The New England states have enacted energy and environmental laws that call for a significant reduction in greenhouse gas emissions. Compliance with these laws is expected to result in changes in the generation and use of electricity. Generators that do not emit carbon will likely produce a much greater percentage of the region’s power supply. In addition, electricity will likely become more prevalent in heating buildings and powering vehicles, significantly changing load amounts, peaks and profiles.

The New England Power Pool (NEPOOL) is embarking on this Future Grid Reliability Study (Study) to understand better the implications of this substantially changed future grid. Specifically, the Study will examine whether revenues from the existing markets will likely be sufficient to attract and retain the new and existing resources that will be needed to continue to operate the system reliably. It will also identify what operational and reliability challenges will need to be addressed in the future grid and identify possible ways to meet those needs.

This document together with the appended assumptions table constitute the “Study Framework” which has been developed through the stakeholder process at joint meetings[[1]](#footnote-2) of the NEPOOL Markets and Reliability Committees (MC/RC) with support from the New England States Committee on Electricity (NESCOE) and Independent System Operator - New England, Inc. (ISO-NE). Although referred to as a Study Framework, the body of work will actually consist of several analyses using different computer models. No single model can address the range of issues that NEPOOL stakeholders desire to assess. The analyses will be conducted in a staggered iterative approach with the results from one analysis informing decisions about what to model or remodel in other analyses. The Study Framework will continue to be refined after being provided to ISO-NE or any consultant based on continued consultation regarding the studies described below. Close collaboration will be required between ISO-NE and any consultants retained by NEPOOL.

1. Study Objective / Scope

NEPOOL approved the Study objective and scope in a document commonly referred to as the “bubble chart.”[[2]](#footnote-3) The objective is to assess and discuss the future state of the regional power system in light of current state energy and environmental laws. The scope is to define and assess the future state of the regional power system identifying: 1) a resource mix or mixes for future years; and 2) resource and operational/reliability needs. A gap analysis will determine whether, in the future state envisioned, the existing markets will likely provide sufficient market revenues to attract and retain the new and existing resources that will be needed to continue to operate the system reliably. The gap analysis will also identify any market deficits that may need to be addressed to assure operability and reliability in accordance with the standards of the North American Electric Reliability Corporation, Northeast Power Coordinating Council, Inc. and ISO-NE.

The Study will therefore encompass both economic and engineering analyses. The economic analyses (production cost and ancillary services simulations, and the revenue sufficiency analysis) will seek to answer questions such as what are the forecasted market revenues, and will they likely be sufficient to attract and retain the different types of resources that will be needed to reliably operate the system in that future. The engineering analyses (ancillary services simulation, resource adequacy screen, and the probabilistic availability and system security analyses) will seek to answer questions about what conditions will likely present operational or reliability issues, the nature of those issues, and whether the system will be able to operate reliably when, for example, variable energy resources (VERs) are the predominant generation resources, when production from VERs exceeds load, and when there may be a sustained reduction in VER production. The studies will be performed in two phases, with immediate efforts focused on phase 1 analyses as described below.

1. Areas of Analysis
2. Production Cost Simulation: ABB GridView (ISO-NE) – Phase 1

**Objectives:** Show economic dispatches and energy market revenues for different scenarios. Provide useful information related to the operational/reliability analyses, and identify conditions upon which further operational/reliability analyses may focus.

**Scope:** New England only; external interfaces are assumed profiles. Assume unconstrained internal transmission initially. Interfaces at the Regional System Plan zonal level (RSP bubbles) will be monitored as part of the analyses such that some sensitivities that recognize constraints may be run.

**Methods:** Customary approach to economic studies – scenario analyses - with some flexibility to reflect the variable operation and maintenance costs of resources in the simulated dispatch. However, the variable operation and maintenance costs of electric storage cycling will be assumed to be $3/megawatt-hour one way. Sensitivities may be performed that assume different cost amounts. Iterate model simulations with updated values informed by the results of other areas of analysis

**Metrics**: Using scenario analysis, perform energy market simulation studies that provide information on system performance, including production costs by resource type and fuel type, location marginal prices, load-serving entity energy expenses, uplift and environmental emission levels (CO2, NOX and SOX) for all matrix and alternative scenarios

**Learning points**: High-level observations about transmission constraints between sub-areas in Gridview and the timing of when those conditions might occur; observations about whether the results suggest scenarios for further study; the results will feed into the probabilistic resource availability analysis.

**[Placeholder**: Further thought is required on: 1) the mix of market facing and non-market facing distributed energy resources; 2) the impact of non-market facing distributed energy resources on load profiles; and 3) a baseline for modeling the duration of storage devices. Allow for sensitivities to examine the impact of different duration assumptions.]

1. Ancillary Services Simulation: EPECS (ISO-NE and Consultant) – Phase 1

**Objectives:** Show if resources will provide the necessary amounts of regulation, reserves, ramping and load following. Provide insight to expected revenues from the existing ancillary services markets under the scenarios studied.

**Scope:** New England only; assume unconstrained internal transmission but interfaces at the RSP bubbles will be monitored. Some sensitivities that recognize constraints may be run. For the: (i) study year; and (ii) selected time periods within the study year

**Methods:** Using the same or complementary assumptions as the energy market simulations described above, use a methodology similar to what is used for those studies. Examine relationships between system imbalance estimates and: a) reserve products, and b) other ancillary services market products. Estimate quantities of ancillary services requirement “gaps” indicated in the scenario analysis. There will be some flexibility to iterate model simulations with updated values informed by the results of other areas of analysis.

**Metrics:** For all matrix and alternative scenarios, analyze the regulation, reserves, ramping, and load following capability needed to maintain the supply/demand balance of the New England bulk electric power system with a significant VER penetration. (The EPECS model provides an integrated platform for assessing simulated operating reserves, interface flows, tie-line performance, and regulation performance. The one-minute time increment used in the EPECS model augments the GridView model, which uses one-hour time-step increments to analyze: day-ahead resource scheduling as a security-constrained unit commitment; real-time resource scheduling as a real-time unit commitment; real-time balancing as a security-constrained economic dispatch; and real-time physical power flow with integrated regulation service.) Environmental emission rates (CO2, NOX and SOX) will be provided for resources providing ancillary services.

**Learning points:** High-level observations about conditions that may stress the grid, the timing of when those conditions might occur and any ancillary service gaps; observations about whether the results suggest scenarios for further study; the results will feed into the probabilistic resource availability analysis.

1. Resource Adequacy Screen and Probabilistic Resource Availability Analysis: GE MARS (ISO-NE) – Phase 1

The same modeling tool will be used to perform two different types of analyses as described below. There are some common elements:

**Scope:** New England only; assume unconstrained internal transmission but interfaces at the RSP bubbles will be monitored. Some sensitivities that recognize constraints may be run.

**Methods:** Use a probabilistic approach (Monte Carlo simulations) that examines all 8760 hours of the study year.

**Metrics:** Loss of load expectation (LOLE) of one day in ten years, loss of load probability (LOLP), expected unserved energy (EUE), loss of load event (LOLEv) which counts the number of events, EUE/LOLEv, and LOLH/LOLEv

[Placeholder: Further thought is required on how to treat new resources with respect to capacity supply obligations, the percentage of resources that will have capacity supply obligations and their capacity values.]

The objectives and methods of the two analyses differ in the following respects.

**1. Resource Adequacy Screen**

**Objective:** Determine Installed Capacity Requirement (ICR) for each future scenario in preparation for the energy market simulation to ensure that LOLE is met for expected system peaks. Include the creation of marginal reliability index demand curves.

**Methods:** Customary approach to ICR performed at a high-level to screen for resource adequacy in preparation for energy market simulations; scenarios found to be resource inadequate will be identified and will add sufficient proxy resources[[3]](#footnote-4) for the case to solve. Some sensitivities could be performed for different proxy resources.

**Metrics:** Evaluate all matrix and alternative scenarios to determine system reliability during the peak hours of the study year. Produce marginal reliability curves for select scenarios chosen by the MC/RC.

**[Placeholder**: Some issues that require further thought are: i) what should be the proxy resource(s) types and should they differ among the scenarios; and ii) what level of availability should be assumed for VERs.]

**2. Probabilistic Resource Availability Analysis**

**Objective:** Analyze the periods of time and system conditions outside of system peaks that may not meet LOLE due to factors such as insufficient capacity, flexible demand, weather risk, etc.

**Methods:** For select matrix and alternative scenarios chosen by the MC/RC, examine correlation of loss of load risk and multi-day VER estimates. Examine the frequency with which elevated risk events are projected to occur over time (e.g., number of times and for how long). Examine the occurrence of loss-of-load probability and identify risk trends (e.g., daily or seasonal instances of increased resource availability risk). Revise scenario assumptions to model other elevated risk events as chosen by the MC/RC. Include flexibility to iterate with updated values informed by the results of other areas of analysis.

**Learning points**: Observations about conditions in which there may not be sufficient resources to meet the LOLE criterion, the timing of when those conditions might occur, and whether there may be a need for certain categories of resources in some amounts in order to meet that criterion; observations about whether the results suggest scenarios for further study or some iterations with the energy and ancillary services analyses; the results will inform the system security analysis.

1. Revenue Sufficiency Analysis: Consultant-based software tool (Consultant)–Phase 2

**Objective:** Compare revenues from the existing markets to resource costs by technology type.

**Scope:** Resources located in New England only; assume an unconstrained internal transmission system but interfaces at the RSP bubbles will be monitored. Some sensitivities that recognize constraints may be run.

**Methods:** For some matrix and alternative scenarios selected by the MC/RC, conduct a Forward Capacity Market simulation for a few “bookend” prices. Add the resultant revenues to the revenues from the energy and ancillary services market analyses results. Compare the revenues from these existing markets to resource going-forward cost estimates. Present results in appropriate metrics for a technology type (e.g., $/kilowatt-month, $/year)

**Learning points**: High-level observations of whether revenues will be sufficient to attract and retain different types of resources.

**[Placeholder:** Further thought is required on how to develop resource going-forward cost estimates.]

1. System Security – Phase 2
2. Transmission Thermal and Voltage Analysis: PSS/E or similar software (Consultant)

**Objectives:** Screen the transmission system for thermal overloads and voltage limits for representative scenarios to identify key areas that may need transmission reinforcement. Make additions of transmission and possibly other devices as needed to have secure cases on which to conduct the stability analysis.

**Scope:** High level review identifying the need for additional transmission and possibly other devices to develop secure cases for stability analysis

**Methods:** The MC/RC selects a few representative scenarios to do a high-level screen for the purpose of identifying and then relieving transmission constraints before performing the stability analysis. The level of detail is less than what is typically modeled in a transmission reliability study. Assumptions will be made by the consultant to relieve constraints without optimizing potential solutions. There will be some flexibility to iterate model simulations with greater or lesser amounts of VERs informed by the results of prior model runs and other areas of analysis.

**Metrics:** Identification of significant thermal overloads or voltage constraints for which relief should be assumed before conducting a stability analysis for the selected scenarios.

1. Stability Analysis: PSS/E or similar software (Consultant)

**Objective:** Do a high-level screen to show whether the decline in inertia from rotating machines combined with the growth of inverter-based resources will result in stability issues that may or may not be solvable with inverter capability. The change in inertia and generation with governors will change the system’s ability to respond to large losses of generation through inertial pickup and increased output from conventional generators.

**Scope:** New England interconnected to New Brunswick and New York, external areas that will be modeled assuming decarbonization on the same scale as New England. Secure cases will be developed by identifying needed additions of transmission and possibly other devices based on the thermal and voltage testing described above.

**Methods:** Model the dynamic response capability of both conventional and inverter-based resources. The stability analysis will determine what, if any, devices are needed to maintain stability on the system for representative contingencies. Start with minimum load conditions (i.e. spring, weekend, mid-day) and consider also testing at peak loads.

**Metrics:** Determine if there is a gap that needs to be addressed by different operational or planning procedures or possible new market mechanisms to procure the required resources needed to maintain reliability.

**Learning points:** The gap analysis will inform the separate discussion that will be held about potential market approaches to solutions such as resource retention, fast-frequency responsive load, primary frequency response from inverter-based resources, minimum inertial generation dispatch requirements (including operation of conventional resources as synchronous condensers), using ultra quick start inverter-based batteries to provide an increase in megawatts (MWs) during a frequency decline, etc.

**[Placeholder:** Ask inverter manufacturers about their capability to provide inertia and use that information to inform the modeling.]

1. Scenarios

Use a matrix approach with alternatives to represent a range of possible futures based on Study proposals that stakeholders submitted to the MC/RC.

**Matrix of Scenarios for Energy and Ancillary Services Market Simulations**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **OSW 8,000 MW**  **DER 18,000 MW** | **OSW 8,000 MW**  **DER 25,000 MW** | **OSW 17,000 MW**  **DER 31,000 MW** |
| **Buildings 9,600 GWh**  **Transport 7,300 GWh** | Scenario  + Alternatives | 1 Case | 1 Case |
| **Buildings 6,600 GWh**  **Transport 18,500 GWh** | 1 Case | Scenario  + Alternatives | 1 Case |
| **Buildings 38,900 GWh**  **Transport 37,500 GWh** | 1 Case | 1 Case | Scenario  + Alternatives |

*OSW = Offshore wind*

*DER = Distributed energy resources (photovoltaics) and electric storage)*

The diagonal scenarios will be run first and, based on the results, an assessment will be made by ISO-NE whether any of the other matrix scenarios appear to be unrealistic, infeasible or not likely to tell something new. Based on that assessment, the MC/RC could decide to drop certain scenarios.

Stakeholders proposed some alternative scenarios. An assessment will be made by the MC/RC after the matrix scenarios as to whether to run each of the alternative scenarios based on factors such as whether an alternative scenario: 1) is likely to answer questions not already answered by the matrix scenarios or another study; 2) is feasible (meaning that the data/assumptions are available); and 3) can be completed in reasonable time.

**Alternative Scenarios**

1. Bi-Directional Transmission (see National Grid 2035)
2. Vehicle to Grid (see Multi-Sector A)

C. Nuclear Retirement (see NextEra/Dominion)

D. 100% decarbonization (see Anbaric)

E. On-shore and off-shore grids (see Anbaric)

**Energy and Ancillary Service Market Simulations:   
9 Matrix Scenarios + 15 Alternative Scenarios = 24 Potential Scenarios**

1. Matrix Scenario 

Matrix scenario1 assumes significant growth in non-carbon emitting generators and electrified load. However, with respect to both the resource mix and load, it assumes a slower pace of change than the two other matrix scenarios. The resource mix in Scenario  assumes approximately 8,000 MW of offshore wind (about 17% of the resource mix) and 18,000 MW of distributed energy resources (about 33% of the resource mix). On the load side, it assumes approximately 16,900 gigawatt-hours (GWh) of electrified building and transportation load weighted towards buildings. The electrified building and transportation load accounts for about 11% of net load. The detailed assumptions for this and each of the scenarios are presented in the appended table.

1. Matrix Scenario 

Matrix scenario  assumes greater growth in distributed energy resources and electrified load than scenario . The resource mix in scenario  assumes approximately 8,000 MW of offshore wind (about 15% of the resource mix) and 25,000 MW of distributed energy resources (about 41% of the resource mix). On the load side, it assumes approximately 25,100 GWh of electrified building and transportation load weighted towards transportation. The electrified building and transportation load accounts for about 18% of net load.

1. Matrix Scenario 

Matrix scenario  assumes significantly greater growth in offshore wind, distributed energy resources and electrified loads than scenarios  or . The resource mix in scenario  is comprised of approximately 17,000 MW of offshore wind (about 28% of the resource mix) and 31,000 MW of distributed energy resources (about 41% of the resource mix). With respect to load, scenario 3 assumes approximately 76,400 GWh of electrified load roughly balanced between buildings and transportation. The electrified building and transportation load accounts for about 45% of net load. Matrix scenario  is based upon the Massachusetts 2050 Roadmap Study results for the All Options Scenario in 2040.

1. Alternative Scenario A:

The objective is to analyze the impact of bi-directional controllable transmission to Quebec. It assumes the addition of a 1,200 MW bi-directionally capable controllable direct current line.

1. Alternative Scenario B:

The objective is to analyze the impact of vehicle to grid storage. It assumes that an additional 100 gigawatts of energy storage is available for a two-hour duration based on an estimated 25% of 8 million electric vehicles with 100 kilowatt batteries capable of providing electric storage and vehicle to grid services.

1. Alternative Scenario C:

The objective is to analyze the impact of the loss of the Seabrook and Millstone nuclear power plants. It assumes the retirement of both plants.

1. Alternative Scenario D:

The objective is to analyze the impact of a power system that is carbon free in 2035 in line with the Biden July 2020 energy plan. It assumes the retirement of the current fossil fuel generation fleet.

1. Alternative Scenario E

The objective is to analyze the different impacts of an on-shore and off-shore grid. It is a variant of alternative scenario E where higher proportions of off-shore wind are interconnected closer to load as suggested in the 2020 Brattle/GE/CHA study (e.g. more even split of offshore wind between SEMA, Boston and CT).

1. **Assumptions**

The detailed assumptions for the different scenarios are shown in the appended table.

1. Deliverables and Output Results
2. Resource Needs: For the resource mix proposed in each scenario studied, provide information related to resource financial viability in the current New England markets.

1. Compare revenues from the existing markets to resource costs by technology type for a selection of existing and new resources

2.Going-forward cost estimates, including a reasonable rate of return, for existing resources and cost of new entry estimates for new resources from the revenue sufficiency analysis

3.Show economic dispatches and energy market revenues for different scenarios from the GridView results

4.Provide insight to expected revenues from the existing ancillary services markets under the scenarios studied from the GridView and EPECS results. Due to GridView and EPECS model configuration, expected ancillary service market revenues may be a general approximation of revenues from current ancillary services markets, and not a direct reflection of estimated market revenues.

1. System Operational and Reliability Needs: Determine for different scenarios whether operational or reliability issues would arise.
   1. Provide useful information related to the operational/reliability analyses, and identify conditions upon which further operational/reliability analyses may focus
   2. Show if resources will provide the necessary amounts of regulation, reserves, ramping and load following
   3. Determine the ICR for each future scenario in preparation for the energy market simulation to ensure that LOLE is met for expected system peaks. Include the creation of marginal reliability index demand curves.
   4. Analyze the periods of time and system conditions outside of system peaks that may not meet LOLE due to factors such as insufficient capacity or flexible demand, weather risk, operational risk, etc.
   5. Show at a high level whether the decline in inertia from rotating machines combined with the growth of inverter-based resources will result in stability issues that may or may not be solvable with inverter capability, and provide insight on what, if any, devices are needed to maintain system stability

C. Carbon Emissions: Provide information on whether each scenario meets New England state law requirements and the resulting degree of grid decarbonization.

1. Estimate the carbon emission / emission reduction levels in:
   * 1. The power sector through the GridView results
     2. Across the broader economy with reference to input assumptions related to heating and transportation electrification
2. Estimate the energy production associated with renewable and clean energy resources through the GridView results

D. Make non-confidential raw data used in the analyses available to interested persons

1. Timing - Preliminary Schedule

– Phase 1

Study assumptions are finalized by March 1, 2021

Preliminary production cost simulation: March 2021 – September 2021

Final production cost simulation: September 2021 – March 2022

Ancillary services simulation: September 2021 – January 2022

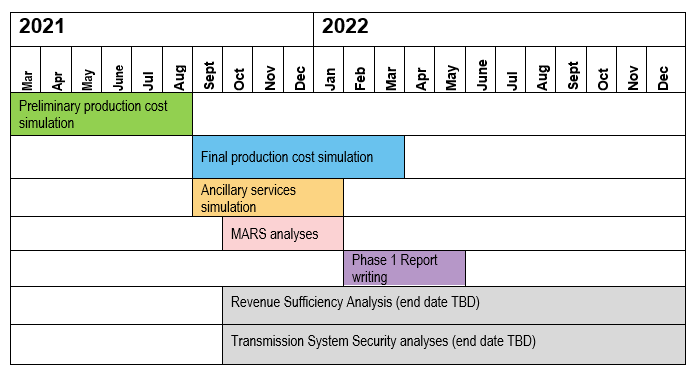
MARS analyses: October 2021 – January 2022

Report writing: February 2022 – May 2022

– Phase 2

Revenue Sufficiency Analysis: TBD but will not start before September 2021

System Security analyses: TBD but will not start before September 2021



1. Deliverables

The deliverables will include: 1) periodic status updates to and consultations with the MC/RC; 2) a PowerPoint presentation(s) and written report(s) on the preliminary production cost simulation results; and 3) a final PowerPoint presentation and written report on the Study results and key findings and observations.

1. Joint meetings of NEPOOL’s MC and RC were held beginning April 2020. Six past/ongoing studies were identified for examination: (1) 2016 NEPOOL Economic Study; (2) 2019 NESCOE Economic Study; (3) Massachusetts 2050 Roadmap Effort; (4) Eversource “Grid of the Future” Study; (5) E3/EFI “Electric Reliability under Deep Decarbonization” Study; and (6) 2019 Brattle Group “Achieving 80% GHG Reduction in New England by 2050” Study. For more information, see: <http://nepool.com/Future_Grid.php>. [↑](#footnote-ref-2)
2. See November 12, 2020 meeting materials, <https://www.iso-ne.com/static-assets/documents/2020/11/a2_presentation_future_grid_reliability_study.pdf> (slide 4) [↑](#footnote-ref-3)
3. Proxy resources may be a single resource type or composed of various resource types. If various resource types are chosen, then priority order must be assigned to be added to the system first to meet LOLE. [↑](#footnote-ref-4)