REGIONAL ELECTRICAL SYSTEM – CITY OF GLOUCESTER, MA

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PREPARED FOR

Gloucester Economic Development & Industrial Corporation

PREPARED BY

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LIST OF ACRONYMS

CO_2	carbon dioxide
GW	gigawatt
GWh	gigawatt hour
kW	kilowatt
kWh	kilowatt hour
MMBtu	Million British thermal units
MW	megawatt
MWh	megawatthour

DEFINITIONS

Arc Flash - is a phenomenon where a flashover of electric current leaves its intended path and travels through the air from one conductor to another, or to the ground.

Asset Condition - is a key parameter in determining the remaining useful life and can be used to predict how long it will be before an asset needs to be repaired, renewed or replaced.

Carrying Capacity - the point at which variable energy is no longer economically competitive or desirable to the system or society.

Faut Duty - the maximum current a system can withstand without interrupting the current.

Hosting Capacity - the amount of distributed energy resources that can be added to distribution system before control changes or system upgrades are required to integrate additional resources safely and reliably.

Load Balancing - the use of various techniques by electrical power stations to store excess electrical power during low demand periods for release as demand rises.

Load Risk Perspective – a subject judgement regarding the electrical power stations and electrical power demand characteristics and severity of a risk.

Load Shed - is the deliberate and selective dropping of electrical load in accordance with a preplanned program.

MVA - or Megavolt-Ampere, is a unit of measurement for apparent power in an electrical system, representing the total power flow in a circuit. It combines both real power (measured in watts) and reactive power (measured in volt-amperes reactive), giving a comprehensive view of the system's overall power demand.

Non-wire Alternatives - technologies or operating practices intended to reduce grid congestion and manage peak demand to offset a utility's need to make additional investments in conventional assets like wires, poles, and substations.

Power Quality – how well the electricity delivered to electrical equipment matches the desired characteristics. Typically this describes voltage and frequency matching the desired values since this has the largest impact on both residential and industrial customers.

Reactive Power - is the power that flows back from a destination toward the grid in an alternating current scenario.

Reliability - the degree to which the performance of the elements in a bulk system result in electricity being delivered to customers within accepted standards and in the amount desired.

Resilience - the ability to avoid, prepare for, minimize, adapt to, and recover from anticipated and unanticipated energy disruptions in order to ensure energy availability and reliability sufficient to provide for mission assurance and readiness, including mission essential operations related to readiness, and to execute or rapidly reestablish mission essential requirements.

Thermal Loading – Thermal loading refers to the amount of heat generated in a transmission line or system, often caused by the electrical current flowing through it. Excessive thermal loading can lead to overheating and reduced efficiency or even failure of the system. Electrical equipment has a thermal rating that cannot be exceeded for long durations.

Single Contingency - loss of a single generator, transmission line, transformer, bus section or DC monopole under any operating condition or anticipated mode of operation.

DISCLAIMER

The analyses supporting the results presented here involve the use of assumptions and projections with respect to conditions that may exist or events that may occur in the future. Although Daymark Energy Advisors has applied assumptions and projections that are believed to be reasonable, they are subjective and may differ from those that might be used by other economic or industry experts to perform similar analysis. In addition, actual future outcomes are dependent upon future events that are outside Daymark Energy Advisors' control. Daymark Energy Advisors cannot, and does not, accept liability under any theory for losses suffered, whether direct or consequential, arising from any reliance on this presentation, and cannot be held responsible if any conclusions drawn from this presentation should prove to be inaccurate.

EXECUTIVE SUMMARY

Daymark suggests that a collaborative approach that seeks cooperation amongst constituents of the City of Gloucester, regional stakeholders, the Massachusetts's Department of Public Utilities, National Grid, and the ISO New England will best advance the following ideas and recommendations:

- System performance, as well as public policies and local plans promoting renewables and electrification, should be thoroughly evaluated to ensure resiliency, reliability, and power quality. Future scenarios should be considered, and computer modeling considered.
- Effective long-range planning efforts should begin as soon as possible to advance much needed near-term improvements. For example, such planning should highlight potential new or expanded economic development or housing plans in the region that are impacted by the energy constraints identified in this Report.
- Load planning criteria should provide redundancy in bulk transmission and multiple interconnected distribution substations to route and move power during outages and maintenance. For example, efforts underway in Gloucester for a comprehensive Master Plan must consider the transmission and distribution information found in this report.
- Utility improvement plans should be adopted and sequenced to address current issues and provide incentives for expansion to support the Region's economy.
- Collaborative planning should engage stakeholders with utility providers. Transparent and up-to-date information about bulk capacity from the East Beverly substation and the Region's distribution network are critical to successful planning and collaboration in the Region.
- Regulatory and legislative policies should be reviewed, and if necessary, changes should be pursued to ensure thorough and timely reviews and actions for critical energy infrastructure development.
- Conceptual planning suggests a need for investments in infrastructure ranging from $70M to $110M to support a resilient and reliable system into the future, as described herein, and involves transmission and distribution system expansion and application of complementary resources in the form of renewable energy and battery energy storage.

Scope of Assessment

Though the focus is Gloucester, the configuration of its electric supply system implicates the entire North Shore Region, involving primarily supply from the East Beverly area, extending northerly and easterly, until circuits reach the city. As such, Daymark's assessment of the electric supply to the City of Gloucester necessarily includes another half-dozen North Shore interconnected communities that face the same or similar power supply conditions – Rockport, Essex, Hamilton, Wenham, Manchester-by-the-Sea, and Beverly – collectively referred herein as the "Region". Daymark notes that solutions to the issues discovered become narrower the more remote the service to supply loads far from the East Beverly substation. To be specific, alternative solutions considered for the Beverly region may or may not benefit the remote loads of Gloucester.

Stakeholder Voice

Daymark considered information gathered via interviews from key government and industry leaders and the EDIC to better understand the current performance of the electrical supply, and to understand drivers that influence future load expansion. This effort complemented Daymark's independent assessment of the system via an in-depth review performed using publicly available information with respect to supply adequacy, performance matters, and related system planning activities.

Daymark also learned that stakeholders are interested in how the application of various technologies involving renewable energy such as solar and wind resources, distributed generation resources, and battery energy storage, might prove beneficial to Gloucester. Daymark holds that improvement and expansion plans should seek to implement complementary improvements that may involve these technologies. Related energy profiles and yield potential on an aggregate basis needs to be carefully evaluated. Bulk transmission and distribution infrastructure is viewed as an enabler to these technologies and provides for high levels of continuous and an available supply offsetting the variability present with intermittent resources such as solar and wind.

Key Takeaways – Impacts

The following key takeaways are noted with respect to impacts to the Region:

- Transmission and distribution systems serving the region have reached capacity.
- The ability to support demand, and accommodate expansion, is limited.
- Gloucester and the North Shore region are exposed to risks of "single point of failure" resulting from service emanating from one transmission substation in East Beverly.
- The potential economic consequences of inaction are significant:

- Local economies, as well as the security, health and safety of the communities are threatened by the state of electric power delivery into and within the region.
- Utility planning processes do not identify improvements or expansion plans to accommodate anticipated load growth from electrification and economic development opportunities.
- Policies, such as "first mover" and "Contribution in Aid of Construction," have significant negative economic impacts that may either delay or block customers seeking to expand or site new facilities.

Daymark suggests a collaborative approach that seeks cooperation amongst constituents of the City of Gloucester, regional stakeholders, the Massachusetts Department of Public Utilities, National Grid, and ISO New England to advance the ideas and recommendations identified below.

- System performance, as well as public policies promoting renewables and electrification, should be thoroughly evaluated to ensure resiliency, reliability, and power quality.
- Effective long-range planning efforts should begin as soon as possible to advance much needed near-term improvements.
- Load planning criteria should provide redundancy in bulk transmission and multiple interconnected distribution substations to route and move power during outages and maintenance.
- Improvement plans should be adopted and sequenced to address current issues and provide incentives for expansion to support the Region's economy.
- Collaborative planning should engage stakeholders with utility providers.
- Regulatory and legislative policies should be reviewed, and if necessary, changes should be pursued to ensure thorough and timely reviews and actions for critical energy infrastructure development.
- Conceptual planning suggests investments in infrastructure ranging from $70M to $110M are necessary to support a resilient and reliable system into the future, as described herein, and involves transmission and distribution system expansion and application of complementary resources such as renewable energy and battery energy storage.

NORTH SHORE REGION

Though the initial inquiry was focused on the City of Gloucester, it became quickly understood this is a North Shore Region matter due to the configuration of supplying transmission and distribution systems. Daymark notes that the configuration of its electric supply system implicates the entire North Shore Region, involving primarily supply from the East Beverly area, extending northerly and easterly, until circuits reach the city. As such, Daymark's assessment of the electric supply to the City of Gloucester necessarily includes another half-dozen North Shore interconnected communities that face the same or similar power supply conditions – Rockport, Essex, Hamilton, Wenham, Manchester-by-the-Sea, and Beverly – collectively referred herein as the "Region". Daymark notes that the solutions to the issues discovered become narrower the more remote the service to supply loads far from the East Beverly substation. That is alternative solutions considered for the Beverly region may or may not benefit the remote loads of Gloucester.

Daymark notes that the North Shore Region of Massachusetts represents the coastal area between Boston and the New Hampshire border. The discussion herein centers on electrical power delivery to a portion of the North Shore, including, but not limited to, Manchester-by-the-Sea, Gloucester, Rockport, Essex, Hamilton, Wenham, and Beverly (the "Region").

Vital Importance

Stakeholder Voice

Daymark considered information gathered via interviews from key government, industry leaders, and the EDIC to better understand the current performance of the electrical supply, and to understand drivers that influence future load expansion. This effort complemented Daymark's independent assessment of the system via an in-depth review performed using publicly available information with respect to supply adequacy, performance matters, and related system planning activities.

Daymark also learned that stakeholders are interested in how the application of various technologies involving renewable energy such as solar and wind resources, distributed generation resources, and battery energy storage, might prove beneficial to Gloucester. Daymark holds that improvement and expansion plans should seek to implement complementary improvements that may involve these technologies. Related energy profiles and yield potential on an aggregate basis need to be carefully evaluated. Bulk transmission and distribution infrastructure is viewed as an enabler to this technology and provides for high levels of continuous energy supply offsetting variability of intermittent resources such as solar and wind.

Local Economy

Gloucester is a city in Essex County, Massachusetts, and part of the Massachusetts North Shore region. The city of Gloucester boasts of its fishing industry and is a popular summer tourist destination during the summer months. Though a major fishing town, Gloucester also consists of an urban core on the north side of the harbor, consisting of 8 urban neighborhoods. At the 2000 census, Gloucester housed 30,274 people, 12,5932 households, and 7,895 families with a population density of 1,116.0 inhabitants per square mile, approximately 450.2 km^2. The 2020 census presented new data of a population decrease to 29,729 inhabitants, but a 0.95% increase in 2023 to 30,011.

As of 2023, Gloucester has 8 public schools, 1 major hospital, 1 primary care facility associated with the said hospital, and 3,489 businesses. The largest business industries in Gloucester include public services (248), restaurants (152), and entertainment agencies and bureaus (102). Daymark notes two industrial parks are situated within Gloucester, the Blackburn Industrial Park and the Cape Ann Industrial Park, which require high quality electric supply with adequate capacity to meet potential new load additions. In addition, the City's largest employers include Gloucester's local government, schools, the Addison Gilbert Hospital, Applied Materials, XPPower, Happy Valley, and Gortons.

Regional Economy

The North Shore Region's current economy and its potential for development and expansion are directly correlated with the availability and capacity of the electricity supply. This economy supports a labor force of approximately 231,000 employees, and with consideration of Essex County alone involves a Gross Domestic Product of $51,359,386, 000 (2021) which represents 37% of the Massachusetts Gross Domestic Product. Regional economic growth can expand with greater availability and capacity added to the electric supply. Currently, Essex County's source of power is generated from the Beverly Substation, which will need to be expanded to meet future economic growth needs of the region.

Figure A1 in the Appendix defines the WorkForce Development Area Profile used as the basis for information.

More Economic Development Challenges

NGRID's contribution in the aid of construction policies, whereby new load uses which require enhancement to the power grid are required to fund, potentially at great cost, some, or all of the cost of improvements, has the potential to stifle growth in the Region. We hold that adequate planning to reinforce the network for resiliency, reliability, and power quality has been overlooked. Looking ahead, if the Region seeks to remain competitive and attractive to business and development, the required improvements to the system should be allocated fairly to the Region's customers through rate base.

Furthermore, the improvement plans suggested in the past by the NGRID for the incorporation of new load customers places increased reliance on a single substation, East Beverly, which is problematic. Without geographically diverse, new, and reliable transmission connections, the North Shore's resiliency, reliability, and power quality will continue to be jeopardized. This poses a significant deterrent to future investments in the Region's economy.

REGIONAL TRANSMISISON & DISTRIBUTION

Current Situation – Baseline of Issues

Figure's 1.0 and 2.0 illustrate the regional transmission system and distribution systems, respectively, that ultimately supply Gloucester and the communities along the North Shore, comingled in between bulk transmission supply and distribution.

National Grid indicates that the Beverly/Cape Ann area serves nearly 50,000 electric customers. Approximately, 16,500 of these customers are in Beverly, with an additional approximately 33,000 customers in the Cape Ann communities of Essex, Gloucester, Hamilton, Manchester-by-the Sea, Rockport, and Wenham. It was indicated in a projection of summer peak loading in 2019, a load of 180MVA for the Beverly/Cape Ann Area. Loading of supplying substations at that time was approximately 34 MVA of the Beverly/Cape Ann Area load served from the Beverly #12 Substation, and 124 MVA from the East Beverly #51 Substation; and the remaining 22MVA served via the 23 kV sub-transmission system from Salem Harbor #45 Substation.

The Region relies on a single remote interconnection to the National Grid (NGRID) 115kV transmission system for bulk supply of electrical energy. A single 115kV substation, NGRID's East Beverly Substation, shown below, is supplied via two adjacent 115kV transmission circuits extending as taps, designated as M191 and N192, radially from National Grid's 115kV Network. These circuits are taps from nearby 115kV lines and are not looped through at East Beverly. These circuits essentially form the "last leg" of the 115kV system and, effectively, are the only source of power to the Region. This arrangement, and the inherent lack of redundant service access, has significant consequences for local reliability for the distribution system. No other interties exist between transmission and distribution systems at any other location within the Region.

The East Beverly substation currently has four power transformers at the substation; two 115kV:34.5kV and two 115kV:13.2kV transformers. Each transformer is responsible for serving a portion of the electrical demand in the Region. The power is stepped down from the 115kV transmission voltage level to the distribution voltage level through several feeders connected to the 34.5kV and 23kV sides of these distribution transformers. The distribution feeders then extend radially to serve the energy demand in the Region. These feeders extend over long distances to serve high-density loads, thereby making voltage considerations a concern. The distribution system appears to lack flexibility, or limited capability to transfer loads between feeders originating from a different primary substation other than East Beverly. Under this configuration, the loss or temporary disruption of a distribution transformer would result in an interruption of service for many customers that are in the Region.

Furthermore, problems with distribution feeders from this substation have also been identified by NGRID as poor performing circuits, as described in Table A4 in the Appendix. One impact is that "end-of-line" consumers, including some of the most significant commercial users, face power quality issues. See Table 3.0 for circuits designated as problem circuits themselves by NGRID over past few years.

The lack of any supply redundancy, e.g., the ability to access multiple distribution substations that are supplied via different points on the transmission grid, is counter to basic, effective distribution system planning principles.

Significant reliance on the East Beverly Substation is noted and made obvious from careful review of the local 345kV and 115kV transmission networks in the vicinity of the North Shore Region shown in Figure 1.0 and 2.0 below. A noticeable gap of transmission infrastructure is apparent to the north of the East Beverly Substation. The image also highlights the lack of a high-voltage transmission loop to intertie and supply distribution substations to the north.

In more simple terms, the block diagrams provided in Figures 2.0 and 4.0 reinforce there is a limited number of distribution feeders that are routed northerly and easterly, to supply ultimately Gloucester. This reinforces the need for expansion and the notion that improvements to reinforce Beverly alone may not directly benefit remote loads at Gloucester.

Furthermore, the underlying three phase distribution circuits networks that extend east and northerly, introduce concerns for end of line customers, as they extend over long distances to serve high-density loads, thereby making voltage considerations a concern. Again, the distribution system appears to lack flexibility, or limited capability to transfer loads between feeders originating from a different primary substation other than East Beverly.

Daymark notes that Gloucester offsets a portion of its municipal electricity demand with energy supply from two local wind turbines at Blackburn Industrial Park; these resources alone are intermittent and small in output compared to overall electrical demands for the area. If additional renewable energy resources would like to interconnect in the Gloucester region, further development into the area's electrical infrastructure would be needed to allow for future resources to deliver reliable energy to the local customers and participate in the ISO markets.

FIGURE 1.0 - REGIONAL TRANSMISSION SYSTEM FOR NORTH SHORE

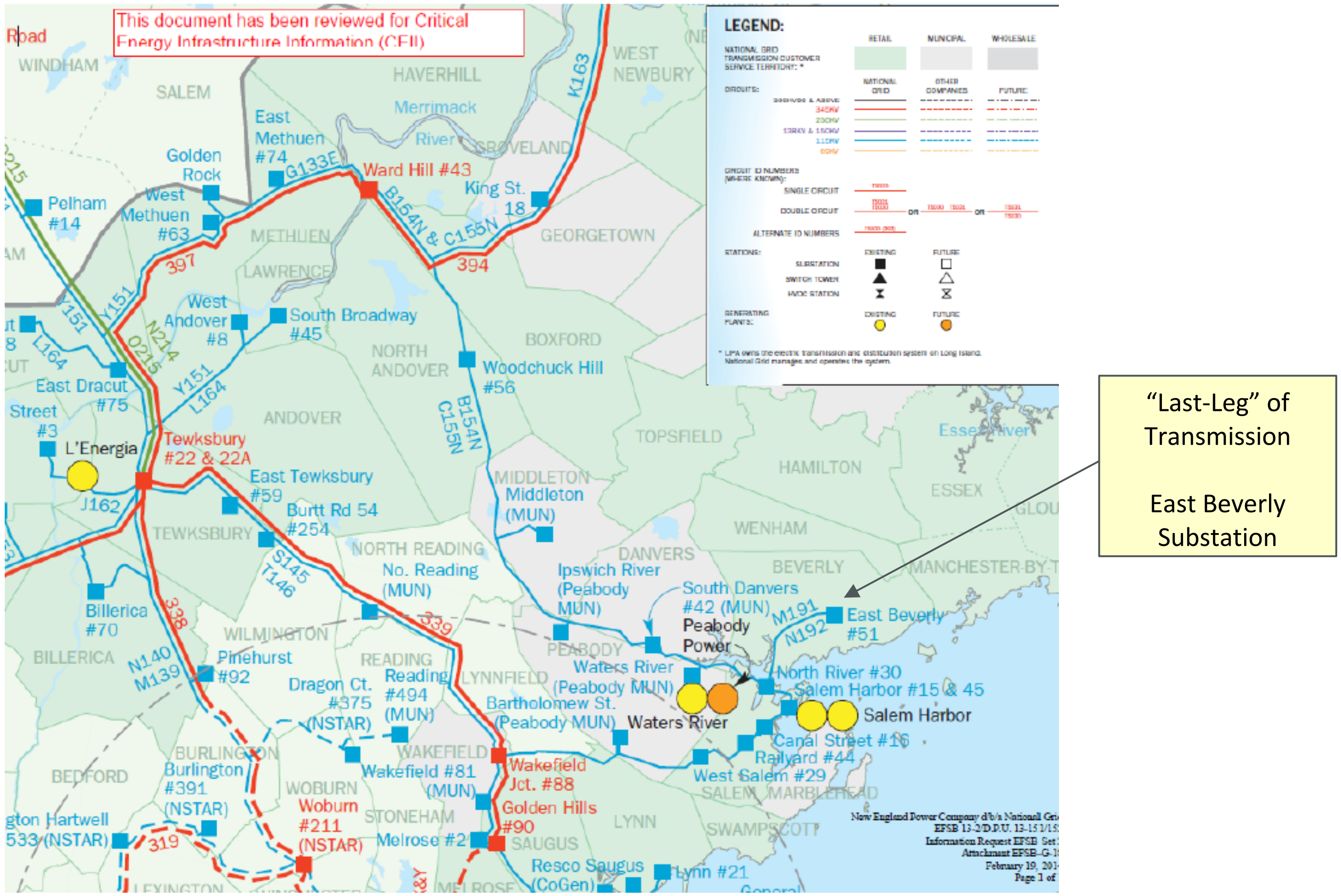


FIGURE 2.0 - REGIONAL DISTRIBUTION SYSTEM FOR NORTH SHORE, THREE-PHASE FEEDERS

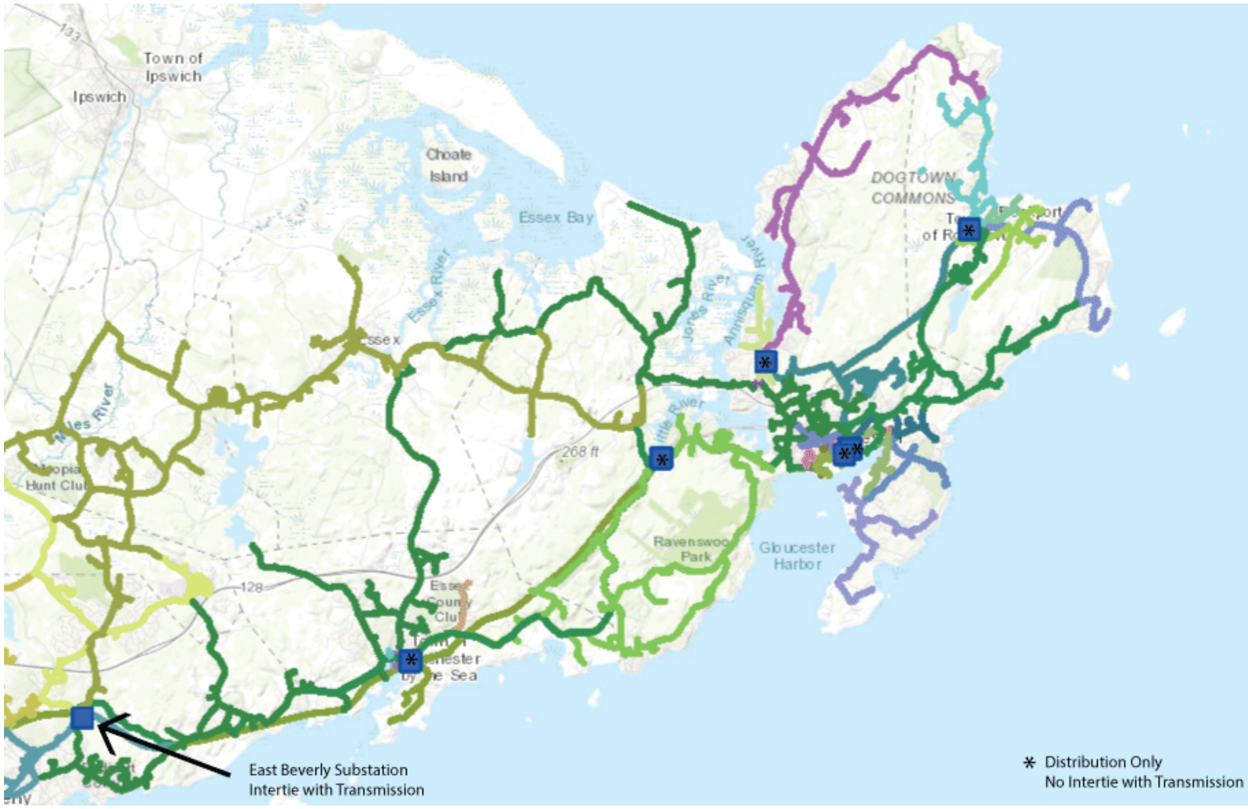


FIGURE 3.0 - REGIONAL DISTRIBUTION SYSTEM FOR NORTH SHORE, BLOCK DIAGRAM, BEVERLY

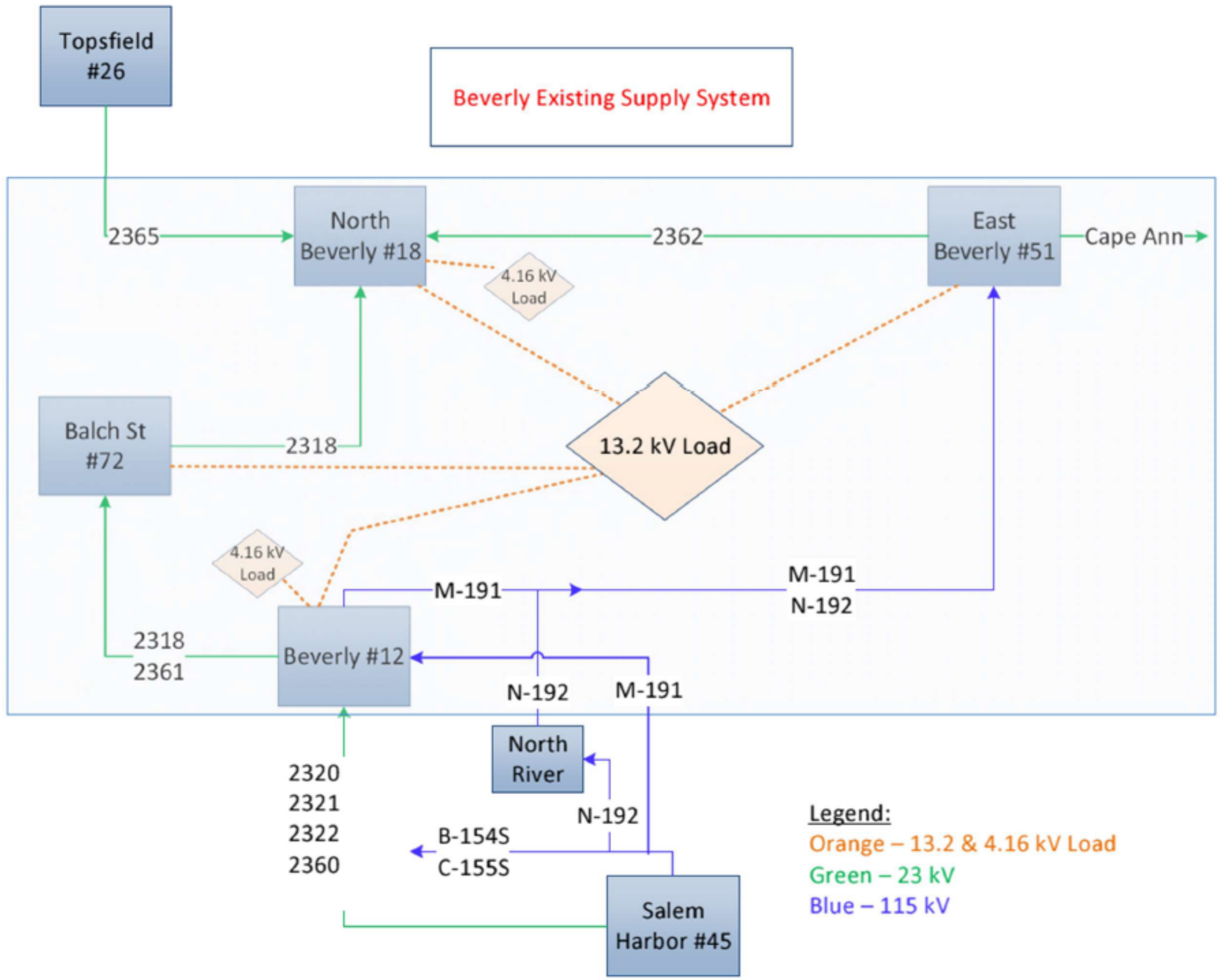
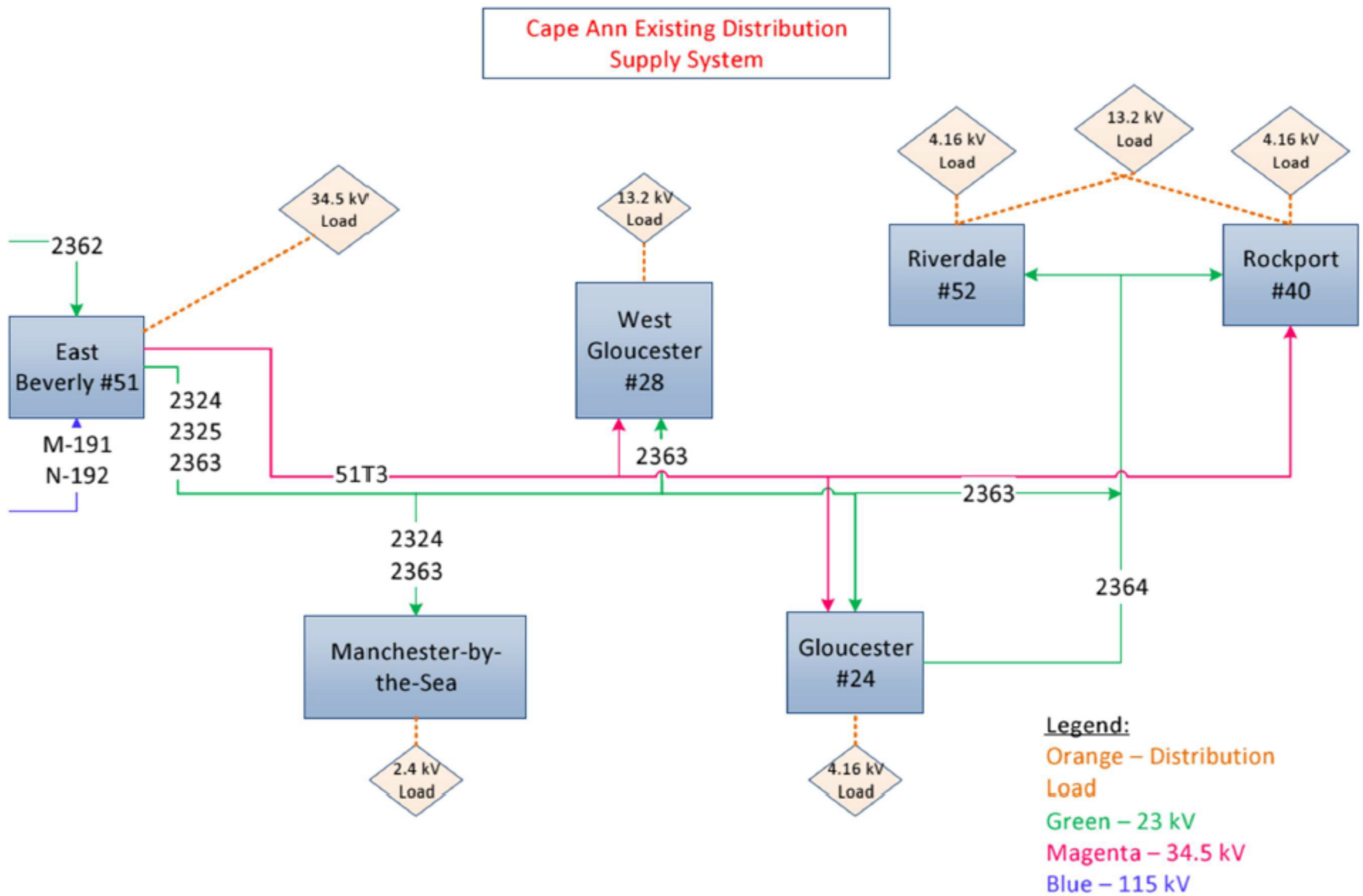


FIGURE 4.0 - REGIONAL DISTRIBUTION SYSTEM FOR NORTH SHORE, BLOCK DIAGRAM, CAPE ANN



PLANNING PROCESSES

Current planning processes by the electric utilities for transmission and distribution lack integrated approaches that evaluate the full range of plausible futures. Generation interconnection processes, seeking to interconnect conventional and renewable energy resources such as solar and wind, and related storage, and large load interconnection are treated in serial or cluster study fashion disconnected from conventional long-range planning that assesses network capacity against different scenarios with load increases driven by continued electrification.

The outcome is delays, uneconomic burdens placed on "first-movers" and a failure to identify cost-effective solutions. Planning processes need to be more pro-active, multi-value, and scenario-based to enable efficient improvement and expansion and to allocate costs appropriately to all beneficiaries.

"First-Mover" Problem

The North Shore Region faces the dilemma, commonly referred to in the industry as a "First-Mover Problem". This means new development or substantial expansion faces substantial investments to upgrade the local transmission and distribution network to meet reliability and capacity needs, while subsequent interconnections of generation and load do not incur costs yet benefit from the original developer's investment. The fact that facility upgrades provide benefits to many stakeholders beyond the initial customer in terms of resiliency, reliability, and power quality, represents the core issue.

National Grid current planning practices for new load additions to the region's distributions system in process includes an impact analysis and allocation of network upgrades to the customer – local and remote from the customer's interconnection point. National Grid requires the customer to pay Contribution in the Aid of Construction (CAIC) for such network improvements. This policy requires the developer to pay for the improvements, but does not afford them with ownership or rights, thus the developer "contributes" these to the utility. When the developer "contributes" to these assets, the utility then maintains the assets. Eventually, the utility must replace them at the end of their useful life.

National Grid's Terms and Conditions for Distribution Service (M.D.P.U.) broadly specify allocation of costs for overhead line extension and underground line extension. The context implies "extension" and makes no delineation of other improvements external to the customer's service, i.e., up-line. This could be an area for challenge to National Grid's practices.

Daymark notes that key and different questions are raised regarding the "First-Mover Problem", appropriateness of study process, and interpretation of National Grid's Tariff. First, recognizing that the beneficiaries of the network upgrades extend beyond just the initial developer, should the costs fall solely on the developer and not all beneficiaries? Second, load additions are currently being treated similarly to resource additions, but should this same treatment apply? Lastly, it might be argued that the interpretation of National Grid's Tariff is too broad allowing the costs of upline improvements that are remote from the load's point of interconnection to be allocated to the customer. It could be argued that CAIC should focus narrowly on extension of service, whether overhead or underground, to be limited to the beyond point of interconnection on the customer's property.

This dilemma threatens long-term economic growth as it stifles interest in expanding or developing local industry and at the same time, the communities are vulnerable to system issues involving resiliency, reliability and power quality described herein.

INTERCONNECTION

Current Basis of Planning

Interconnection of resources to NGRID's Transmission System or Distribution System involves planning and designation of network upgrades. The applicable planning authority for interconnection processes depends on whether FERC or state jurisdictional processes apply which are generally based on point of interconnection, supply voltage and access to markets. The designation of upgrades is specific to each resource interconnection and addresses incremental improvements to expand capacity and maintain reliability. These projects are queued in order and assessed in serial processes with total costs of remote network improvements being assessed to the resource or load being interconnected. This approach to planning interconnection is also followed for large load additions to the distribution system, which are key to economic growth in the Region.

Suggested Basis of Planning

The above planning method is problematic because it does not efficiently or accurately predict or promote future growth for a region. Instead, it is largely reactionary, addressing need not opportunity. The process does not recognize opportunities that might support future scenarios, such as building out capacity to encourage development or configuring circuits with future expandability. With the current planning approach, "first-movers" face significant costs since the system is planned in a siloed fashion, not identifying the most cost-effective solutions to address the full range of plausible scenarios with load growth.

Transmission System

Current Basis of Planning

The planning of the 115kV transmission circuits to the East Beverly Substation falls under NGRID's transmission planning. NGRID is then subject to oversight by the ISO New England (ISO-NE). The ISO-NE represents the authority over the Region as Planning Authority as recognized by the North American Electric Reliability Corporation (NERC), which has been designated by the Federal Energy Regulatory

Commission (FERC) as the nation's Electric Reliability Organization (ERO). Therefore, transmission planning must adhere and comply with mandated laws that specify reliability requirements for planning and operations of the North American bulk power system. NGRD, in concert with the ISO New England, develops Reliability Transmission Upgrades for defined ISO-NE pool transmission facilities, and separately conducts local planning for non-pool transmission facilities. Enforcement actions violating NERC's Standards can result in civil penalties from thousands to millions of dollars.

Suggested Basis of Planning

Currently, Daymark's review of publicly available information for NERC's enforcement actions does not indicate any violations of applicable planning standards by the ISO-NE or NGRID. Any future transmission developments in the Region will have to adhere to the NGRID, ISO-NE, and NERC standards. The step-down transformers at the East Beverly Substation and the distribution lines supplying power to the Region are not defined as Bulk Electric System assets and fall under local distribution planning system criteria set by National Grid. We acknowledge that the concerns over distribution power quality, distribution energy capacity, and distribution resiliency are not governed by NERC or ISO-NE. However, Daymark notes that it is prudent to evolve practices to examine transmission and distribution planning and operations from an integrated approach, as new energy resources are integrated, and continued electrification occurs.

Distribution System

Current Basis of Planning

NGRID's Distribution Planning incorporates criteria and strategies that are reviewed by the Massachusetts Department of Public Utilities. System performance criteria is established for normal and contingency conditions that considers asset condition, thermal loading, non-wires alternatives, fault duty, protection and arc flash, reliability, resilience, reactive power, load balancing and hosting capacity. Violations in criteria drive infrastructure investment or system modification.

NGRID's distribution planning criteria allows load shed of 10MW for transformer loss and 20MW for sub-transmission line (distribution operating at 34.5kV) loss, with transfer of loads to adjacent substations and feeders. NGRID's planning criteria state that alternatives to eliminate or significantly reduce risks will be evaluated and prioritized considering the load at risk, reliability impacts and costs. Visibility into the consideration of such alternatives is not publicly available at the Massachusetts Department of Public Utilities.

Suggested Basis of Planning

It is our view that the Region's load should be evaluated from a load risk assessment perspective, given the composite nature of residential, commercial, and industrial load. By understanding the various load types, usage patterns and their risks, better planning and investment decisions can be made to support the Region's energy needs.

NGRID should plan reinforcements to problem circuits in a transparent manner that considers alternatives that take advantage of opportunities to address resiliency, reliability, and power quality. evaluates and benefits the region.

By providing transparent and accessible information on these issues, NGRID can foster a more informed and collaborative approach to addressing the region's energy challenges. This transparency may also encourage the exploration of alternative solutions that could improve overall system performance and contribute to a more reliable and resilient energy infrastructure for the Region.

SYSTEM PERFORMANCE

Requirements for Resiliency and Robust Economic Development

The Region should seek a power grid planning strategy that addresses both resiliency and reliability to ensure continuous supply of energy. Furthermore, the strategy should build in capacity over time to accommodate traditional load growth as well as the large load additions that come from commercial industry and distributed generation of electric power.

Both resiliency and reliability need to be enhanced to support the regional economy and to counter the ever-present threat long-duration outages pose to public safety. Resilience is the ability to adapt to or "bounce back" from extreme events such hurricanes, coastal storms, and flooding. It can also include physical attacks on infrastructure as well as cyber-attacks, either of which could cause long-term or extended disruption in electric power supply. The duration of long-term outages is driven by lead times to replace or rebuilding of major equipment such as substations, transmission lines, and transformers. Reliability is the everyday ability of the transmission and distribution system to provide for switching of the networks minimize impacts to customers for short duration planned and forced outages. Resiliency and reliability both depend on multiple connections to the transmission system and multiple paths to distribute power within the Region.

Different strategies are often employed to improve resiliency and reliability of service, ranging from increasing the number of available paths from power sources to local, distributed generation. The carrying capacity of the Region's transmission and distribution network must also be considered. Going forward, the system must accommodate increases in energy demand related to expansion of commercial and industrial loads; the electrification of transportation and building heating/cooling; and the need for grid flexibility.

The Region's current infrastructure has a single infeed from transmission. Power quality concerns of electricity in the area are currently causing issues such as voltage drops or sudden electrical changes that impact larger industries in the region. While some smaller shifts in electricity use can happen close to the East Beverly Substation, it's more difficult for areas farther north. Ideally, mixed load types should be separated on distribution feeders to provide express feeders to large loads, especially, in the case of rotating machinery, with sourcing from different supplying substations. This might mean using different power sources for these larger industries. Adjusting the flow of electricity dynamically could also help improve the situation.

The North Shore Region's current situation involves a significant reliance on a single substation, the East Beverly substation, which is heavily loaded during peak conditions with a configuration that introduces operating issues with transfer of loads across transformers and feeders with a single contingency. Given there are multiple distribution voltage systems served from this location, limited flexibility exists to transfer loads between transformers and feeders. Two separate 115/34.5kV transformers at best can supply 55MVA on the 34.5kV system, assuming the ability to transfer loads completely from failed transformer to surviving transformer and no transfer to other systems. These transformers are not configured in parallel. Separately, two paralleled transformers, 115/23kV are located at this substation, but again difference in secondary voltages limit transfer of load only within the 23kV system.

Daymark further notes that primary service to the east and north involves Feeder: 51T3, 34.5kV and Feeders: 2324, 2325, 2363 (23kV). Though there is a 23kV tie between the North Beverly substation, there is no in feed connection at this location from transmission. Comparing the 180 MVA loading of the region and the publicly available capacity of the region for 2019, it seems likely that the region is approaching capacity. National Grid's own plans to reinforce East Beverly were noted to be load driven. While these plans were previously put forth, they were canceled due to unknown reasons, however most likely due to the lack of significant population growth in the region. An actual determination of supply capacity requires modeling and power flow analysis via computer simulation which is outside the scope of this assessment currently.

Daymark notes that no recent improvement or expansion plans has been identified at this time for reinforcement of the Region to reinforce either East Beverly or to provide a new supply to the Region, based on a review of documents publicly available by ISO New England and National Grid.

Daymark holds that any attempts to expand the existing East Beverly substation to accommodate future load growth, while expedient, is inconsistent with best utility practices for resiliency and reliability. The challenges to siting and constructing new transmission lines and distribution substations to the Region need to be overcome to reinforce reliability to the Region and supply long term needs.

POTENTIAL IMPROVEMENTS & EXPANSION

The Region's residential, commercial, and industrial loads will continue to be negatively impacted without critical improvement and expansion of the Region's fragile transmission and distribution systems. Economic development is threatened by the current state of infrastructure. Improvement and expansion plans are essential to reinforce the Region's transmission and distribution systems, to ensure reliable service to existing loads, to permit expansion of these loads and to accommodate the evolving landscape of electrification of transportation and building design as well as the growth of solar and other generation assets.

Strain on Regional Infrastructure

Based on a recent 2019 National Grid, the electrical load in the region was approximately 180MVA (Beverly, East Beverly, Cape Ann), which represents a substantial energy demand necessitating distribution planning strategies that promote resiliency, reliability, and power quality. In the 21st century, amidst climate change and the advent of new technologies, electrification of transportation and sustainable building design are increasing demand for electricity beyond previously forecasted levels.

Without expansion and enhancement of the existing transmission and distribution systems, the Region will continue to be subject to "single point of failure" risks and has the potential to stifle economic development.

Daymark's basic analysis of the delivery to prospective commercial and industrial loads in the Region indicates that virtually no capacity exists to accommodate new load without substantial improvements that are cost prohibitive, and unfairly punish "first-movers" with economic development.

According to Gloucester stakeholders, reliability and power quality issues are prevalent and threaten economic development. Drivers related to electrification of transportation and building heating systems is further contributing to the rise in demand for electricity. To address the needs of existing and new commercial and industrial establishments, there is a crucial need to improve and expand the current transmission and distribution systems.

Extreme weather events in the North Shore Region and failure to update the grid for resiliency and reliability will result in an increase of outages and a decrease in the socio-economic lifestyle of Gloucester.

Strategic Infrastructure Investments

Strategic investments are needed in bulk infrastructure for both transmission and distribution systems to enhance reliability and to provide capacity for expansion. Figure 5.0 illustrates, conceptually, the extension of the existing transmission network to create geographically diverse paths for the delivery of power within the Region. The involved distances of transmission circuits construction are noted in Table A1 in the Appendix. Conceptually, this means creating a 115kV transmission loop that begins at the East Beverly Substation, extending into the north easterly area of the City of Gloucester and to the west and north to interconnect with transmission at a point within the existing transmission corridor in Boxford, Georgetown, or West Newbury.

New distribution substations could be interconnected at strategic locations along the loop to provide multiple in-feeds to the Region's distribution system. The existing distribution system feeders in the Region should be reconfigured to allow for open primary loops that allow transfer of loads between the distribution substations. State of the art advances in distribution system management and fault location could also be leveraged to provide "smart" restoration to maintain reliability. Distributed generation and energy storage also have a role that should be considered to ameliorate current issues.

Infrastructure costs related to improvement and expansion plans greatly depend on many factors including acquisition of land and rights-of-way; terrain, grading, river, or highway crossings influencing design of structures; required substation designs; undergrounding of distribution feeders; and related protection and control.

Alternative approaches involving expansion of the East Beverly 115kV substation itself, in lieu of constructing new transmission and distribution, are technically feasible, but introduce issues counter to good planning practices, and perpetuates the problems identified herein. For completeness, Table A2 in the Appendix summarizes improvement and expansion alternatives, the benefits and risks, beneficiaries, and estimated costs.

Sequencing of the alternatives may represent the best plan as there are current issues to address and certain alternatives can be implemented more quickly, though incrementally, may not represent the least-cost basis to the Region.

Daymark notes that NGRID had considered an option to replace the existing 115/34.5kV transformers at East Beverly and add a backup unit in parallel driven by load growth; however, this project was canceled. It also cited that alternatives to expand the substation would be more expensive and less operationally convenient, triggering the expansion of the substation fence and possible permitting and resulting delays possibly. This was indicated in its National Grid Local System Plan 2020 PAC Presentation to the ISO New England. Review of subsequent plans indicates no new developments with resolution of issues at this substation.

FIGURE 5.0 – POTENTIAL IMPROVEMENTS & EXPANSION

REFERENCES

The basic things about substations you MUST know in the middle of the night! (n.d.). Electrical Engineering Portal. Retrieved February 26, 2023, from https://electrical-engineering-portal.com/substation-basics

Department of Energy, Office of Policy . Building a Better Grid: Addressing Climate Change and Bolstering Electric Grid Security Through Planning & Innovation. 18 Jult 2022.

Distributed Energy Resources (DER) Project Costs. (n.d.). Retrieved February 26, 2023, from https://www.eversource.com/content/residential/about/doing-business-with-us/interconnections/massachusetts/distributed-energy-resources-project-costs

Distribution Assets Overview. (n.d.). National Grid - Massachusetts System Data Portal. Retrieved February 26, 2023, from https://ngrid.apps.nationalgrid.com/NGSysDataPortal/MA/index.html

Distribution Planning Guide (Rev 1). (2011, February). National Grid.

Distribution Planning Overview 2022, National Grid [PowerPoint slides]. (n.d.). Retrieved February 2, 2023, from https://www.nrel.gov/docs/fy17osti/68869.pdf

EIA Profile Analysis (Massachusetts). (n.d.). Retrieved February 26, 2023, from https://www.eia.gov/state/analysis.php?sid=MA

Hirsch, R. F., & Koomey, J. G. (n.d.). *Electricity Consumption and Economic Growth: A New Relationship with Significant Consequences*.

National Grid. (n.d.). *DPU 22-SQ-11 - Massachusetts Electric CY21 SQ Report* [Spreadsheet]. https://eeaonline.eea.state.ma.us/DPU/Fileroom/dockets/bycasetype

National Grid. (n.d.). *DPU 23-SQ-11 -CY 2022 MECO Electric SQ Report* [Spreadsheet]. https://eeaonline.eea.state.ma.us/DPU/Fileroom/dockets/bycasetype

National Grid. (2020, October 21). *National Grid Local System Plan 2020*.

Net Zero Grid Distribution Planning Lab. (n.d.). Massachusetts Clean Energy Center. Retrieved February 2, 2023, from https://www.masscec.com/program/net-zero-grid-planning-lab

New England Power Company d/b/a National Grid. (2019, June). *Energy Facilities Siting Board Application, EFSB 19-04 Salem and Beverly, Massachusetts,*

Pfeifenberger, J. (2022, August 9). *Generation Interconnection and Transmission Planning*.

TPL-001-5: Transmission System Planning Performance Requirements. (2020, January 23).

Transmission Cost Estimation Guide for MTEP22. (2022, April 12).

Transmission Planning Technical Guide. (2019, September 13).

USA Population Density Map. (n.d.). Retrieved February 26, 2023, from https://www.arcgis.com/apps/View/index.html?appid=49471c66463e486c880ca8ff43b2ecbd

Workforce Development Area (WDA) Profile, North Shore WDA. (n.d.). Retrieved May 24, 2023, from https://masshire-northshorewb.com/regional-economy/workforce-development-area-wda-profile/

Appendix A Reference Information

TABLE A1 - REFERENCE DISTANCES

LOCATION	LATITUDE	LONGITUDE	
East Beverly Substation	42.56427° North	-70.84982° West	
Rockport	42.6557° North	-70.6203° West	Distance from East Beverly Substation to Rockport (est. 15 Miles)
King Street Substation	42.73645° North	-71.01216° West	Distance from Rockport to King Street Substation (est. 20 Miles)

Table A2 – POTENTIAL IMPROVEMENTS & EXPANSION

Improvement & Expansion Options	Benefits	Limitations	Risks	Beneficiaries	Costs
Option No. 1: Expand East Beverly 115kV Substation, installing transformer capacity and reinforcing express distribution feeders	• Advances efforts to reinforce current power delivery in terms of capacity, and potentially reliability to extent provided with new transformer capacity.	• Limited capacity gains • Does not address resiliency issues. • Feeder reliability issues are marginally addressed as redundant paths still needed. • End of line power quality issues remain	Benefits to key stakeholders having locations further north and east are limited	Primarily stakeholders, near the vicinity of the East 115kV Beverly Substation, up to the end points of actual feeder improvements.	Total $20M-$30M • Substation Expansion, $10M-$15M • Distribution Feeders, $10M-$15M
Option No. 2: Expand 115kV transmission to form North Region loop, with new 115kV substation to supply at new infeed location, with modification of topology to introduce new express distribution feeders	• Key enabler to reinforcement of economy and its expansion • Addresses resiliency, reliability and power quality issues • Construction might be phased over time, to complete overall 115kV transmission loop, advancing from west or south to central point according to ease of permitting and land use issues	• Intensive planning effort to overcome obstacles of right of way, acquisition, permitting and land use issues.	Time to advance through planning, design, permitting, and construction	Entirety of North Shore Region	Total $70M-$110M Transmission, $1.5M-$2M per mile, overhead, 35 miles Substations $7.5M-$15M per new substation; two minimum Distribution Feeders, $1M-$1.7M, overhead; $2M -$10M, underground

TABLE A3 – LOAD FORECAST (EAST BEVERLY SUBSTATION)

Feeder	Substation	Peak	Forecast	Last_Update d

Planning Area			Operating Voltage (kV)	2022 (MVA)	2013.2 (MVA)	2024 (MVA)	2025 (MVA)	2026 (MVA)	2027 (MVA)	Peak_Pct _Current _Year	
Beverly	05_12_51L1	EAST BEVERLY 51	13.2	8.4	8.6	8.7	8.8	8.9	9.1	75.70%	3/29/2013.2
Beverly	05_12_51L2	EAST BEVERLY 51	13.2	7.5	7.7	7.8	7.9	8	8.1	61.90%	3/29/2013.2
Beverly	05_12_51L3	EAST BEVERLY 51	13.2	9	9.2	9.3	9.5	9.6	9.7	82.60%	3/29/2013.2
Cape Ann	05_12_51T1	EAST BEVERLY 51	34.5	13.2.7	24.5	24.8	25.2	25.5	26.1	81.60%	3/29/2013.2
Cape Ann	05_12_51T2	EAST BEVERLY 51	34.5	15.3	15.8	16	16.3	16.5	16.8	52.80%	3/29/2013.2
Cape Ann	05_12_51T3	EAST BEVERLY 51	34.5	8.1	8.4	8.5	8.7	8.8	8.9	25.00%	3/29/2013.2

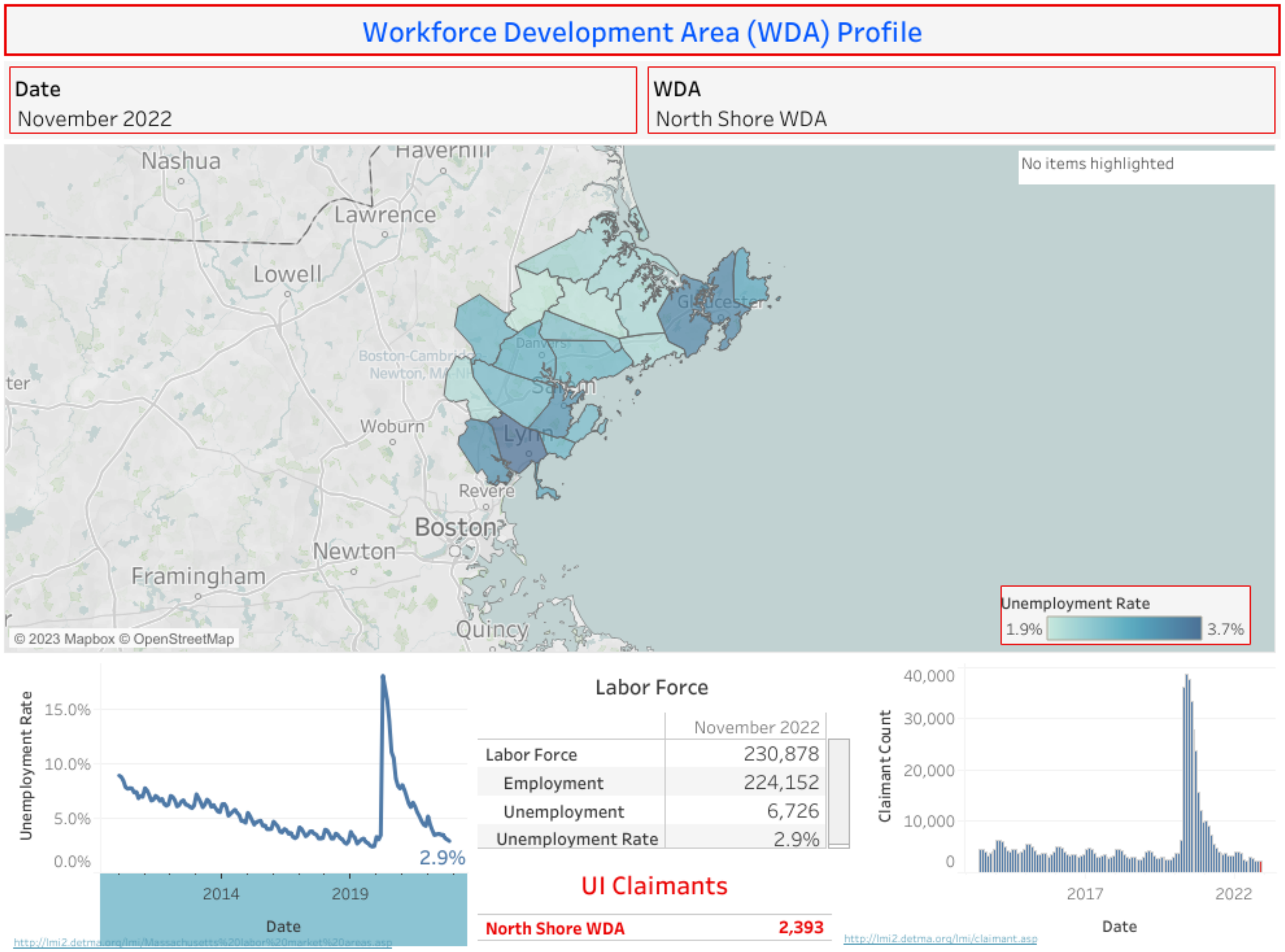
Source: https://systemdataportal.nationalgrid.com/MA/

TABLE A4 – POOR CIRCUIT REMEDIATION

Feeder ID No.	CKAIFI or CKAIDI	Prior Year	Current Year	No. of Poor Years	Reason for Performance in CY2022	Steps to Improve Reliability
12-24J9	CKAIFI	2020: 3.967	2021: 3.008302304	2	There were three (3) circuit breaker lockouts due to: substation issue (1), cable failure (1)., and unknown (1), There were two (2) fused branch outages due to: tree (1) and other company activities (1).	Complete infrared scans. Perform monthly patrols. Review for spot tree trimming. Complete ERR Monthly Visual and Operational Inspection. Completed relays upgrade at Gloucester 24 substation
12-51T2	CKAIFI	2020: 3.691	2021: 2.751740025	2	There was one (1) circuit breaker lockout due to a motor vehicle. There was one pole top recloser lockout due to a device failure. There were four (4) mainline areas sectionalized due to tree (1), unknown (1), deterioration (1), and a vehicle (1). There were forty-seven (47) fused branch outages due to the following: trees (29), device failed (5), unknown (3), vehicle (4), lightning (3), deterioration (1), other company activities (1), and a cable failure (1). There were sixteen (16) transformer outages due to device failed (7), animal (4), lightning (2), tree (1), vehicle (1), and deterioration (1).	Complete infrared scans. Perform monthly patrols. Review for spot tree trimming and Hazard tree removals Complete ERR Monthly Visual and Operational Inspection Replacing hundreds of spacer cable spreaders. Early Fault detection Pilot

Feeder ID No.	CKAIFI or CKAIDI	Prior Year	Current Year	No. of Poor Years	Reason for Performance in CY2022	Steps to Improve Reliability
12-35J2	CKAIFI	2021: 4.000	2022: 3.188427152	2	There were four (4) circuit breaker lockouts due to supply (4). There were four (4) fused branch lockouts due to deterioration (2), vehicle (1) and a deviced failed (1). There was one(1) transformer outage due to deterioration. There were two (2) secondary outages due to vehicle (1) and deterioration (1).	Complete infrared scans. Perform monthly patrols. Review for spot tree trimming. Complete ERR. Monthly Visual and Operational Inspection. Installed supply auto-transfer.

FIGURE A1 - WORKFORCE DEVELOPMENT AREA – NORTH SHORE



Source: Bureau of Labor Statistics (BLS), Local Area Unemployment Statistics (LAUS), MA Department of Economic Research (DER)
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