Transition to the Future Grid

Concepts for Stakeholder Discussion

NEPOOL Joint MC and RC Meeting

May 27, 2020

Overview

- NESCOE's Point and NEPOOL's Objective
- Thoughts on Feedback from Last Meeting
- Some On-Going Relevant Studies
- Frontloaded Work on Study Areas

Context

- All materials are preliminary and offered for the purpose of facilitating reactions, questions and discussion.
  - This presentation is being made to prompt discussion and feedback to move the process ahead.
- None of the materials reflect the views of NESCOE or any NESCOE Manager.
  - NEPOOL's feedback may help inform those views.
- Nothing in this material is intended to imply a view about NEPOOL processes and none should be inferred.

NESCOE's point, in asking for work on Markets & State Laws

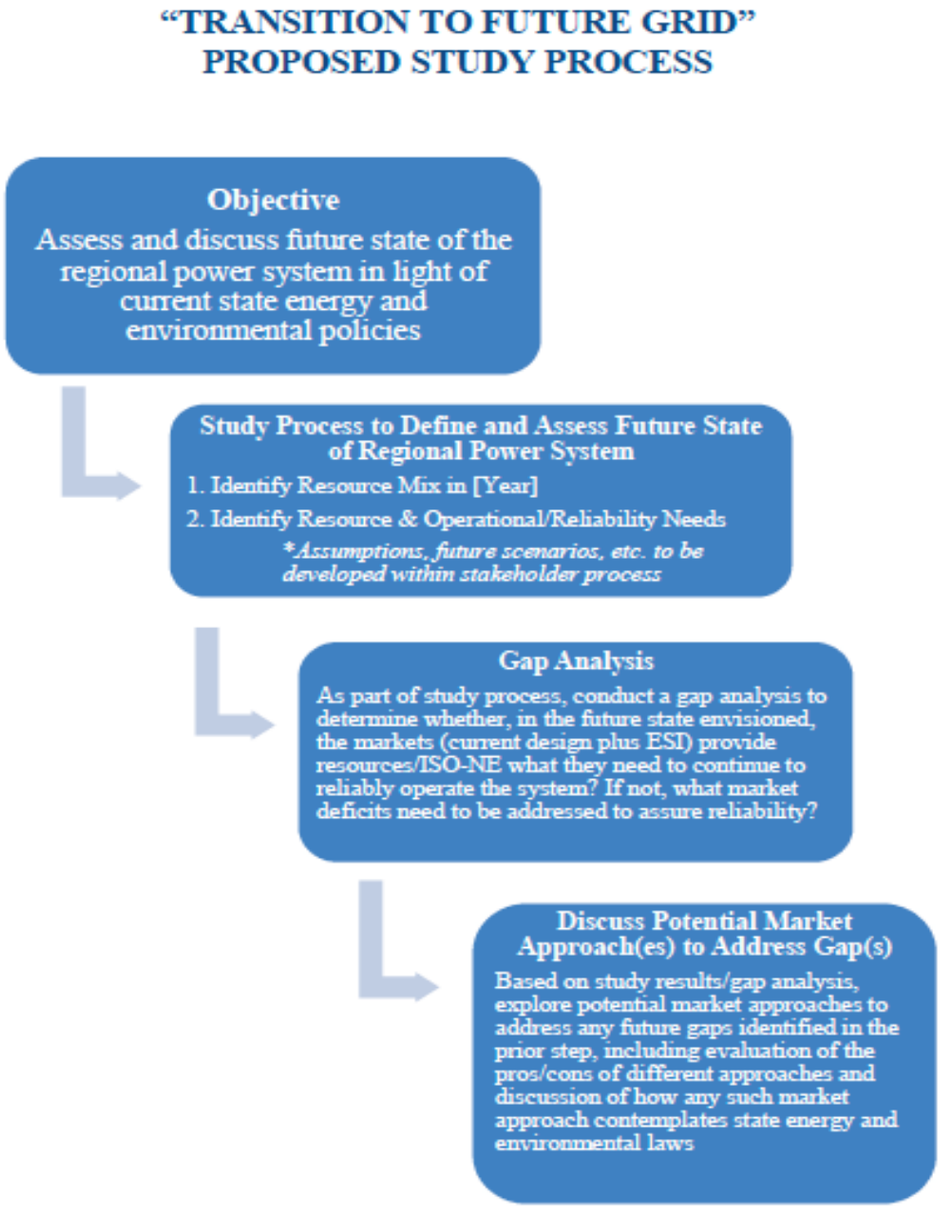
Ultimately, to support states and stakeholders in analyzing and discussing potential future market frameworks that contemplate and are compatible with the implementation of state energy and environmental laws, consistent with reliable power system operations.

Reference *NESCOE July 2019 Work Plan Request*
http://nescoe.com/wpcontent/uploads/2019/07/WorkPlan2020Request_16July2019.pdf

NESCOE
New England States Committee on Electricity

NEPOOL identified interest in analysis, which ISO-NE and NESCOE support

February 2020



NEPOOL Feedback to NESCOE April MC/RC Preliminary Discussion on Analysis

1. What is the most efficient way to move necessary analysis along?

2. What about other relevant studies in process? Is additional study needed? If so, of what level of analysis?

3. How would a new study interact with ongoing discussions on market mechanisms ?

Our Thoughts on NEPOOL Feedback

- We share interest in finding efficiency
- We're talking with other study sponsors to understand:
  1. Can preliminary assessment of the "Gap Analysis" bubble on Slide 5 be determined from these past/current studies – are we already 80% of the way there?
  2. If a reasonable preliminary assessment can be accomplished from past/current studies, can the discussion on the last bubble begin without a new study?
  3. If additional study elements are required, then:
     1. Can carbon compliant resource mixes (and other assumptions) be determined from these past/current studies?
     2. Can these studies' scenarios be imported into any economic and/or engineering analyses for efficiency?
     3. Could they be limited in scope to answer specific unanswered questions from past/current studies?

- Answering these questions will help "Transition to the Future Grid" process (slide 5) and achieve NESCOE's point (slide 4)
- Any "Transition to the Future Grid" study will overlap with discussions about market mechanisms happening now in various forums. The "Future Grid" analysis could help inform those discussions, and vice versa, as well as when NEPOOL begins to discuss market mechanisms.
  - What might sound reasonable in the short-term may not be the place we want to be in the long-term.
  - Knowing where we want to be in the future could guide short-term actions.

One Possible Approach

- First assess current studies and identify what analysis remains necessary.
- Conduct any additional analysis ("gap analysis") to determine whether, given the requirements of state laws (power, heating, transportation), the wholesale markets and transmission network enable reliable system operation, and if not, what deficits need to be addressed to achieve reliable power system operations.
- To that end -
  - leverage existing analyses (to narrow what needs to be analyzed as appropriate and to capture efficiencies in remaining analysis),
  - ensure sufficient economic, operational, and engineering analyses as necessary to inform discussions,
  - examine operational issues, reliability concepts, and resource economics in a hypothetical future with an electricity grid that is carbon compliant pursuant to the requirements of state laws (power, heating, transportation, etc.),
  - per NEPOOL direction, plan on an MC/RC forum for participation and transparency, and
  - deliver actionable information as quickly as possible in clear, concise, and plain language and graphics.
- Discuss potential market approaches to address any such gaps, and their pros and cons, ("market framework discussions").
- Provide useful and actionable information by the end of 2020, which timing may also inform other near-term market framework discussions.

What we plan to do next

- Continue talking to stakeholders and provide our thoughts on the previous questions
- Seek out stakeholder views on the same
- Request to hear from as many other study sponsors as possible at the next RC/MC
- Continue to work with NEPOOL and ISO-NE on the overall process

Review of Current Studies

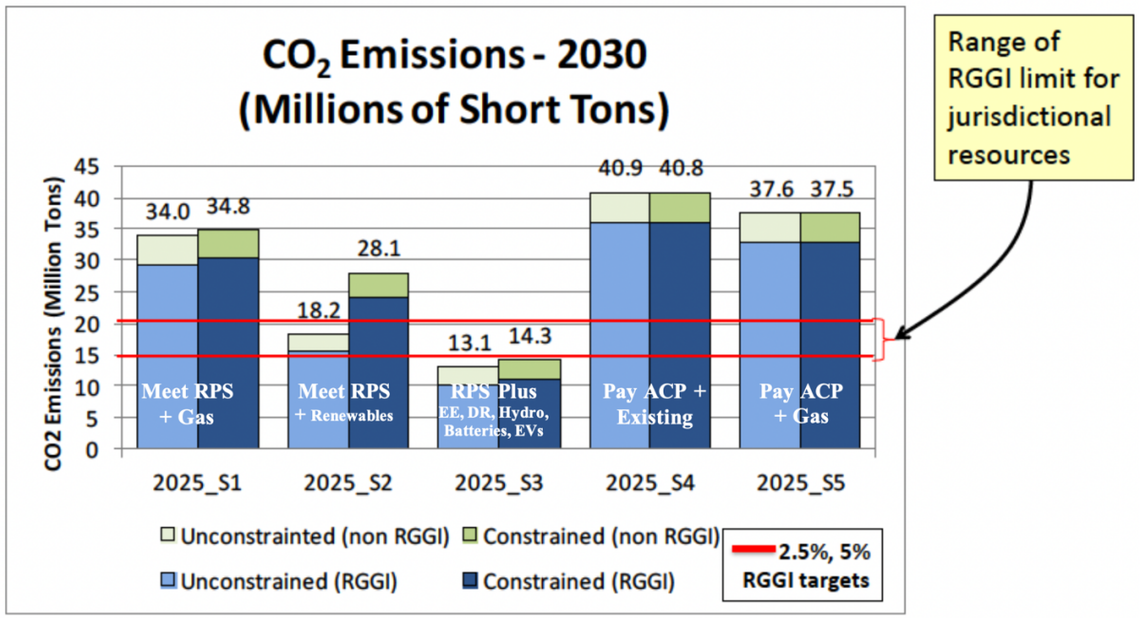
The list of studies here is non-exhaustive and is provided for information. Discussion of studies does not indicate a preference for any particular study, scenario, consultant, project, or mechanism.

Also see NEPOOL's Transition to the Future Grid Reference Library

Review of Current Studies

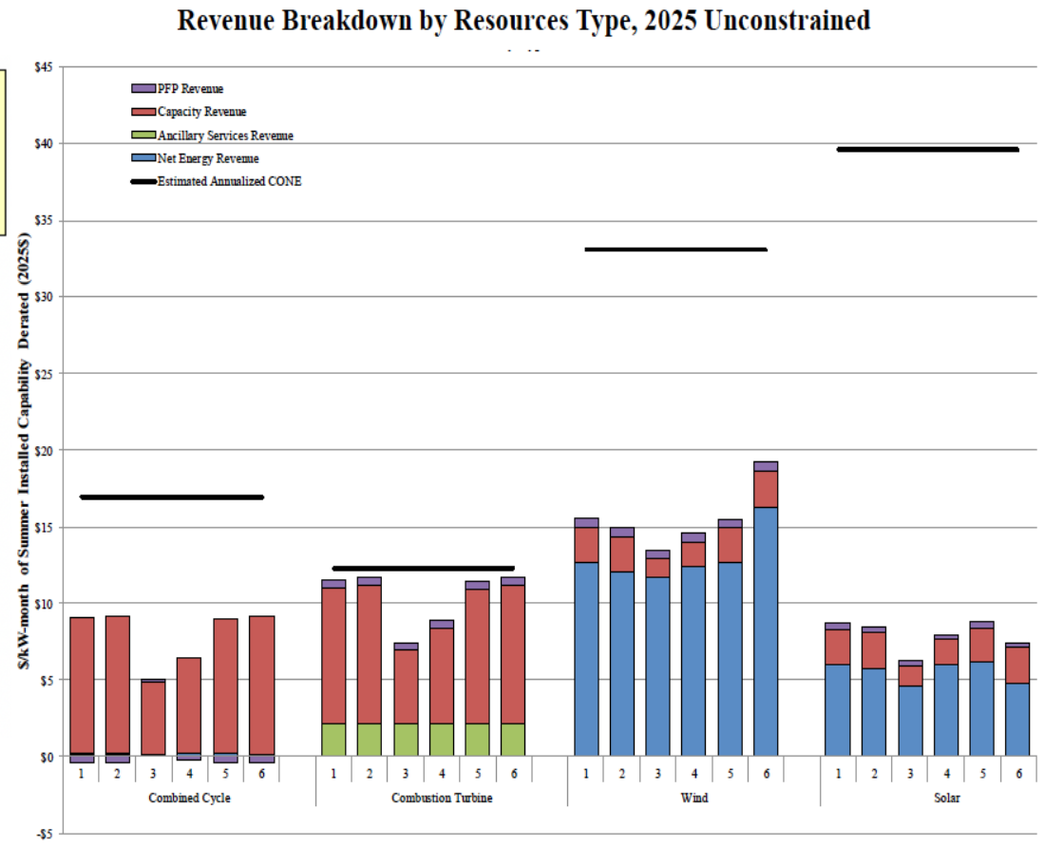
	Study	Study Objective	Finding(s)
1	NEPOOL 2016 Economic Study	Scenario analysis in 2030 – Energy, Capacity, Ancillary Services, High Level Tx Cost Estimates	"As the quantity of new clean resources added to the system increases, the cost (per MWh or MW) of supporting clean resources increases. The gap in revenue requirement (for new entry) needs to be filled by other sources because of decreases in revenues from both the FCM and energy markets." ~ Analysis Group "Higher carbon prices reduce emissions only when carbon prices effect the economic dispatch order of generating units and lower carbon emitting replacement energy is available" – ISO-NE Carbon Sensitivity Results
2	Conservation Law Foundation 2017 Economic Study	Low-carbon-emitting resource-expansion scenarios and potential effects on resource adequacy, operating and capital costs, and options for meeting environmental policy goals	The EE + Offshore scenario has the lowest CO2 emissions and, along with the Renew Plus scenario, meets both the 2.5% and 5% RGGI targets for both the constrained and unconstrained cases. The relative annual resource cost (RARC) for the EE + Offshore scenario is similar to the reference RARC (the Renew Plus scenario, 2016 NEPOOL Scenario Analysis 3)
3	NESCOE 2019 Economic Study	Offshore Wind Integration in 2030 – Energy, Ancillary Services, High Level Tx Cost Estimates	High Level Transmission Findings (to date) • Based on the currently expected transmission system for 2030, the ISO anticipates that the depicted levels of offshore wind additions (approx. 7,000 MW) have the potential to be accomplished without major additional 345 kV reinforcements* • This assumes FCA 13 retirements have occurred, including the retirement of Mystic 8 & 9 Ancillary Services (TBD)

Review of Current Studies – NEPOOL 2016 Economic Study



Source: 2016 Economic Studies: Draft Results Part II, slides 107-108, available at https://www.iso-ne.com/static-assets/documents/2016/09/a6_2016_economic_study_draft_results_part_2.pdf.

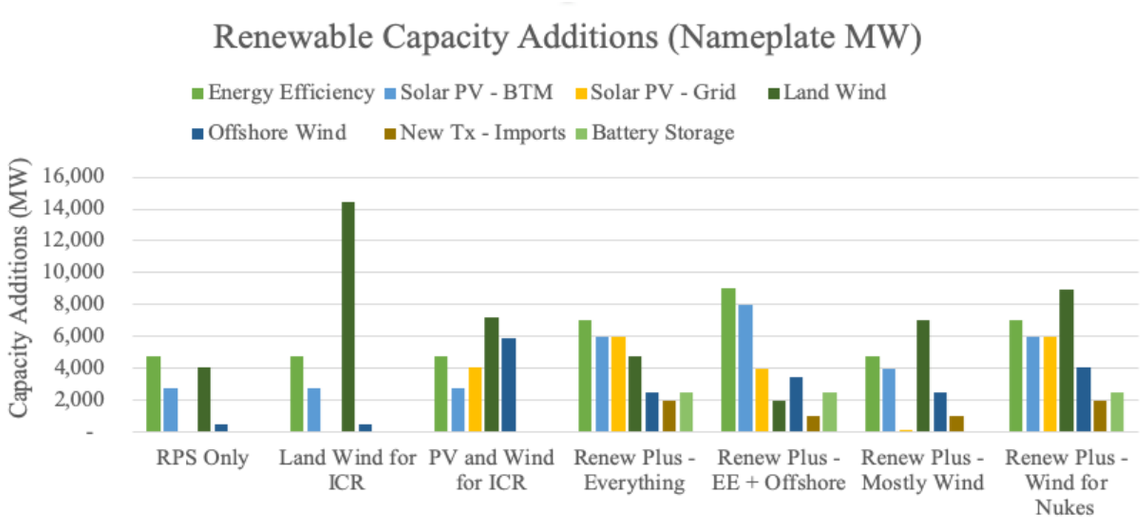
(Source: NEPOOL 2016 Economic Study)



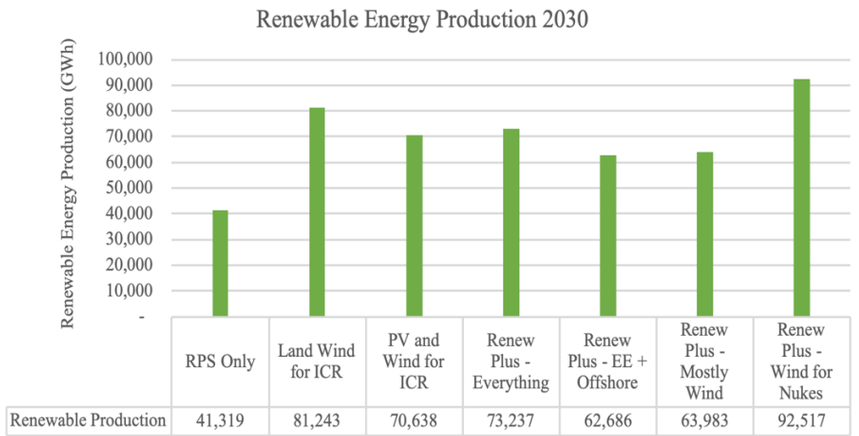
(Source: Analysis Group for NEPOOL 2016 Economic Study)

Review of Current Studies - NEPOOL 2016 and CLF 2017 Economic Studies

How much renewable and clean energy did those studies analyze?



'Status quo' → Increasing Penetration → 'All-of-the-Above' and variations



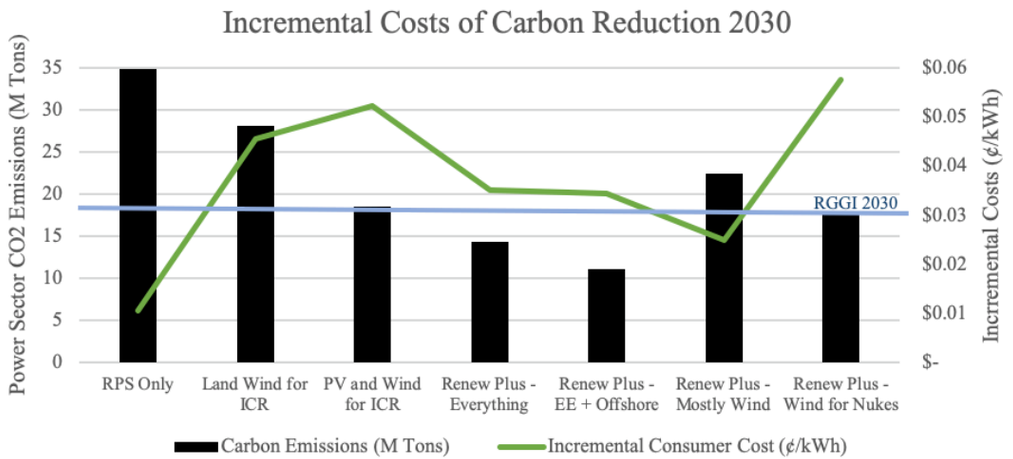
	RPS Only	Land Wind for ICR	PV and Wind for ICR	Renew Plus - Everything	Renew Plus - EE + Offshore	Renew Plus - Mostly Wind	Renew Plus - Wind for Nukes
Renewable Production	41,319	81,243	70,638	73,237	62,686	63,983	92,517

'Status quo' → Increasing Penetration → 'All-of-the-Above' and variations

Data Sources: ISO-NE 2016 and 2017 Economic Study Results
Charts: NESCOE Staff Analysis

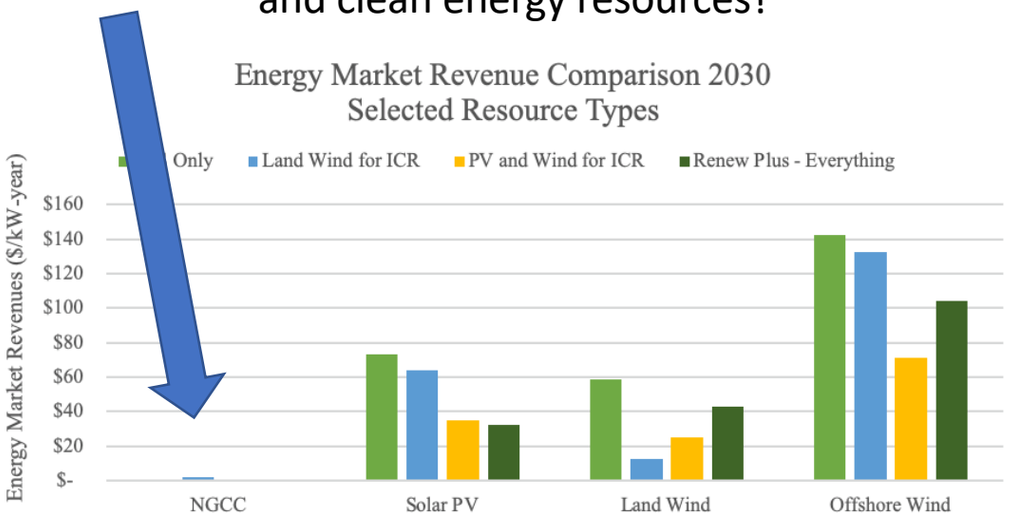
Review of Current Studies – NEPOOL 2016 and CLF 2017 Economic Studies

How much power sector carbon emissions resulted from resource mixes with the assumed new renewable and clean energy resources?



'Status quo' → Increasing Penetration → 'All-of-the-Above' and variations

What are the energy market revenues resulting from resource mixes with the assumed new renewable and clean energy resources?



Data Sources: ISO-NE 2016 and 2017 Economic Study Results
Charts: NESCOE Staff Analysis

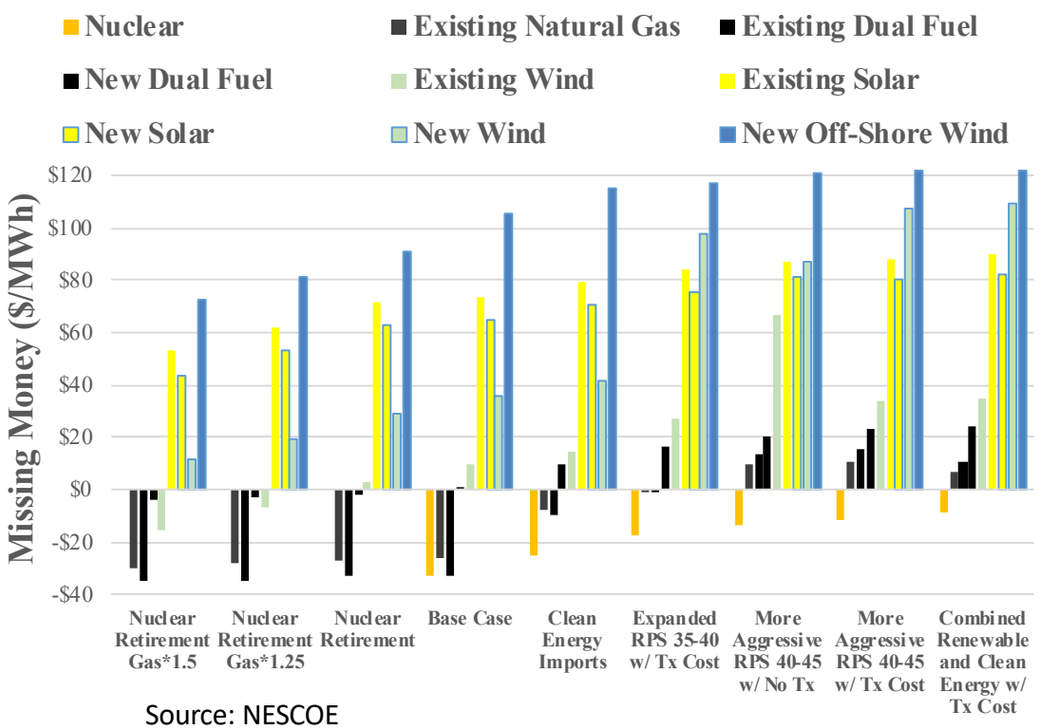
Review of Current Studies

	Study	Study Objective	Finding(s)

4	NESCOE Renewable and Clean Energy Scenario Analysis and Mechanisms 2.0 Study (Spring 2018)	Economic analysis of some of the possible incentive mechanisms states may wish to use to support meeting their renewable and clean energy requirements	• Wholesale energy and capacity costs move in the opposite direction from mechanism costs, and both directly affect consumer bills
			  • As energy and capacity costs decline, mechanism costs increase
			  • Temporary capacity cost declines have a significant impact on total costs to consumers
			• "Missing Money" increases outweigh the difference in estimated cost among mechanisms.
			• Whether one or more mechanisms may better serve consumers than another depends on a state's objectives and the trade-offs a state is interested in making

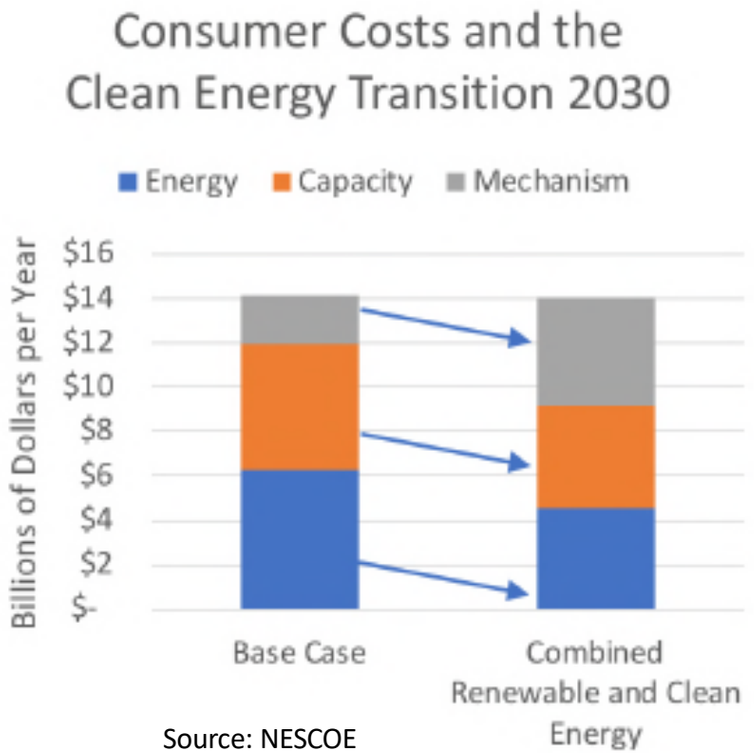
Review of Current Studies – NESCOE Mechanisms 2.0 Study

Estimated Missing Money: Selected Resource Types - 2025



Source: NESCOE

Illustration of the Shift in Costs from Markets to Mechanisms



Source: NESCOE

Review of Current Studies

	Study	Study Objective	Finding(s)
5	Clean Energy Accelerator by Brattle (Sept 2019)	Scenario analysis in 2030 – Energy, Capacity, Ancillary Services, High Level Tx Cost Estimates	Annual clean energy resource additions need to increase by a factor of four to eight times the current level (4x to 8x) to achieve 2050 carbon emissions reduction goals
6	Deep Decarbonization with HQ (April 2018)	Economic scenario analysis of the Northeast (New York and New England) and Hydro Quebec energy supply mix in 2050	More interconnections between the Northeast and HQ may be a less expensive approach to decarbonization than an alternative with an even greater reliance on offshore wind and solar
7	Deep Decarbonization in California by E3 (June 2019)	Examine resource adequacy under future scenarios in which California's economy is deeply decarbonized and heavily dependent on renewable energy	The least-coast electricity portfolio to meet the 2050 economy-wide greenhouse gas goals for California includes 17-35 GW of natural gas generation capacity for reliability

Review of Current Studies

	Study	Study Objective	Finding(s)
8	FCEM Detailed Design by Brattle (Sept 2019)	Propose a detailed market design for a competitive, regional forward clean energy market (FCEM) for clean energy attributes	Broad competition will minimize the costs of achieving carbon goals
9	NESCAUM White Paper (Sept 2018)	Provide high-level insights about the magnitude of actions needed to achieve New England's ambitious climate goals	• Immediate action is required • Electrify end-use energy consumption • Decarbonize the electric grid

Gap in Current Studies

Figure 11 - Business-as-Usual and Mitigation Scenarios through 2050 for New England

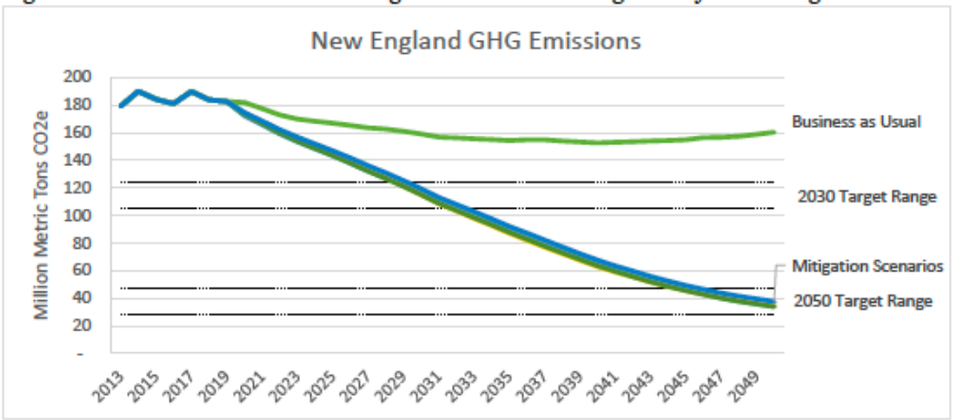
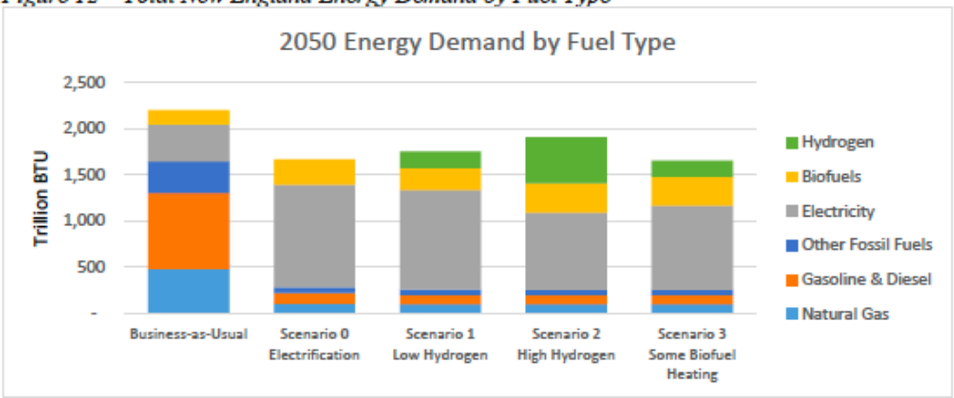


Figure 12 – Total New England Energy Demand by Fuel Type



Source: NESCAUM

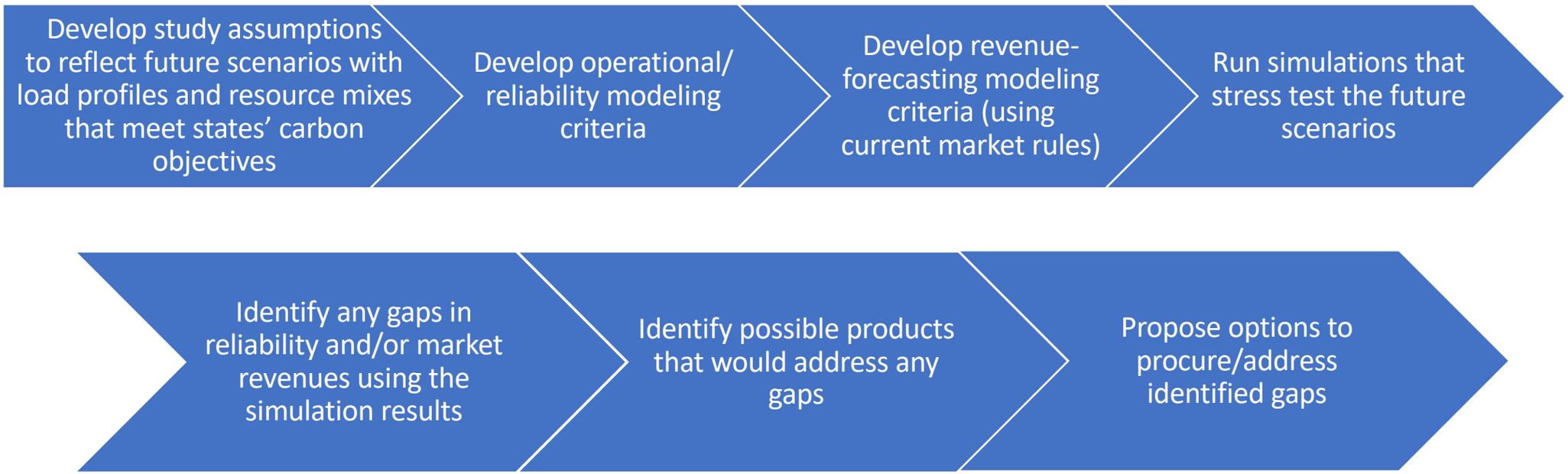
- Decarbonize Power System & Electrify Heating and Transportation
  - How much new load and when?
  - Managed heating and transportation loads or coincident? – Daily load shapes?
  - Retirements to decarbonize
  - New renewable and clean energy resources to serve loads with lower power sector air emissions

General Study Approach

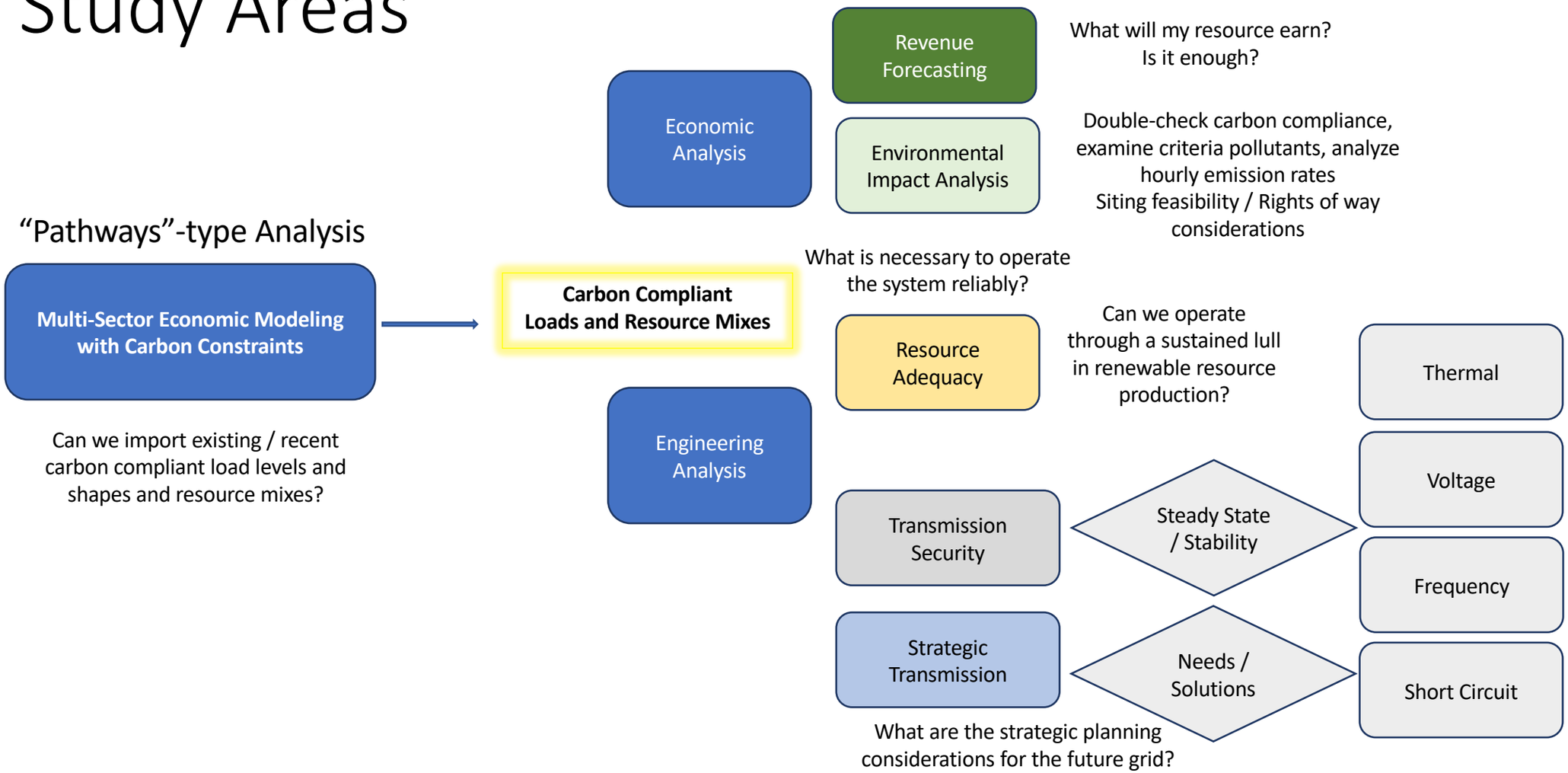
We believe we need to assess the prior studies and answer the questions just identified before deciding what analysis remains.

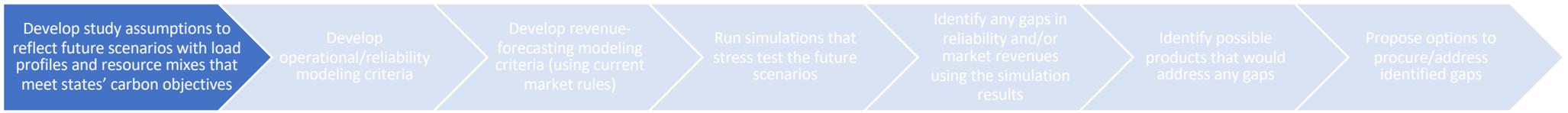
In the interest of time, we frontloaded some work on study analysis to make use of time and to facilitate everyone's thinking. We review that next and note it would need to be revisited after assessing current studies.

General Study Approach



Study Areas


"Pathways"-type Analysis
Multi-Sector Economic Modeling with Carbon Constraints
Can we import existing / recent carbon compliant load levels and shapes and resource mixes?
Carbon Compliant Loads and Resource Mixes
Economic Analysis
Revenue Forecasting
What will my resource earn? Is it enough?
Environmental Impact Analysis
Double-check carbon compliance, examine criteria pollutants, analyze hourly emission rates
Siting feasibility / Rights of way considerations
What is necessary to operate the system reliably?
Resource Adequacy
Can we operate through a sustained lull in renewable resource production?
Engineering Analysis
Transmission Security
Steady State / Stability
Thermal
Voltage
Frequency
Strategic Transmission
Needs / Solutions
Short Circuit
What are the strategic planning considerations for the future grid?



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Relevant "Pathways"-type Studies on the Future New England Power Grid

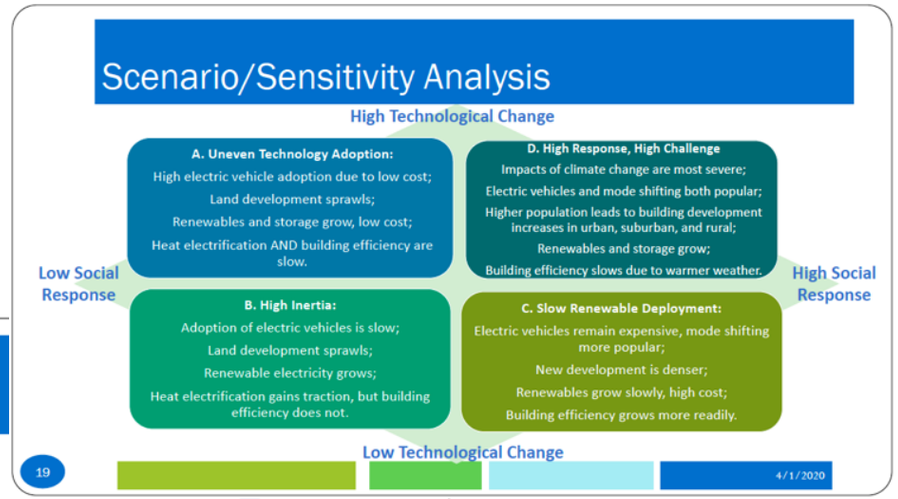
Key Issues:

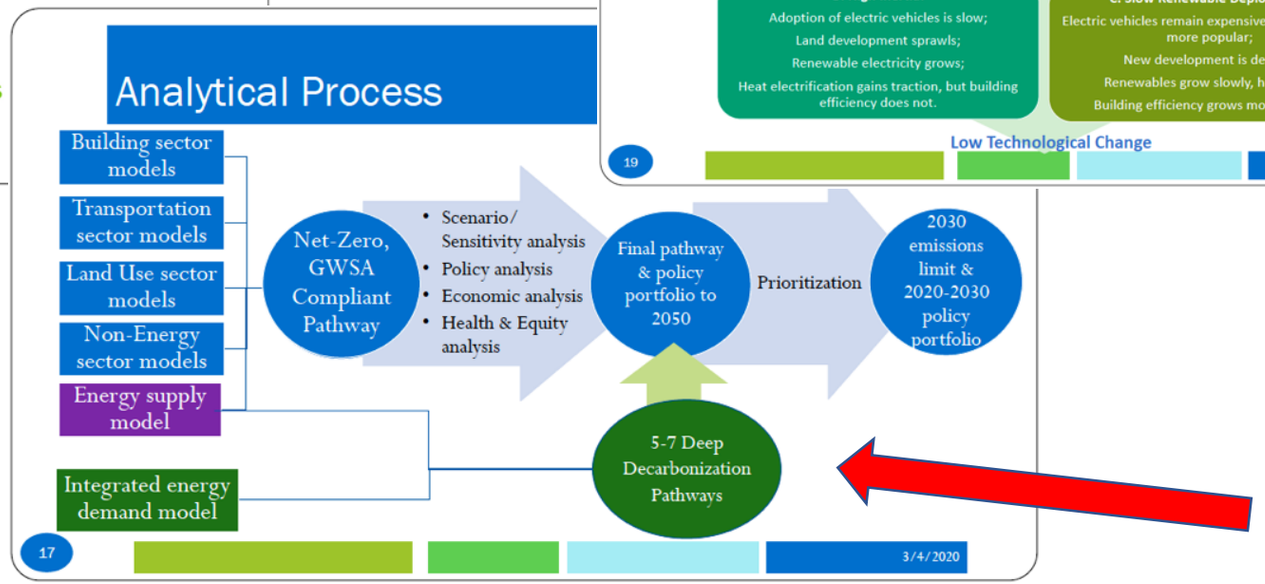
- Whether carbon compliant resource mixes (and related details) can be determined from ongoing or recently completed analyses?
- To what extent do these studies inform the questions the Future Grid Study asks?
- Can scenarios from existing studies be successfully imported into the economic and engineering analyses to save time in the overall process?

Relevant ”Pathways”-type On-Going Studies

	Study	Study Objective	Progress to Date	Expected Finish Date
10	Massachusetts 80 by 50 with Cadmus and Evolved Energy Research	Scenario Analysis 2030-2050	Pathways modeling underway	Winter 2020
11	Connecticut Clean Energy Pathways Analysis with Levitan	Scenario Analysis in 2035-2040 with more heating and transport loads and 100% renewable by 2040 – Energy, Capacity, Resource Adequacy, Gas Infrastructure Hydraulics	Pathways modeling underway	Fall 2020
12	Calpine (and others?) “?” with Energy Futures Initiative		?	Fall 2020
13	Eversource with London Economics	Grid of the Future Study: Scenarios cover a range of potential technology and policy pathway scenarios that achieve economy-wide carbon reduction	Pathways modeling almost complete	Summer 2020
14	National Grid 2020 Economic Study	Scenario Analysis in 2035 with more heating and transport loads – Energy, Ancillary Services, and High-Level Tx Cost Estimates • Examine mitigating renewable curtailment with batteries and incremental bi-directional interconnections with neighboring systems	Beginning scoping and assumptions	1st and 2nd quarter 2021

Relevant “Pathways”-type Studies - Massachusetts

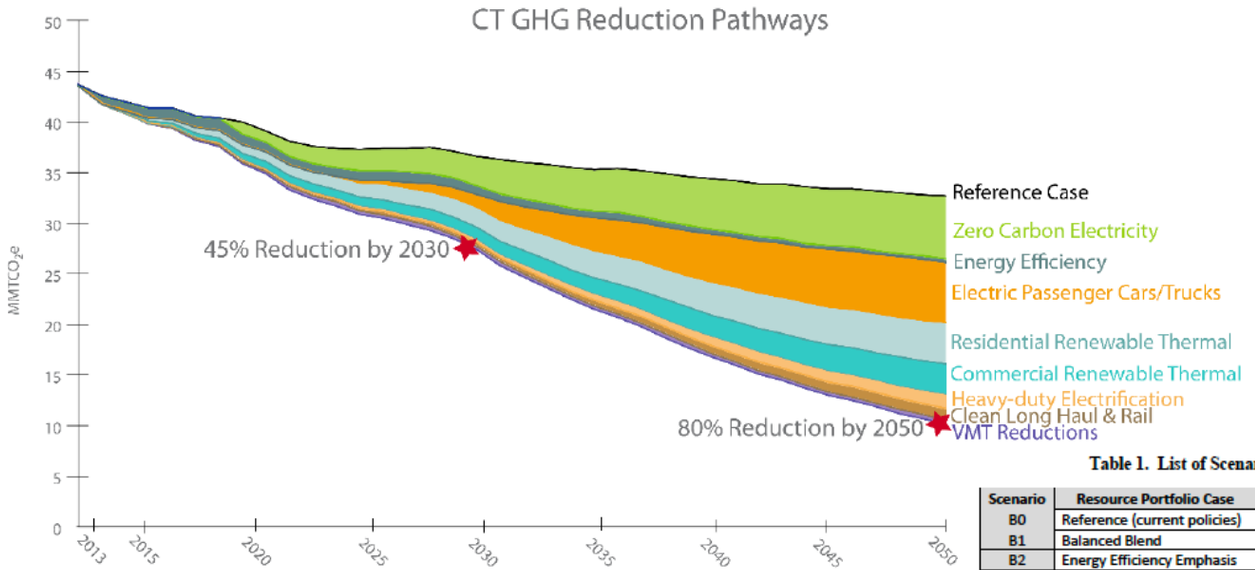




[Massachusetts Decarbonization Roadmap]

Relevant “Pathways”-type Studies – Connecticut

GOVERNOR’S COUNCIL ON CLIMATE CHANGE



Appendix C: Connecticut Business-As-Usual Case

The first step in developing a climate strategy is building a Connecticut-specific business-as-usual reference case to provide a basis for examination of potential GHG mitigation technologies and measures. Utilizing projection data from the Energy Information Administration and factors expected to shape Connecticut’s future energy consumption, Northeast States for Coordinated Air Use Management (NESCAUM), GC3’s technical consulting group, developed a reference case projection of future emissions through 2050.

Table 1. List of Scenarios

Scenario	Resource Portfolio Case	Gross Load Case
B0	Reference (current policies)	Base
B1	Balanced Blend	
B2	Energy Efficiency Emphasis	
B3	Offshore Wind Emphasis	
B4	Solar (grid & BTM) Emphasis	
B5	HQ Hydro Emphasis	
B6	Millstone PPA Extension	
E0	Reference (current policies)	Electrification
E1	Balanced Blend	
E2	Energy Efficiency Emphasis	
E3	Offshore Wind Emphasis	
E4	Solar (grid & BTM) Emphasis	
E5	HQ Hydro Emphasis	
E6	Millstone PPA Extension	

Connecticut Department of ENERGY & ENVIRONMENTAL PROTECTION

Energy and Technology Policy

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February 24, 2020

INTEGRATED RESOURCES PLAN

ATTACHMENT A: CLEAN ENERGY PATHWAYS ANALYSIS MODELING ASSUMPTIONS AND INPUTS

Purpose

The purpose of this Factor Inputs memorandum is to identify key input assumptions and data that Levitan and Associates, Inc. (LAI) is using in the electric system simulation modeling for the Clean Energy Pathways study for each of the 14 scenarios.

Regional Electric System Simulation Modeling Approach and Software Tools

LAI utilizes the zonal version of Aurora, a production cost and capacity expansion optimization model licensed from Energy Exemplar, for long-term capacity planning and hourly commitment and economic dispatch of resources. LAI uses the default database provided by Energy Exemplar as a foundation. LAI augments the database with extensive customization based on public data sources, proprietary calculations, and professional judgment informed by ongoing consultation with the Department of Energy and Environmental Protection (DEEP).

Study Period, Base Weather Year, and Time Steps

LAI will run Aurora for a 20-year period, from 2021 to 2040. The planning horizon corresponds to the endpoint of Connecticut’s statutory goal to meet 100% of power generation needs with clean energy.

Given the importance of weather-based coincident relationships among load, solar energy, and wind energy under increased penetration of variable energy resources (VER), consistent hourly load, solar PV output and wind output profiles must be used. The best way to ensure the correct correspondence between load and VER generation is to use a common historic weather year to set the load and VER generation profiles. LAI analyzed load data for 2007 through 2012, the years for which NREL data is available for hourly wind and solar PV output profiles. 2011 was selected as the most representative year based on being most typical as measured by deviations from average monthly energy demand and summer and winter hourly peak loads over the six years.

Capacity expansion and retirement decisions are made in Aurora on an annual time-step. Production cost simulation is conducted using chronological 8760 hourly dispatch.

[Connecticut Integrated Resources Planning]

Relevant “Pathways”-type Studies – Market Participants

CALPINE®

ENERGY FUTURES INITIATIVE

EVERSOURCE

LE LONDON ECONOMICS

nationalgrid

Relevant ”Pathways”-type Studies - Eversource’s Grid of the Future Study

Background

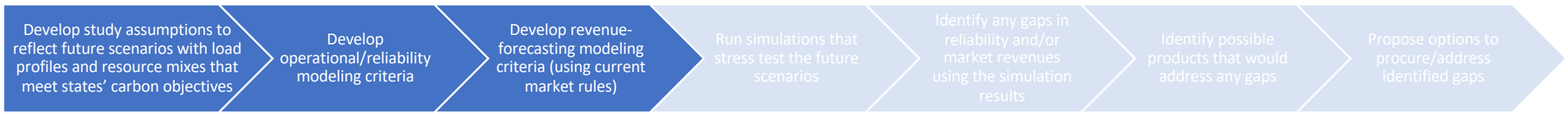
- Meeting regional carbon emission reduction targets will result in major changes to the electric system over the next three decades
- As New England’s largest energy delivery company, it’s our responsibility to help implement the changes needed to meet these goals, while reliably and affordably delivering energy
- With a primary objective of understanding the impact of decarbonization policies on the electric grid, we have been working with London Economics International (LEI) to model a variety of scenarios that achieve economy-wide carbon reduction

Overview of Study

- Scenarios cover a range of potential technology and policy pathways
  - All scenarios are driven by either current policy (80% economy-wide carbon reduction by 2050) or more aggressive policy (95% economy-wide carbon reduction by 2040)
  - Scenarios make different technology assumptions for supply capacity expansion: balanced assumptions across all renewable resources, expansion focused on distributed solar, or expansion focused on offshore wind
  - Electrification of heating and transportation are driven directly by carbon reduction policy targets in those sectors, not by forecasted market-based adoption rates
- Modeling methodology uses hourly simulations to develop supply mix that meets emission and reliability objectives
  - Renewable energy production profiles and electrification demand profiles based on public data sources (e.g. NREL, EIA)
  - Battery storage used as the unit of choice for resource adequacy and to balance intermittent supply with demand
  - Allows for intra-regional transfer limit increases for reasonably uncongested flows
- Detailed zonal outputs include hourly supply and demand, energy market prices, storage operation, etc.

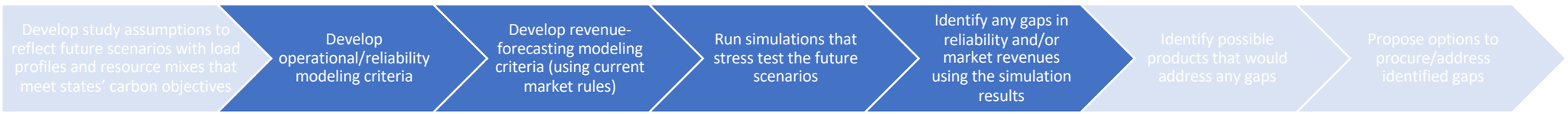
EVERSOURCE

More Detailed Approach



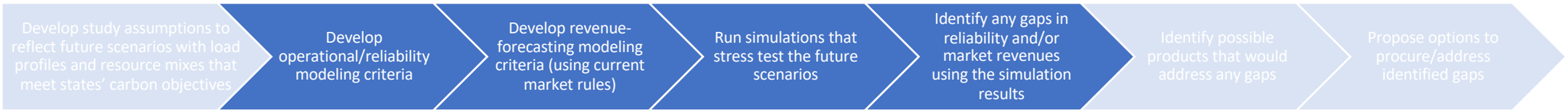
- **Study Components 1-3:** Agreement on Future Grid Analysis
  - **Key Issue:** Developing carbon compliant resource mixes that meet the requirements of state laws (power, heating, transportation, etc.) is a significant analytical challenge on its own. Time matters in this process if the region is to work through this matter on a calendar of its making, rather than in a reactive posture. For that reason, and for overall efficiency, as noted earlier, there is interest in exploring whether carbon compliant resource mixes (and related details) can be determined from ongoing or recently completed analyses.
  - Can scenarios from existing studies be successfully imported into the economic and engineering analyses to save time in the overall process?
  - Some level of data translation / mapping / supplementation may be necessary
  - Details to be determined in consultation with market participants

More Detailed Approach - Continued



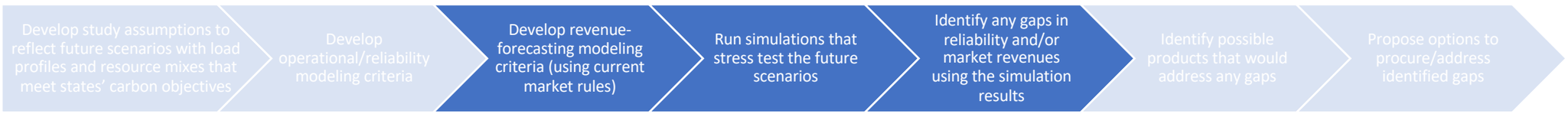
- **Study Components 2-5**: Economic and Engineering Analyses
  - Ancillary Services Requirements Analysis
    - Depending on available information and the scope of other aspects of the analysis, this would identify system operational needs like ramping, regulation, load following, etc.
  - Time-Series Approach to Probabilistic Reliability Analysis
    - Seasonal Energy Sufficiency – Analysis and/or internal constraint
      - Several week time frame
      - production lull and load pattern coincidence - extent and duration
    - Multi-Area Reliability Simulation – Estimate available dispatchable capacity needed to maintain LOLE statistics over a time series by examining the magnitude, frequency and duration of reliability events
      - Resolution and many details TBD –

More Detailed Approach - Continued



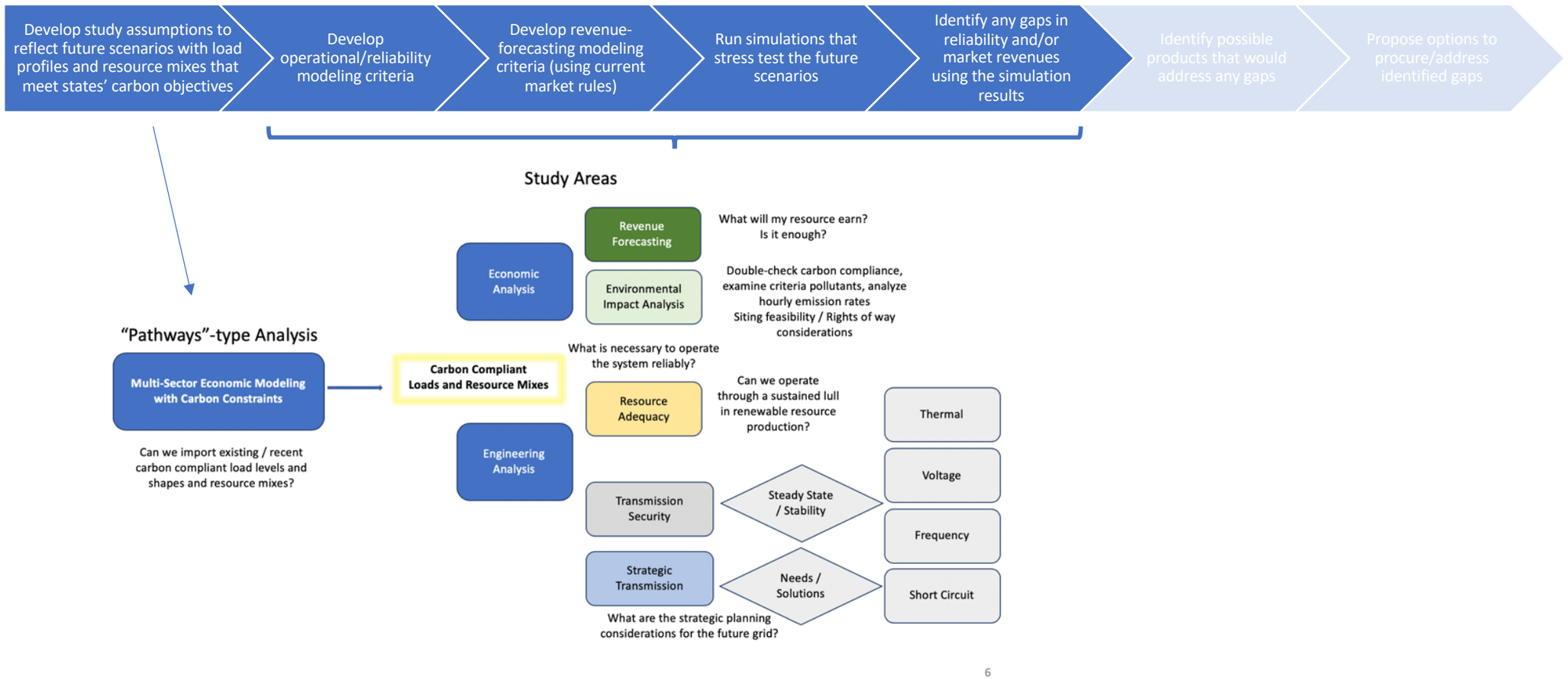
- **Study Components 2-5**: Economic and Engineering Analyses
  - Transmission Security
    - Dynamic stability issues from weak grid and operational characteristics of resource mix
      - Operating through a contingency (i.e., managing frequency and volt-var regulation) in a system with diminished spinning mass and increased inverter-based resources; Analyze dynamic capabilities of power electronics and storage devices
  - Strategic Transmission
    - High-level feasibility of upgrades necessary for future resources mixes that serve power, heating, and transport loads

More Detailed Approach - Continued



- **Study Components 2-5**: Economic and Engineering Analyses (cont.)
  - Revenue Forecasting
    - Energy and Ancillary Services
      - Production Cost and/or Capacity Expansion
      - Resolution and many details TBD – for example:
        - Hourly, sub-hourly, shorter time frames (more detail on ancillary services)
        - Copper sheet, zonal, nodal (that's where the distributed generation is)
        - Load shape availability and resolution also important
    - Capacity Market Simulation
      - Energy and Ancillary Services Revenues inform Resource Adequacy Offers
      - Resource Adequacy Simulation Results Inform Resource Mix
        - Two approaches: Jump forward in time vs. evolve market year-over-year
        - Economic retirement logic TBD

Suggested Study Approach - Summary



Study Approach – Summary continued

Develop study assumptions to reflect future scenarios with load profiles and resource mixes that meet states' carbon objectives

Develop operational/reliability modeling criteria

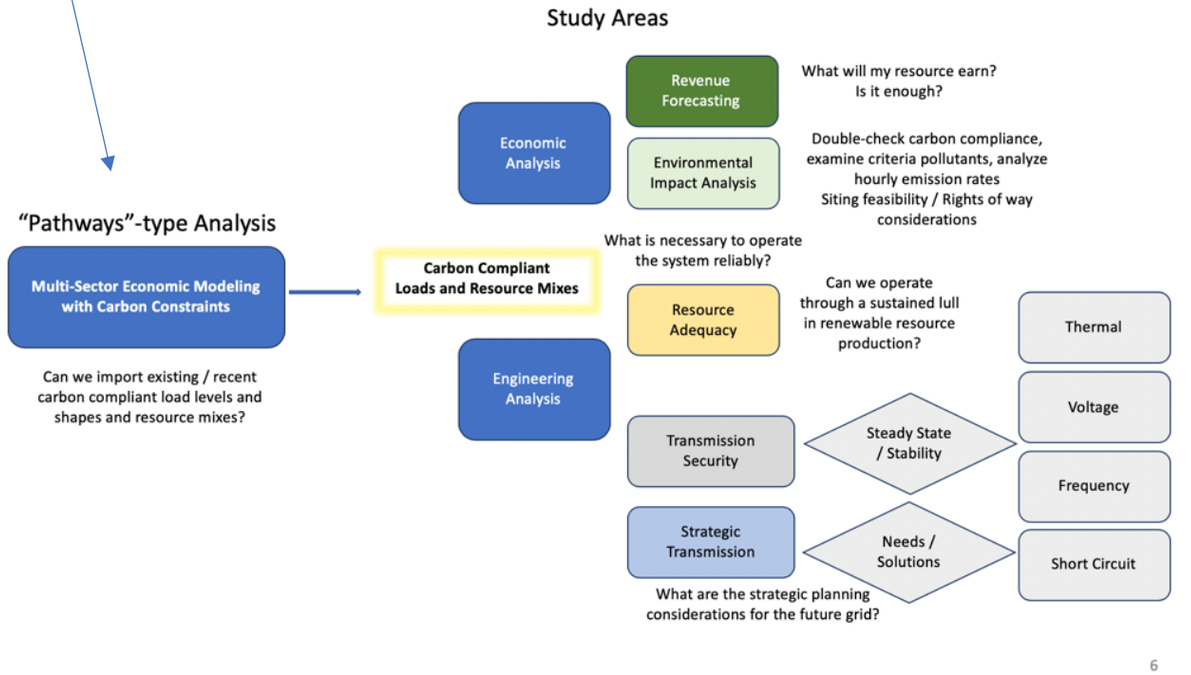
Develop revenue-forecasting modeling criteria (using current market rules)

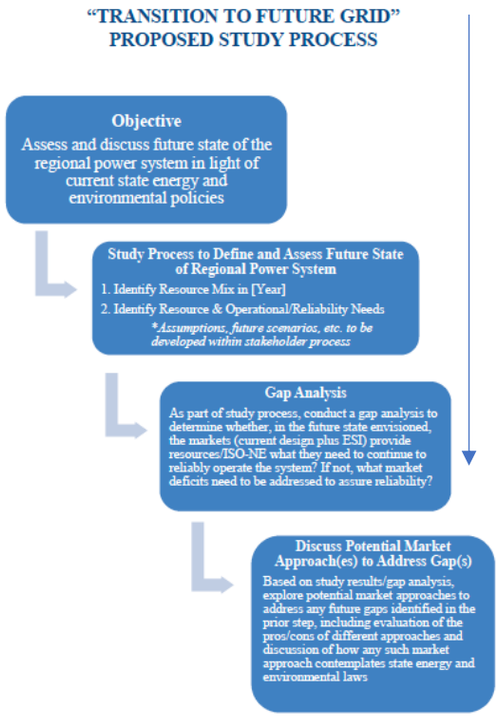
Run simulations that stress test the future scenarios

Identify any gaps in reliability and/or market revenues using the simulation results

Identify possible products that would address any gaps

Propose options to procure/address identified gaps





Study Preparation- Next Steps

- Come back in June with more information about the relevant ”Pathways”-type studies
  - Other study sponsors are encouraged to present their studies
- Work towards selecting scenarios from the “Pathways”-type studies
  - Loads
  - Resource Mixes
  - Dispatches
- Continue to develop analytical approaches for the economic and engineering analyses that could help inform questions about the Transition to Future Grid

Questions?

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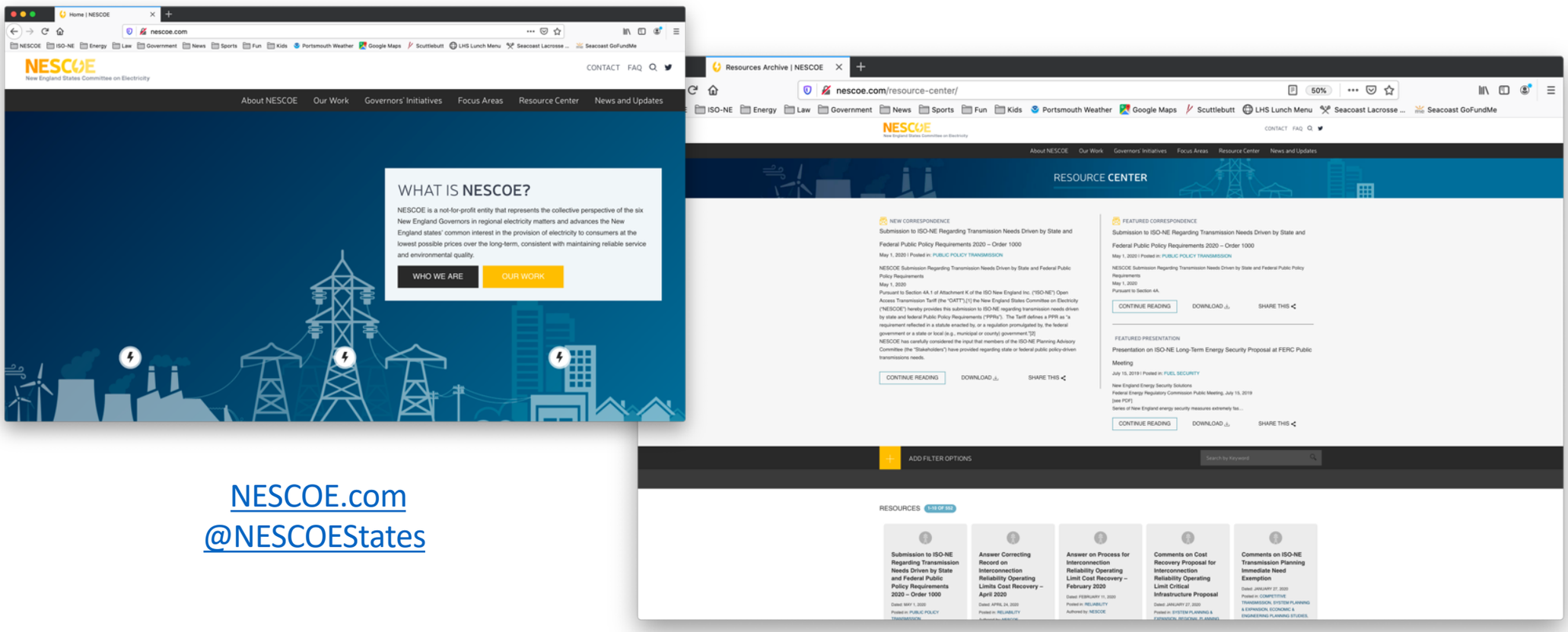

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