down, resulting in a loss in operating time, as well as a subsequent loss of hourly employee salaries. Additionally, power outages lead to a reduction in productivity for those workers who are still able to work which only serves to further compound the effect. As a whole, this results in a significant reduction in gross GNP during the outage period. Additionally, extended power outages can lead to school and government closures. This can, in turn, impose increased economic costs on parents, such as a requirement to modify their work schedules or hire child care services. Certain industries are uniquely vulnerable to economic losses as a result of power outages, namely manufacturing and healthcare industries. According to a study by the Ponemon Institute, healthcare organizations face an average cost of $690,000 per outage, with costs rising as the length of the outage increases[5].

North Carolina Power Outages

While Hurricane Sandy represents an extreme case, North Carolina is uniquely susceptible to major weather events in the form of hurricanes and tropical storms, as was displayed by Hurricane Florence. This is particularly true due to the abnormal length of the power outages in North Carolina, which is nearly double the national average for the length of a power outage at a length of eight hours. Given these extended power outages, it is estimated that large commercial energy customers, who are classified as using over 50,000 annual kWh of electricity, lose on average $84,083 in terms of lost sales and other business income over the course of the eight-hour power outage, based on national averages. For commercial businesses using under 50,000 annual kWh of electricity, this number falls to a loss of $4,690 during the power outage. Lastly, for residents, this number is on average a loss of $17.20 in terms of lost economic productivity and other efficiency losses[6]. When these numbers are scaled up based

[5] Power Outage Costs and the Value of Electric Reliability. (2018, May 7). *Microgrid Knowledge*. https://microgridknowledge.com/power-outage-costs-electric-reliability/

[6] Understanding and Managing Grid Reliability and Resiliency. (2018, July 25). Retrieved September 23, 2019, from Advanced Energy website: https://www.advancedenergy.org/2018/07/25/gridreliabilityandresiliency/

on the total number of businesses and residents affected, the total losses incurred due to a lengthy power outage can grow to be very high. For instance, as previously stated, it is projected that roughly 2.3 million customers were affected by power outages due to severe weather in 2018 in North Carolina. If this outage rate is multiplied by the economic cost of an eight-hour power outage, the average duration, this leads to an expected economic loss of $39,560,000 for residents alone. Additionally, grid repair costs after major weather events add significantly to the total cost of power outages. For instance, Hurricane Florence alone caused a projected $540 million worth of damage to Duke Energy infrastructure throughout the Carolinas[7]. When all of these costs are aggregated, the total loss becomes staggering, only serving the emphasize the need for policy changes to be implemented surrounding grid reliability and resiliency.

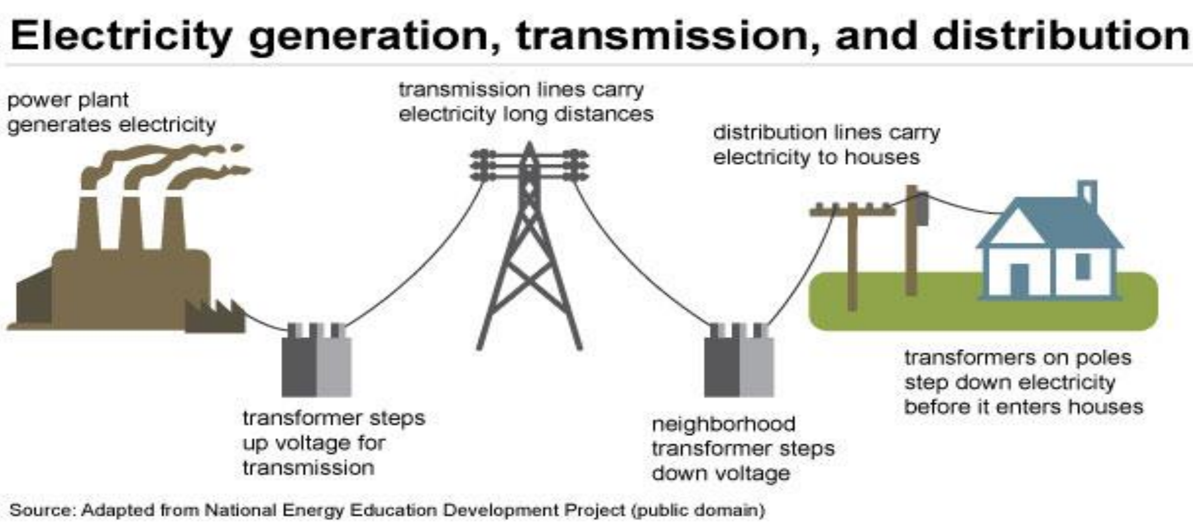
[7] *Hurricane repairs for Florence and Michael hit $900M at Duke Energy*. (n.d.). Charlotte Business Journal. Retrieved April 16, 2020, from https://www.bizjournals.com/charlotte/news/2018/11/02/hurricane-repairs-for-florence-and-michael-hit.html

Background

Traditional Electric Market Structure

Historically, electricity markets have been governed by a vertically integrated market structure that relies on a singular monopolistic company for all energy in a geographic region. This means that one company controls and is responsible for all of the generation, transmission, and distribution resources necessary to provide electricity, as displayed below in Figure 1[8]. These companies are subject to regulation, typically either by the state legislature or through the formation of the public utility commission to oversee the entire electricity process. Additionally, these electricity producers are subject to regulations passed by the Federal Energy Regulatory Committee (FERC) and the Department of Energy (DOE). These companies can either be state-owned or investor-owned, depending on their structure and frequently are guaranteed a certain profit level by the regulatory body governing them. For instance, Duke Energy is guaranteed a return on equity of 10.5% under the most recently approved rate case[9]. This structure frequently incentivizes vertically integrated utilities to spend money on capital intensive infrastructure projects, which may not always be the most beneficial for consumers or the overall reliability and resiliency of the grid.

Figure 1: Vertically Integrated Electric System



[8] U.S. Energy Markets 101: How Electricity Markets Work. (n.d.). *LevelTen Energy*. Retrieved February 24, 2020, from https://leveltenenergy.com/blog/clean-energy-experts/energy-markets-101/

[9] *Duke Energy Carolinas seeks $291M rate hike in NC*. (n.d.). Charlotte Business Journal. Retrieved February 23, 2020, from https://www.bizjournals.com/charlotte/news/2019/09/30/heres-how-much-duke-energy-is-seeking-to-raise.html

Electricity Cooperatives

Electricity co-ops are a variation of the traditional electric model and are consumer-owned and not for profit. These co-ops are established to provide at-cost electricity to communities as opposed to the retail rate of electricity typically supplied by traditional utilities, which typically includes overhead and guaranteed profit. However, cooperatives typically only manage the distribution stage of the electricity process, with co-ops still relying on traditional utilities for the generation and transmission stages of the process, although there are some exceptions to this[10]. Co-ops are typically governed by a board elected from the region which the co-op serves, but are also still subject to regulation, typically by the public utility commission in the state. In certain regions of North Carolina, these co-ops provide an alternative to the vertically integrated utility structure provided by investor-owned utilities.

New Electricity Market Technologies

There are a variety of new technologies and techniques which have the potential to drastically transform the energy market in North Carolina. I will discuss three which have the potential to impact the North Carolina electric market in the coming years: distributed energy resources (DERs), battery storage, and regional transmission organizations (RTOs).

Distributed Energy Resources:

Distributed energy resources are decentralized sources of energy generation that do not occur at large scale energy generation power plants. The most common form of DERs are solar panels, which typically take the form of community or residential solar installations. DERs allow individuals to generate their own power and sell excess power back to the grid, lessening the amount of energy that typical producers need to generate. This has the potential to drastically overhaul the typical vertically integrated structure of current electric markets.

Battery Storage

Battery storage for electricity is still an extremely new technology and has not yet achieved widespread adoption. Under the current electricity generation structure, energy must be used almost as soon as it is produced, as transportation over transmission and distribution lines is nearly instantaneous. However, battery storage would allow for energy to be produced and stored for later use. Battery storage typically is discussed as going hand in hand with DERs, as this would allow for individuals to produce energy throughout the day and store it for later times when they are unable to generate electricity.

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[10] *America's Electric Cooperatives: 2017 Fact Sheet*. (2017, January 31). America's Electric Cooperatives. https://www.electric.coop/electric-cooperative-fact-sheet/

RTOs

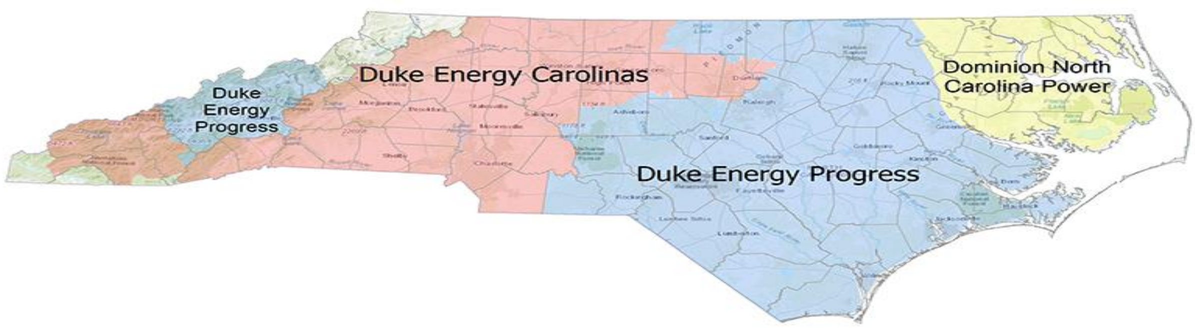
An RTO is an organizational grid operator that allows for energy to be traded across state borders and from a variety of different energy generation sources. As opposed to the vertically integrated utility structure, RTOs allow for private firms to produce electricity and then sell this energy on the marketplace created by the RTO. RTOs allow for the decentralization of the energy generation process and currently generate electricity for roughly two-thirds of North American electricity customers[11].

[11] *ISO/RTO COUNCIL – Coming together to create a smarter & stronger North American power grid*. (n.d.). Retrieved March 21, 2020, from https://isorto.org/

North Carolina Electricity Providers

The North Carolina electric sector is primarily controlled by two investor-owned vertically integrated utilities: Duke Energy and Dominion Energy, as can be seen in Figure 2 below. Duke Energy is split into two separate subsidiaries in the state, Duke Energy Carolinas and Duke Energy Progress. Duke Energy Carolinas covers roughly 24,000 square miles of territory and serves roughly 2.6 million customers through the generation of approximately 20,200 megawatts of energy[12]. Duke Energy Progress focuses on the eastern portion of the state and covers around 32,000 square miles of service area with roughly 1.6 million customers and an owned electric capacity of approximately 12,700 megawatts[13]. In addition to the major vertically integrated utilities, North Carolina also relies on co-ops and municipally owned electric utilities. There is a total of 29 electricity co-ops and 76 municipally owned electric utilities that provide services in North Carolina[14].

Figure 2: North Carolina Investor-Owned Utility Map



Source: North Carolina's Public Utility Infrastructure & Regulatory Climate Presented by North Carolina Utilities Commision (October 2017)

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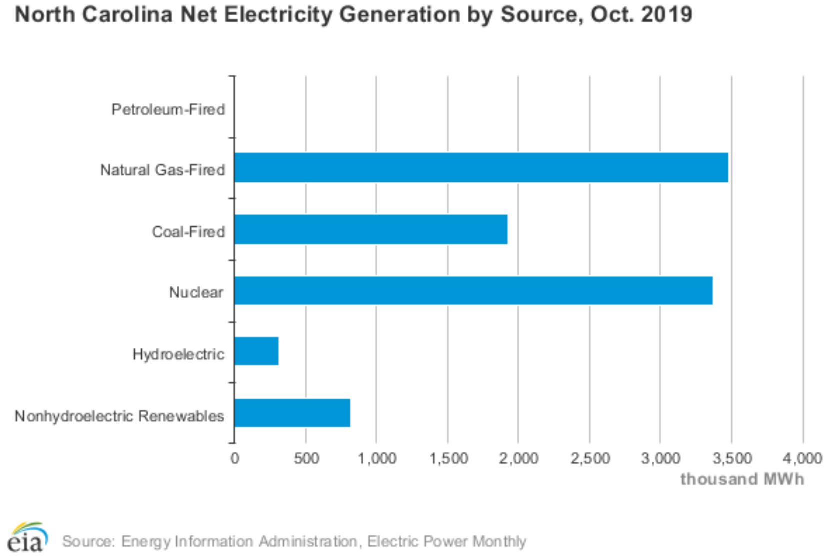
[12] *Regulated Utilities—Business*. (n.d.). Duke Energy. Retrieved February 23, 2020, from https://www.duke-energy.com/Our-Company/About-Us/Businesses/Regulated-Utilities

[13] Ibid

[14] Maps. (n.d.). *NC Sustainable Energy Association*. Retrieved February 23, 2020, from https://energync.org/maps/

NC Electricity Sector Overview

Figure 3: North Carolina Generation Mix



North Carolina customers receive their electricity generation from a broad variety of sources. As can be seen in Figure 3, natural gas-fired plants account for the largest MWh output of electricity generation of any source, with nuclear energy not far behind. In 2018, North Carolina was fifth in the nation in terms of net electricity generation from nuclear power sources[15]. Additionally, North Carolina has the most installed solar generating capacity of any state outside of California, with 4,100 megawatts installed as of 2018. This wide array of generation sources puts North Carolina in the top ten states in terms of total electricity generation[16]. However, North Carolinians also use an outsized amount of energy, ranking fourth among all states in terms of total energy usage by the residential sector[17]. As a result of this North Carolina uses more energy than it produces, meaning that electricity is required to be imported from the regional grid.

Table 2: November 2019 North Carolina Electricity Overview

	Residential	Commercial	Industrial
Customers Served	4,670,411	710,785	9,724
Electricity Prices (₵/KWh)	11.57	8.82	5.86
Revenues from Sales (Millions $)	487	318	118
Electricity Sales (Thousand Megawatthours)	5,217	3,788	2,206

The numbers in Table 2 above serve to help summarize the North Carolina electricity market in terms of the three main customer bases for the consumption of electricity. In total, the year to date power sales revenue ending November 2019 for all energy consumption sectors combined was $11,886,000,000[18]. The total year to date net generation from utility-

[15] *North Carolina—State Energy Profile Overview—U.S. Energy Information Administration (EIA)*. (n.d.). Retrieved February 23, 2020, from https://www.eia.gov/state/?sid=NC#tabs-4
[16] *Ibid*
[17] *Ibid*
[18] *Electric Power Monthly with data for November 2019*. EIA (2020). 282 https://www.eia.gov/electricity/monthly/current_month/epm.pdf

scale facilities was 103,100,000 MWh from electric utilities, with an additional 16,290,000 MWh being produced by independent power providers[19].

Legislative and Regulatory Governance

North Carolina Utilities Commission (NCUC)

The main regulatory entity for the North Carolina electric grid is the NCUC. There is a total of seven commissioners who are appointed by the Governor and approved by the General Assembly for six-year terms. The primary law which governs this body is the Public Utilities Act of 1963 (c.1165, s.1). This act authorized the NCUC to "regulate public utilities generally, their rates, services and operations, and their expansion in relation to long-term energy conservation and management policies and statewide development requirements"[20]. The mission statement of the organization has expanded beyond this and now states that the NCUC must[21]:

- Provide fair regulation of public utilities in the interest of the public.
- Promote the inherent advantage of regulated public utilities.
- Promote adequate, reliable, and economical utility service.
- Promote least-cost energy planning.
- Provide just and reasonable rates and charges for public utility services and promote the conservation of energy.
- Assure that facilities necessary to meet future growth can be financed on reasonable and fair terms.
- Encourage and promote harmony between utility companies and their customers.
- Foster planned growth of public utility services.
- Coordinate energy supply facilities with the State's development.
- Cooperate with other states and the federal government in providing interstate and intrastate public utility service and reliability of energy supply.
- Facilitate the construction of facilities in and the extension of natural gas service to unserved areas.
- Promote the development of renewable energy and energy efficiency

Federal Energy Regulatory Committee (FERC)

At the federal level, the primary regulatory body which oversees the operation of the electric grid is the Federal Energy Regulatory Committee. The Federal Water Power Act of 1920 created the Federal Power Commission, which oversaw hydroelectric plants. In 1935, the act

[19] Ibid

[20] *Chapter_62.pdf*. (n.d.). Retrieved February 23, 2020, from https://www.ncleg.net/EnactedLegislation/Statutes/PDF/ByChapter/Chapter_62.pdf

[21] *NCUC: About Us*. (n.d.). Retrieved February 23, 2020, from https://www.ncuc.net/Aboutncuc.html

was expanded into the Federal Power Act, which increased the oversight of the FERC to wholesale power sales and interstate electricity transmission. Additionally, in 2005, the Energy Policy Act expanded the jurisdiction of FERC further, to include the regulation of the reliability of the electric grid and the implementation of policies concerning reliability[22].

Grid Resiliency and Reliability

Grid reliability and resiliency are two metrics through which utility companies analyze their electricity grid. Reliability refers to the percentage of time that the grid is functioning to produce energy, while resiliency refers to the ability of the grid to prevent, endure, and quickly recover from power outages. Resiliency and reliability are chiefly affected in the transmission and distribution stages of the energy generation process. According to the Department of Energy, roughly 90% of electric power interruptions occur during the distribution stage of energy production. These interruptions frequently come in the form of downed power lines or damaged transmission equipment. The cause of these damages is from weather-related incidents, however other sources such as damage from animals and human error contribute to the interruption of energy. There are three main metrics that the Energy Information Administration (EIA) uses to evaluate the frequency and severity of outages. The first is the System Average Interruption Duration Index (SAIDI) which measures the average length of all power outages for specific customers over a specified period of time. The second is the Major Event Day (MED) which is used to measure longer outages when the SAIDI exceeds a certain level for a given period, typically one day. Lastly, the System Average Interruption Frequency Index (SAIFI) is used to measure the average number of outages that a customer experiences over a year. Taken together, these measurements are used to determine the efficacy of resiliency and reliability strategies taken by utility companies.

[22] *FERC: Federal Statutes*. (n.d.). Retrieved February 23, 2020, from https://www.ferc.gov/legal/fed-sta.asp

NC Reliability and Resiliency

Figure 4: NC Outages by Source

Following the general trend at the national level, the majority of outages in North Carolina are weather-related, as seen in Figure 4. In 2016, the SAIDI for North Carolina was two hours without including MEDs', and increased to eight hours when MEDs' were included[23]. The national average for MEDs' is just over four hours, displaying that North Carolina is much worse in terms of the length of outages than the national average[24]. As previously discussed, North Carolina is frequently hit by hurricanes, which leaves the state uniquely susceptible to MED outages. However, this difference is not explained by a difference in the number of outages measured by SAIFI, as without MEDs there was an average of 1.25 outages per year and with MEDs, this number climbed to 1.75. The national average is roughly 1.4, meaning that North Carolina experienced only a marginally higher number of outages per year than the national average[25]. This serves to highlight that the major challenge to grid resiliency and reliability is from the occurrence of Major Event Days such as hurricanes or other major storms.

Best Practices

The most common form of addressing issues of reliability and resiliency is through measures that are intended to "harden" the electricity grid. Hardening measures can take a variety of different forms, each of which has its strengths and drawbacks based on regional needs. Common examples of hardening activities are listed below:

Burying Vulnerable Power Lines

One of the most commonly implemented hardening reforms is to identify distribution lines which are at risk from damage from major weather events and to subsequently bury these lines underground. This helps to take the power lines out of harm's way and is effective in instances of high-speed winds causing damage to power lines. Burying power lines has been common practice in residential power lines for decades, however, the practice has become a popular solution for addressing reliability and resiliency issues in recent years. Burying power lines was part of Florida Power and Light's $3 billion investment in grid hardening technologies,

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[23] Understanding and Managing Grid Reliability and Resiliency. (2018, July 25). Retrieved September 23, 2019, from Advanced Energy website: https://www.advancedenergy.org/2018/07/25/gridreliabilityandresiliency/
[24] Delivery to consumers—U.S. Energy Information Administration (EIA). (n.d.). Retrieved September 23, 2019, from https://www.eia.gov/energyexplained/electricity/delivery-to-consumers.php
[25] Ibid

which has been proven to be effective in reducing the length of power outages[26]. A drawback for burying power lines in certain regions of North Carolina is that buried power lines do not function well in areas that are prone to flooding.

Increasing the Strength of Distribution Poles

Another frequently used technique to increase grid reliability and resiliency is to upgrade the poles which elevate distribution lines. These poles are frequently constructed of wood and can be damaged or knocked over relatively easily in the case of heavy winds or flooding. Instead, these poles are replaced by ones constructed from concrete, making them much more able to withstand damage from heavy winds and flooding. After Superstorm Sandy, Con Edison embarked on major changes to their overhead power line infrastructure. One of the main changes which they made was to require all of their overhead distribution poles to be able to withstand wind gusts up to 100 MPH[27].

Elevating Substations

A tactic that is frequently used in regions that are subject to high degrees of flooding or which are vulnerable to hurricanes is to elevate electric substations on concrete stilts to prevent them from being damaged by floodwater. This technique was implemented by CenterPoint Energy in Texas after Hurricane Ike left a large portion of their substations flooded, greatly reducing their ability to try and regain the flow of power. In response, CenterPoint began raising all of their vulnerable substations to heights of 22 feet above sea level to prevent flooding and subsequently help to increase grid reliability and resiliency[28].

Hardening Applications:

There are a variety actions that have been taken at the state level to try to address issues of grid reliability and resiliency in addition to the ones listed above , particularly in areas that are subject to extreme weather events. The majority of past actions by utilities have been classified as grid hardening solutions. Below are examples of the implementation of grid hardening solutions in states that are geographically proximate to North Carolina and that suffer from similar threats to grid reliability and resiliency from major weather patterns.

In Florida, the Florida Legislature recently passed Senate Bill 796, which is designed to specifically address weather-related issues. The law allows utilities in Florida to assess a fee to their customers with the funds being appropriated towards a ten-year plan for improving the

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[26] *Emerging best practices for utility grid hardening*. (n.d.-a). Utility Dive. Retrieved February 23, 2020, from https://www.utilitydive.com/news/emerging-best-practices-for-utility-grid-hardening/541301/
[27] *Storm Hardening the Grid*. (2014, October 1). T&D World. https://www.tdworld.com/grid-innovations/distribution/article/20964810/storm-hardening-the-grid
[28] Ibid

reliability and resiliency of the grid[29]. In particular, these funds will go towards hardening measures. The three primary hardening strategies which are being invested in are targeted undergrounding of transmission wires, vegetation management around transmission wires, and the installation of stronger transmission poles and wires[30].

South Carolina is another geographically proximate state facing almost identical reliability and resiliency issues as North Carolina. The governor of South Carolina recently signed the Energy Freedom Act, which is aimed at addressing the reliability and resiliency issues which the state recently faced in the aftermath of Hurricane Florence[31]. This act provides new guidelines for utility companies to follow when calculating their avoided costs for the construction of new projects. These guidelines place a greater monetary value on the resiliency of new projects to be constructed. As a result, this legislation helps to promote the use of distributed energy generation sources, in particular, distributed photovoltaic solar panels. Additionally, this legislation helps to encourage battery storage technologies for distributed energy generation sources. Distributed energy generation sources are important to the increase of the reliability and resiliency of the grid because they decentralize the power generation structure away from the traditional model of large power plants providing energy for the majority of citizens. Decentralizing the energy generation process means that fewer transmission lines are needed to transport power to individuals, which in turn decreases the likelihood that a major weather pattern or other event disrupts these power lines.

Other Risks to Grid Reliability and Resiliency

Cybersecurity Threats

The risk of intrusion into the electricity grid via a cyber-attack is ever-increasing as electric grids continue to age. According to former National Security Administrator Michael Rodger, it is likely that China, as well as a host of other countries, have the capability to shut down the U.S. power grid[32]. This point has only been emphasized in recent years, as a utility company in Vermont, a nuclear power plant in the United States, and various U.S. energy

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[29] *701079.pdf*. (n.d.). Retrieved from https://www.gao.gov/assets/710/701079.pdf
Coming Full Circle in Florida: Improving Electric Grid Reliability and Resiliency. (n.d.). Retrieved October 28, 2019, from Energy.gov website: https://www.energy.gov/articles/coming-full-circle-florida-improving-electric-grid-reliability-and-resiliency
[30] Ibid

[31]Costello, M. B. (2019, July 30). Energy Freedom Act: South Carolina Takes Steps Towards Resilience. Retrieved October 28, 2019, from Clean Energy Group website: https://www.cleanegroup.org/energy-freedom-act-south-carolina-takes-steps-towards-resilience/
[32] Erdman, Shelby, C. M. G. N. C. D. (n.d.). How vulnerable is the U.S. power grid to a cyberattack? 5 things to know. Retrieved October 7, 2019, from Ajc website: https://www.ajc.com/news/national/how-vulnerable-the-power-grid-cyberattack-things-know/YujzcltJ5wB2z8zJHyzPvI/

companies have all been the subject of cyberattacks in the past several years[33]. Any cyber intrusion which effectively shuts down the grid would drastically affect the resiliency and reliability of the electric grid. The risk of a cybersecurity threat in North Carolina has been recently highlighted by recent sanctions by federal regulators. In February of 2019, Duke Energy received a $10 million fine, the largest cybersecurity-related fine in history[34]. This was because Duke Energy had violated the North American Electric Reliability Corporation's (NERC) Critical Infrastructure Protection (CIP) rules, suggesting that Duke Energy has not taken adequate security measures to protect its grid infrastructure. This means that the reliability and resiliency of North Carolina's electricity are under threat from potential cyberattacks.

Terrorism Threats

While cyber-attacks pose threats to the components of the grid, the physical structures of the grid are also exceedingly vulnerable to damage by nefarious actors. Many large-scale generation facilities have little meaningful security and there are thousands of miles of unguarded transmission lines. Coordinated measures by terrorists to attack key generation and transmission facilities has the potential to severely cripple the ability of the electric grid to function and could leave countless customers without power. Current projections estimate that a well-coordinated attack could eliminate power for weeks if not longer. This has the potential to lead to billions of dollars of economic losses for affected parties, as well as the potential for loss of life[35].

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[33] Ibid

[34] Mai, HJ, US power sector recognizes cyber risks, but violations show enforcement issues. (n.d.). Retrieved October 7, 2019, from Utility Dive website: https://www.utilitydive.com/news/us-power-sector-recognizes-cyber-risks-but-violations-show-enforcement-iss/552558/

[35] *Read "Terrorism and the Electric Power Delivery System" at NAP.edu*. (n.d.). https://doi.org/10.17226/12050

Evaluative Criteria

The mission statement of the North Carolina Clean Energy Technology Center (NCCETC) reads as follows: “We are a public service center seeking to advance a sustainable energy economy by educating, demonstrating, and providing support for clean energy technologies, practices, and policies.” As such it is important to attempt to include a metric in the criteria which captures the essence of this mission statement, while also including enough other criteria to fully evaluate all potential options. All of the policy options were evaluated along five metrics: political feasibility, cost-effectiveness, environmental sustainability, administrative sustainability, and ease of implementation.

The political feasibility of each policy option will indicate the extent to which the measure is likely to be passed by the governing body responsible for legislating the policy option. For instance, three of the proposed policy options would need to be passed by the state legislature, where Republicans hold a 65-55 majority in the House and a 29-21 majority in the Senate. In the House, the Standing Committee on Energy and Public Utilities would have jurisdiction over the legislation. There are two Republican chairs of the committee, Representative Dean Arp and Representative John Szoka. In the Senate, jurisdiction would likely fall to the Standing Committee on Agriculture, Environment, and Natural Resources. This committee is co-chaired by Republican Norman W. Sanderson and Republican Andy Wells. The Majority Leader in the House is Republican John Bell IV and, in the Senate, Republican Harry Brown serves as the Majority Leader. This will mean that all of the policy options will need to be evaluated based on the likelihood of Republican support in the House and Senate for the measure. After passing through the Legislature, Governor Roy Cooper, who is a Democrat, would have to approve the measures. As such these options will also be evaluated based on the likelihood that Governor Cooper would support them and subsequently build a coalition around the policy options. Additionally, one of the proposed policy options would be implemented by the North Carolina Utilities Commission (NCUC). This policy option will be evaluated based on the likelihood of support from members of the NCUC. The consideration of other major stakeholders will also need to be taken into account as these stakeholders hold political sway and can influence the feasibility of an option. As previously mentioned, Duke Energy and Dominion Power have a great deal of influence over proceedings affecting the energy space and as such their support of any measures will have to be weighed to determine the feasibility of any option. Additionally, labor unions will likely have input surrounding changes to the energy industry, in particular the International Brotherhood of Electrical Workers and the North Carolina AFL-CIO.

The second criterion for evaluating my policy alternatives is the cost-effectiveness of each option. The outcome which I will be measuring for my cost-effectiveness measure is a quantified decrease in the total number of hours of outages which will result from the implementation of each policy option. The majority of the focus will be on the major weather episode outages, as this is a more commonly faced challenge to the grid in North Carolina. The total cost of each policy alternative will be divided by the expected reduction in the total number of hours of outages to provide a metric by which the policy alternatives can be directly compared. While this is by no means comprehensive, the major costs will likely be the upfront costs of any necessary infrastructure investments as well as increased electricity costs for consumers. Costs will be evaluated for a ten-year time frame and will subsequently be discounted. These will likely be quantified by using precedent from transformations of the electric grid in other locations.

The third criterion which I will use to evaluate the potential policy options will be the extent to which the project is administratively sustainable. This criterion will evaluate whether the policy option is self-sustaining once it has been implemented, or if continued oversight will be necessary to maintain the viability of the project. This will take into account the expected popularity of the program with the administering agency and the subsequent effort level which they will be expected to put forward to maintain the program. In this sense, the general sustainability will be largely qualitatively discussed, however, the extent of continued spending will be quantified wherever possible. The length of implementation and viable lifespan of the policy options will also be taken into account in this section.

The fourth criterion is derived from the mission statement of the NCCETC and will be based on the environmental sustainability of the policy alternative. The evaluation of this criterion will be based upon the extent to which the solution addresses long term environmental challenges facing the North Carolina electric grid. This criterion will take into account the degree to which solutions contribute to the spread of green technologies as well as to the reduction in carbon emissions from the power sector in North Carolina. This section will likely contain more easily quantified data, as a large portion of the proposed policy alternatives are slanted towards environmental sustainability goals. The quantified measures will be the reduction in the tons of carbon dioxide emitted. However, this section will carry a small weight in the final evaluation, so as not to overly affect those options which may not be focused on environmental sustainability but are nonetheless effective solutions for addressing reliability and resiliency concerns.

The fifth criterion used to evaluate the alternatives is the degree to which the options can be effectively implemented by the appropriate administrative agency. In this case, the agencies which will likely be most directly tasked with actually implementing the policy options are the major energy providers in North Carolina and the North Carolina Utilities Commission. This is because the policy proposals are all focused on state-level interventions and as such these two stakeholders will bear the brunt of implementation. The NCUC also publishes rules and regulates the rate of return on new capital investment in utility rate cases. Additionally, the Federal Energy Regulatory Committee (FERC) and the Department of Energy (DOE) will have some say in the implementation process of certain policies, depending on the statutory requirements of the policy options. As such, the ability to which each of these organizations has the legal, organizational, and financial capability to achieve the policy recommendations will be evaluated and scored.

Taken together these five criteria will help to provide a broad framework through which the five policy options can be comprehensively evaluated. These criteria will be weighted based on their relative importance to the issue at hand as well as their importance to the NCCETC. Using this weighted framework system for evaluation will help to provide the optimal policy solution from the potential policy options. This will go on to be the recommendation from the report.

Alternatives

This section provides a comprehensive analysis of potential solutions to address the reliability and resiliency challenges that face the North Carolina electric grid. While national regulations are currently being debated by the Department of Energy and the Federal Energy Regulatory Committee, the alternatives which are proposed in this memo will focus on policies that would be implemented at the state level, either by the state legislature or the utility companies in the state. Five alternatives are proposed: Joining the PJM Interconnection, maintaining status quo hardening expenditures, implementing an RPS, increasing hardening expenditures, and subsidizing battery storage devices.

Join the PJM Interconnection

One alternative to address grid reliability and resiliency is to join PJM, which is a regional transmission organization (RTO). An RTO is an electricity grid transmission systems operator who operates over a multi-state electric grid[36]. Essentially RTOs allow for decentralization of the energy generation process by creating a market for energy generation, with other utilities, private contractors, or private households able to provide energy generation. This is in stark contrast to vertically integrated utilities, where one utility controls the energy generation process entirely. Switching from a strictly vertically integrated investor-owned utility structure has the potential to display benefits for reliability and resiliency, largely due to increased generation and transmission options through which grid operators can route the flow of energy[37]. To join PJM the North Carolina legislature would pass legislation that directs the

[36] FERC: Industries—RTO/ISO. (n.d.). Retrieved November 30, 2019, from https://www.ferc.gov/industries/electric/indus-act/rto.asp

[37] Average frequency and duration of electric distribution outages vary by states—Today in Energy—U.S. Energy Information Administration (EIA). (n.d.). Retrieved November 30, 2019, from https://www.eia.gov/todayinenergy/detail.php?id=35652#

NCUC to initiate the process of becoming part of the RTO. Then, utility companies operating in the state would be required to join PJM.

This solution would likely have a slight lag time, as it would take time for legislation to pass and for the utilities in North Carolina to integrate into the PJM Interconnection. The process of connecting to PJM is estimated to take roughly two and a half years, as there are a variety of studies and agreements between all parties which must be completed prior to joining. While RTO's display positive benefits for grid resiliency they also increase grid reliability, as if a power generation source is knocked out by a major event, such as weather or a cyber-attack, the generation source can be easily switched to another provider in the generation network, due to the increased number of generation providers under an RTO model. As a result, outage times will be significantly reduced. However, this option does little to mitigate the effects of distribution lines which are damaged, since this option largely focuses on the generation and transmission phases of electricity production.

Maintaining Status Quo Hardening Measures

The current status quo in terms of attempts to address reliability and resiliency concerns in North Carolina consists of a patchwork of policies being implemented by individual utilities and electricity co-ops without a comprehensive plan or communication. In the wake of Hurricane Florence, Duke Energy came to an agreement with the NCUC to invest in a four-year, $2.5 billion, grid hardening plan[38]. Many co-ops have elected to rebuild and relocate their power lines in an attempt to strengthen them. Dominion Energy has elected to invest in smart grid technologies which help to detect outages when they occur and provide more real-time feedback about grid needs. This status quo option would be to allow all of the electric providers in North Carolina to continue the implementation of their grid transformation plans with no intervention from the North Carolina legislature or the NCUC. Hardening efforts have been shown to be effective in addressing the challenges caused by major weather events. These measures are the typical route through which utilities have sought to address grid reliability and resiliency concerns in the past.

[38] Brumbaugh, J. (n.d.). *Electric Companies Upgrading Infrastructure After Florence*. Retrieved March 20, 2020, from https://www.publicradioeast.org/post/electric-companies-upgrading-infrastructure-after-florence

Renewable Portfolio Standard

A third potential option to address grid reliability and resiliency is for the North Carolina Legislature to pass a law that will establish a Renewable Portfolio Standard (RPS). An RPS is a piece of binding legislation which requires all utilities in the affected area to derive a certain portion of their total energy generation from renewable energy sources. Neighboring Virginia recently implemented an RPS of 100% by 2045, an ambitious goal that would likely serve as an exemplar that North Carolina could use to create their RPS[39]. This option recommends that the North Carolina legislature passes a bill that implements an equivalent RPS of 100% by 2045. In order for this option to be a binding standard, rather than simply a stated goal as some states have proposed, it would need to be implemented through legislation that passes through both chambers and then is signed into law by the Governor.

Adding more renewables is beneficial for reliability and resiliency for an array of reasons. The first is that renewable energy farms are typically smaller in scale than coal or nuclear energy plants, meaning that more power generation sources are required. This helps to decentralize the energy production process, which helps to increase the reliability and resiliency of the grid. Renewables are also used in distributed energy resources, such as residential solar, that help to further decentralize the grid. Implementing an RPS would likely increase the rate at which distributed energy resources are used. Additionally, according to a recent study by the American Wind Energy Association, in regards to grid reliability, large scale wind and solar farms provide "grid reliability services as well as or better than conventional power plants" under the correct conditions[40]. Currently, North Carolina has an RPS of 12.5% required by 2021[41]. However, North Carolina is uniquely positioned to be able to expand this RPS due to the viability of renewable energy sources in the state. For instance, a 2010 study completed by the National Renewable Energy Laboratory found that North Carolina has the potential to implement offshore wind with a capacity of 297 GW, which is the largest of any state on the east coast of the United States[42]. Additionally, solar energy has experienced rapid growth recently in North Carolina, with roughly 5600 MW added in the last twelve years[43]. This

[39] *Virginia Gov. Northam Sets Clean Energy Standards*. (n.d.). US News & World Report. Retrieved February 6, 2020, from https://www.usnews.com/news/best-states/articles/2019-09-17/virginia-gov-northam-calls-for-100-renewable-energy-by-2050

[40] *Whitepapers—U.S. Wind Energy Industry | AWEA*. (n.d.). Retrieved March 21, 2020, from https://www.awea.org/resources/publications-and-reports/white-papers

[41] North Carolina: An Energy and Economic Analysis. (2013, August 1). Retrieved November 30, 2019, from IER website: https://www.instituteforenergyresearch.org/fossil-fuels/coal/north-carolina-an-energy-and-economic-analysis/

[42] Schwartz, M., Heimiller, D., Haymes, S., & Musial, W. (2010). *Assessment of Offshore Wind Energy Resources for the United States* (NREL/TP-500-45889, 983415). https://doi.org/10.2172/983415

[43] Electric Power Annual 2018—U.S. Energy Information Administration. (n.d.). Retrieved November 30, 2019, from https://www.eia.gov/electricity/annual/

displays the viability of the solar industry in North Carolina and displays encouraging signs for the expansion of renewables.

Implement Increased Hardening Measures

Another potential option to address issues of grid reliability and resiliency is to implement a variety of grid hardening options that are above and beyond what the current expenditure levels are by the utilities and co-ops. This option calls for an extension of the current status quo hardening expenditures by a period of two years with an additional expenditure of $1.25 billion, bringing the total to $3.75 billion over a six-year time span. This plan would recommend that utilities strengthen distribution and transmission poles, elevate substations, and implement smart grid technology. The North Carolina PUC has already researched the hardening option of burying power lines, after a large snowstorm in 2002 left millions of customers without power[44]. The study found that undergrounding all of the power lines in North Carolina would take roughly twenty-five years and cost upwards of $40 billion[45]. This cost would, in turn, be passed on to customers, leading to a projected increase in rated of roughly 125%. Additionally, burying lines makes maintenance in these lines much more difficult. For instance, it is projected that routine maintenance to buried power lines takes 60% longer than maintenance to overhead power lines. It was recommended that undergrounding the entire electric grid would not be feasible and that pockets of high-risk power lines should be identified to be buried.

This recommendation suggests that the NCUC initiate new rates case under which the utilities and electric co-ops would be required to implement a variety of hardening measures at the expenditure levels stated above. The first of these would be to identify substations that are considered at risk of flooding and to subsequently elevate these substations. In Hurricane Florence, a total of nine substations flooded with an extra seven only not flooding because of temporary preventative measures taken by Duke Energy[46]. Elevating substations is of utmost importance because unlike other damaged grid infrastructure they cannot be repaired until after the flood has fully receded, leading to longer delays in repair times. The second hardening measure implemented would be to strengthen distribution poles by replacing wooden poles with concrete. This practice has been proven to be effective in reducing the number of downed distribution lines in severe weather events. This proposal would require an independent commission to determine which distribution lines would be deemed to be at risk and would require for IOUs and electric co-ops to replace all of these poles with concrete alternatives.

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[44] CNN, D. S. (n.d.). *Isn't it better to just bury power lines? That may depend on where you live*. CNN. Retrieved February 6, 2020, from https://www.cnn.com/2017/09/14/us/underground-power-lines-trnd/index.html

[45] Ibid

[46] Kuckro, R., E, Thursday, E. N. reporter E., October 4, & 2018. (n.d.). *EXTREME WEATHER: Soaked substations trip up post-hurricane power restoration*. Retrieved March 20, 2020, from https://www.eenews.net/stories/1060100456

Lastly, a rule would be implemented which requires expansion of self-healing technology for the grid. This technology allows for the flow of electricity to be rerouted away from downed power lines and proceed to customers through a different route. This was used with success by Duke Energy during Hurricane Florence to shorten the outage time for roughly 80,000 customers[47].

Subsidize Residential Battery Storage Devices

The final potential option to address the reliability and resiliency issues in North Carolina is to promote the expansion of residential battery storage devices through subsidies implemented by the North Carolina Legislature. Residential battery storage devices draw energy from a generation source, which is almost always in the form of a distributed energy resource, and store this energy for later usage. This allows for residents to still have a reliable source of power, even in the event of an outage, as the power will be drawn from the battery rather than needing to tap into the grid. Currently, battery storage devices are almost always packaged with home solar panels for purchase. While there exists a multitude of subsidies in North Carolina for the purchase of home solar panels, there are none for the residential battery storage devices which can be paired with the DERs. Battery storage devices are extremely expensive with the current levels of technology and while these costs are projected to decrease as the technology improves, the cost is still prohibitively expensive for many at this time. For instance, the average cost of a package of solar panels and a battery storage system typically costs around $28,000, which serves as a large barrier to their adoption.

This option recommends that the North Carolina legislature passes a bill that implements a ten-year energy storage rebate following the same compensation structure as laid out in the Solar Massachusetts Renewable Target (SMART) Program. Essentially, this program provides an additional rebate for the purchase of battery storage systems based on the total storage hours at rated capacity as well as the total storage capacity of the battery. A further breakdown of the storage plus adder is displayed in Appendix A. For the costing calculations a baseline rebate of $.0797/kwh was used. This incentive structure has been shown to dramatically increase the demand for battery storage installations, largely because it reduces the time that it takes for the owner to break even on their initial capital investment in the battery. This option addresses the issues of reliability and resiliency in a variety of ways. First, it provides a backup source of energy that can be tapped into even if the grid is not functioning. In the case of a major weather event, solar plus storage could be used to keep power running for an estimated time period of seven days, drastically increasing the resiliency of the grid. This strategy would begin to immediately address the problem, however for a large-scale impact, it

[47] Brumbaugh, J. (n.d.). *Electric Companies Upgrading Infrastructure After Florence*. Retrieved March 20, 2020, from https://www.publicradioeast.org/post/electric-companies-upgrading-infrastructure-after-florence

would likely take a number of years for the infrastructure to be constructed to adequately support the grid.

Findings

	Implement 100% RPS by 2045	Status Quo Hardening Investment	Join the PJM Interconnection	Increased Hardening Investment	Incentivize Solar plus Storage
Cost Effectiveness (30%)	2	3	1	3	4
Political Feasibility (20%)	2	4	2	3	3
Environmental Sustainability (10%)	4	1	2	1	3
Ease of Implementation (20%)	3	3	2	3	3
Administrative Sustainability (20%)	2	4	3	4	3
Total	13	15	10	14	16

Cost-Effectiveness:

Incentivizing battery storage represents the most cost-effective solution to addressing issues surrounding grid reliability challenges. While residential battery storage represents a small market in North Carolina currently, providing proper incentives allows for the industry to rapidly grow in terms of the amount of installed MW of storage. This rapid growth helps to scale storage, making it so that the total number of hours of storage scales to a level which would be widely useful in case of a major weather event, while also not costing nearly as much as many of the other options. The two hardening options are both fairly cost-effective. While they both represent much greater levels of expenditure than some of the other policy proposals, they also would lead to a significant reduction in the number of hours of outages experienced by the grid. Implementing an RPS and joining PJM score lower in this section. Renewable energies are still being worked into the grid and challenges arise when penetration rates of renewable sources of generation become too high. Additionally, there is a significant projected increase in cost to ratepayers if the RPS were to be implemented, making this option prohibitively expensive. Joining PJM would help in the transmission and generation stages of outages, however, this option largely fails to address the main stage where outages occur, which is the distribution stage.

The total cost of the status quo hardening measure is roughly $2.3 billion after discounting over the four year time period, with the total cost of the increase hardening measures increasing to $3.3 billion after discounting over the six-year period of suggested investment. The hardening measure costs pale in comparison to the projected costs of implementing the RPS option. Over a ten-year period, this option is projected to cost roughly $19 billion, with these costs largely being born by ratepayers. On the other end of the spectrum, the total projected costs of the solar plus storage option are drastically less. Assuming similar growth rates as with the SMART program and then plateauing growth of 5% after two years, the total projected cost of the rebate program is only estimated to be $3.7 million dollars, significantly less than the other options.

Political Feasibility:

For the status quo option, joining PJM, establishing an RPS, and incentivizing solar plus storage options, the state legislature is the main focus of the analysis and these measures will need to be passed through legislation. The increased hardening expenditures would be governed by the willingness of the NCUC and the utilities to take up the issue of grid reliability and resiliency. The status quo option receives the highest score in this instance as the spending on hardening investments has already started and thus requires no political action. There is a reduction in the score for the increased hardening investment because Duke Energy originally proposed spending more on hardening investments, but this was opposed by many groups and was worked down to the current status quo figure by the NCUC. This means that any increases in hardening spending would likely be politically unfavorable. Joining the PJM interconnection and implementing an RPS both score fairly low in this category. While there has been prior interest in RTO's in North Carolina, the generation mix of North Carolina is vastly different from that of many states in PJM, making it so that this option is not currently gaining traction with legislators due to concerns over energy pricing. There have been recent efforts to scale back the current RPS guidelines by North Carolina legislators, although these have not passed. As such, the passage of a new and stringent RPS remains fairly unlikely in North Carolina. North Carolina, as well as Duke Energy, offers a host of rebates for solar installation. As such, providing a storage adder rebate on top of these solar rebates would likely not meet much resistance from the legislature or major stakeholders, as they have already shown an appetite for solar subsidies.

Environmental Sustainability:

Both hardening options score low on the environmental sustainability aspect of this evaluation, as hardening activities do little to reduce carbon emissions and instead are focused solely on infrastructure changes. Implementing an RPS represents the most dramatic change in terms of the reduction of carbon emissions as this is the only option that proposes a tangible level of emissions reductions and as such receives the highest score. Incentivizing solar plus storage will reduce carbon emissions by encouraging the spread of renewable energy generation sources and through decentralization of the grid, meaning it scores relatively well in this category. However, due to uncertainty surrounding the level of adoption of this technology it is difficult to ascertain a definitive level of reduction which would result due to the implementation of this policy option. The environmental benefits of joining PJM are uncertain given the generation mix of North Carolina, which has a significant amount of solar in use. On the other hand, PJM is much more reliant on natural gas and coal for its main generation sources and as such it is unclear if joining PJM would force North Carolina to shift some of its generation structure towards generation sources which emit more carbon in order to fit within the pricing guidelines that are laid out by PJM.

Ease of Implementation:

All of the options score fairly well in terms of how easily they can be adopted by the entity that administers the policy change. The two hardening investment options would both be implemented by the major utilities and co-ops in North Carolina, with these companies mostly having prior experience with this type of grid maintenance. The implementation of joining PJM, overseeing an RPS, and administering battery storage incentives would fall on the NCUC. The NCUC has experience implementing an RPS based on its implementation of the RPS currently in place, however, the scale of the proposed RPS has the potential to cause challenges for the NCUC. Residential battery storage remains relatively scarce in North Carolina, however, the NCUC has experience implementing incentives for solar alone, meaning that adding the battery storage incentive should not be too taxing for the NCUC.

Administrative Sustainability:

The two hardening measures score well here as they have the shortest length of time over which they would have to be administered, however, the status quo would require commitment from Duke Energy to continue allocating the funds to this measure. The other three options all have lifetimes which are at least a decade, naturally providing a challenge to the continued sustainability of the policy upon implementation. In particular, the RPS would continuously face challenges from outside stakeholders throughout the 25-year lifecycle of the RPS, meaning that the NCUC would have to employ continuous efforts to ensure the program remained viable.

Recommendation:

I recommend a two-part solution to address the issues of grid reliability and resiliency that are facing North Carolina. These solutions are intended to address both the short term and long-term challenges that the grid faces due to changing weather patterns as well as trends in the electric industry. For the short-term solution, I am proposing that the NCUC ensures that Duke Energy continues their current levels of hardening expenditures over the entirety of the four-year time frame which Duke has planned. This level of investment is necessary for the transformation of the grid and attempts by Duke Energy to initiate new rate cases which change the expenditure level on grid hardening activities should be resisted by the NCUC. Targeted hardening practices along the lines of which Duke is implementing have been shown to be effective in preventing outages across a variety of states. While this option has a high cost, the efficacy in preventing outages greatly helps to offset this in terms of the cost-effectiveness measure. Given that this option is currently in progress, concerns surrounding political feasibility are exceedingly low, with the same applying to ease of implementation as well. While this option does lack in the environmental sustainability rating, the program only lasts for four years and as such when paired with the long-term option this shortcoming can be offset.

For the long-term solution, I propose that the North Carolina legislature passes legislation that creates a ten-year incentive for the purchase of residential battery storage technology, which would then be implemented by the NCUC. This option, when combined with the hardening measures described above, provides the most comprehensive solution to the grid reliability and resiliency issues. Given the relatively low levels of current battery storage in North Carolina, there will be a lag time in adoption before storage can scale up to the size necessary to make a dramatic impact on power outages. However, once storage has attained a more significant hold in the state it will be a highly efficient means of reducing the total outage time. This is not only because of the benefits of battery storage kicking in when an outage occurs, but also because battery storage systems and their associated DER systems naturally decentralize the generation process, greatly reducing the distance which energy must travel in order to reach its end destination. This reduction in energy traveling over transmission and distribution lines is integral to the reliability and resiliency improvements displayed by this option and distinguishes it from the rest of the potential options. The incentive is a relatively cheap way of accelerating the rate of adoption of storage systems to the point where storage can have a sizable impact, making this option highly cost-effective. Additionally, the political feasibility and ease of implementation for this policy option remain high due to the similarity between this incentive and existing solar incentives which are already in place at the state level.

As such, the mechanism for adoption would be relatively similar for both the legislature and implementing agency, in this instance the NCUC.

Appendix A: SMART Program Rebates

ENTER INFORMATION IN BLUE CELLS ONLY						
Energy Storage Adder Block Tranche #		1				
Solar PV Capacity (kW DC)		800				
Storage Nominal Rated Power Capacity (kW)		750				
Storage Hours at Rated Capacity		7				
Adder Multiplier		0.045				
Storage Adder ($/kWh)		0.079688				

- The Storage Nominal Rated Power Capacity cannot be less than 25% Solar PV DC Power Capacity, Incentivized for no more than 100%
- The Storage Hours at Rated Capacity cannot be less than 2 hours, Incentivized for no more than 6 hours
- Energy Storage Systems may exceed 100% of capacity and/or 6 hours or duration, but will receive no incremental adder for capacity beyond these limitations

Table of Formula Results

		Storage Hours at Rated Capacity								
		2	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**5.5**	**6**
Storage kW as % of Solar PV kW	**25%**	$0.0247	$0.0271	$0.0291	$0.0307	$0.0321	$0.0334	$0.0345	$0.0356	$0.0365
	30%	$0.0321	$0.0352	$0.0377	$0.0399	$0.0418	$0.0434	$0.0449	$0.0462	$0.0474
	35%	$0.0382	$0.0419	$0.0450	$0.0476	$0.0498	$0.0517	$0.0535	$0.0551	$0.0565
	40%	$0.0428	$0.0470	$0.0504	$0.0533	$0.0558	$0.0579	$0.0599	$0.0617	$0.0633
	45%	$0.0460	$0.0504	$0.0541	$0.0572	$0.0599	$0.0622	$0.0643	$0.0663	$0.0680
	50%	$0.0481	$0.0527	$0.0565	$0.0598	$0.0626	$0.0650	$0.0673	$0.0692	$0.0711
	55%	$0.0494	$0.0542	$0.0581	$0.0614	$0.0643	$0.0668	$0.0691	$0.0712	$0.0730
	60%	$0.0502	$0.0551	$0.0591	$0.0625	$0.0654	$0.0680	$0.0703	$0.0724	$0.0743
	65%	$0.0507	$0.0557	$0.0597	$0.0631	$0.0661	$0.0687	$0.0710	$0.0731	$0.0750
	70%	$0.0511	$0.0560	$0.0601	$0.0635	$0.0665	$0.0691	$0.0715	$0.0736	$0.0755
	75%	$0.0513	$0.0562	$0.0603	$0.0638	$0.0667	$0.0694	$0.0717	$0.0739	$0.0758
	80%	$0.0514	$0.0564	$0.0605	$0.0639	$0.0669	$0.0696	$0.0719	$0.0740	$0.0760
	85%	$0.0515	$0.0565	$0.0606	$0.0640	$0.0670	$0.0697	$0.0720	$0.0742	$0.0761
	90%	$0.0515	$0.0565	$0.0606	$0.0641	$0.0671	$0.0697	$0.0721	$0.0742	$0.0762
	95%	$0.0515	$0.0566	$0.0607	$0.0641	$0.0671	$0.0698	$0.0721	$0.0743	$0.0762
	100%	$0.0516	$0.0566	$0.0607	$0.0641	$0.0671	$0.0698	$0.0722	$0.0743	$0.0763

Appendix B: Joining PJM Cost Effectiveness

Costs

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
59,000,000	56,190,476	53,514,739	50,966,418	48,539,446	46,228,044	44,026,708	41,930,198	39,933,522	38,031,926

$478,361,478.86	Total Cost

Effectiveness

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
80,000,000	76,190,476	72,562,358	69,107,008	65,816,198	62,682,093	59,697,232	56,854,506	54,147,149	51,568,713
38603.70403	15481.432	14744.221	14042.116	13373.443	12736.613	12130.107	11552.483	11002.365	10478.443

154,144.93	Outage Reduction
3103.322865	Cost Effectiveness

Appendix C: Status Quo Hardening Cost Effectiveness

Costs

	2019	2020	2021	2022
$ 2,327,030,018.36	$ 625,000,000.00	$ 595,238,095.24	$ 566,893,424.04	$ 539,898,499.08
Total Costs				

Effectiveness

	2019	2020	2021	2022
	$ 22,345,679.84	$ 21,281,599.85	$ 20,268,190.33	$ 19,303,038.41
83,198,508.42	Reduced Outage Hours			
27.96961223	Cost Effectiveness			

Appendix D: RPS Cost Effectiveness

Costs

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
2,390,080,000.00	2,276,266,666.67	2,167,873,015.87	2,064,640,967.50	1,966,324,730.95	1,872,690,219.95	1,783,514,495.19	1,698,585,233.52	1,617,700,222.40	1,540,666,878.47

$ 19,378,342,430.52	Total Cost

Effectiveness

143,503,200.00	Outage Reduction
135.0377025	Cost Effectiveness

Appendix E: Increased Hardening Cost Effectiveness

Costs

	2019	2020	2021	2022	2023	2024
	$625,000,000.00	$595,238,095.24	$566,893,424.04	$539,898,499.08	$514,189,046.74	$489,703,854.04
3,330,922,919.14	Total Cost					

Effectiveness

	2019	2020	2021	2022	2023	2024
	$ 22,345,679.84	$ 21,281,599.85	$ 20,268,190.33	$ 19,303,038.41	$ 18,383,846.10	$ 17,508,424.86
119,090,779.39	Reduced Outage Hours					
27.97	Cost Effectiveness					

Appendix F: Solar Plus Storage Cost Effectiveness

Costs												
	2020	2021	2022	2023	2024	2025	2026	2026	2028	2029		
34437.79195	1	60	3600	3780	3969	4167.45	4375.8225	4594.61363	4824.34431	5065.56152		
Kw	1000	60000	3600000	3780000	3969000	4167450	4375822.5	4594613.63	4824344.31	5065561.52		
Kwh	1750	105000	6300000	6615000	6945750	7293037.5	7657689.38	8040573.84	8442602.54	8864732.66		
	139.475	7970	455428.571	455428.5714	455428.571	455428.571	455428.571	455428.571	455428.571	455428.571	$3,651,538.05	Total Cost
Effectiveness												
	# of installations											
9.3 kw battery	107.53	6,451.61	387,096.77	406,451.61	426,774.19	448,112.90	470,518.55	494,044.48	518,746.70	544,684.03		
.78 hours per installation												
	83.87	5,032.26	301,935.48	317,032.26	332,883.87	349,528.06	367,004.47	385,354.69	404,622.43	424,853.55	2,888,330.94	Outage Reduction
9.3												
											1.26423811	Cost Effectiveness

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