Toward a Future-Ready Resource Adequacy Framework for New Brunswick Power

Prepared for New Brunswick Power

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Energy+Environmental Economics

Energy and Environmental Economics (E3) is an analytically driven consulting firm focused on the transition to clean energy resources with offices in San Francisco, Boston, New York, Calgary, and Denver. Founded in 1989, E3 delivers analysis that is widely utilized by governments, utilities, regulators, and developers across North America. E3 completes roughly 350 projects per year, all exclusively related to the clean energy transition, across our three practice areas: Climate Pathways and Electrification, Integrated System Planning, and Asset Valuation, Transmission, and Markets. The diversity of our clients – in their questions, perspectives, and concerns – has provided us with the breadth of experience needed to understand all facets of the energy industry. We have leveraged this experience and garnered a reputation for rigorous, unbiased technical analysis and strong, actionable strategic advice.

This study was prepared by E3 and sponsored by New Brunswick Power. This study concentrated on evaluating NB Power's current resource adequacy (RA) methodology and processes, as well as on developing recommendations for a more comprehensive analytical and procedural RA framework that integrates with planning and procurement. The scope of this study did not include reviewing or validating any results of past RA studies, nor assessing the prudence or cost-effectiveness of specific NB Power projects. Consequently, our recommendations are confined to the design of the framework, and are not intended as findings concerning the adequacy or prudence of any individual procurement decisions.

Study Authors: Arne Olson, Jun Zhang, Adrian Au, Ruoshui Li, and Alexandra Gonzalez

Energy and Environmental Economics, Inc. (E3)
44 Montgomery Street, Suite 1250
San Francisco, CA 94104

Energy+Environmental Economics

Table of Contents

Table of Figures

Table of Tables

Acronym Definitions

Acronym	Definition
aLOLP	Annual Loss of Load Probability
APS	Arizona Public Service Company
BA	Balancing Authority
BHE	Black Hills Energy
CEP	Clean Energy Plan
C&I	Commercial and Industrial
CO-12	NPCC CO-12 Working Group
CPCN	Certificate of Public Convenience and Necessity
CP-8	NPCC CP-8 Working Group
CRRA	NPCC Comprehensive Review of Resource Adequacy
DESC	Dominion Energy South Carolina
DR	Demand Response
DSM	Demand-Side Management
E3	Energy and Environmental Economics
EEA	Energy Emergency Alert
ELCC	Effective Load Carrying Capability
EFORd	Equivalent Forced Outage Rate on Demand
EOI	Expression of Interest
EPE	El Paso Electric Company
ERP	Electric Resource Plan
EUB / NBEUB	New Brunswick Energy and Utilities Board
EUE	Expected Unserved Energy
FPL	Florida Power & Light
GE-MARS	General Electric Multi-Area Reliability Simulation
GWh	Gigawatt-hour
ICAP	Installed Capacity
IESO	Independent Electricity System Operator
IRP	Integrated Resource Plan
IRRA	NPCC Interim Review of Resource Adequacy
ISO	Independent System Operator
ISO-NE	ISO New England

JTS	Just Transition Solicitation
L&R	Load and Resource
LOLH	Loss of Load Hours
LOLE	Loss of Load Expectation
LOLP	Loss of Load Probability
LRAO	NPCC Long-Range Adequacy Overview
LTRA	NERC Long-Term Reliability Assessment
MISO	Midcontinent Independent System Operator
MW	Megawatt
NB Power / NBP	New Brunswick Power
NMPRC	New Mexico Public Regulation Commission
NPCC	Northeast Power Coordinating Council
NERC	North American Electric Reliability Corporation
NSIESO	Nova Scotia Independent Energy System Operator
NSPI	Nova Scotia Power Inc.
NVE	NV Energy
NYISO	New York Independent System Operator
PCAP	Perfect Capacity
PGE	Portland General Electric
PJM	Pennsylvania-New Jersey-Maryland Interconnection
PLNGS	Point Lepreau Nuclear Generating Station
PNM	Public Service Company of New Mexico
PSCo	Public Service Company of Colorado
PSE	Puget Sound Energy
PUC	Public Utilities Commission
PUCT	Public Utility Commission of Texas
RA	Resource Adequacy
RC	Reliability Coordinator
RFEI	Request for Expressions of Interest
RFP	Request for Proposals
RIGS	Renewable Integration and Grid Security
RTO	Regional Transmission Organization
SPP	Southwest Power Pool
SRA	NERC Summer Reliability Assessment
TRN	Total Reliability Need

UCAP	Unforced Capacity
VER	Variable Energy Resource
WRA	NERC Winter Reliability Assessment

Executive Summary

Overview

New Brunswick Power ("NB Power") is entering a period of heightened reliability and planning challenges. Load growth, driven by electrification, population increases, and more extreme weather, is accelerating faster than projected in the 2023 Integrated Resource Plan (IRP), bringing forward the risk of capacity shortfalls to as early as 2028. At the same time, the system's dependence on the single-unit Point Lepreau Nuclear Generating Station, aging hydroelectric assets, and the anticipated retirement of firm fossil capacity create additional risks related to resource adequacy. These conditions prompted NB Power's proposal for the Renewable Integration and Grid Security (RIGS) project, its first new firm capacity build in decades.

In this context, NB Power engaged Energy and Environmental Economics ("E3") to recommend a transparent, evidence-based framework for identifying the need for new power capacity and determining when to build it. In this report, E3 addresses the following key questions:

1. **What process should NB Power follow to identify the need for new power capacity and demonstrate it to the New Brunswick Energy and Utilities Board ("NBEUB") and its stakeholders?**
2. **What technical analysis should NB Power conduct to quantify the need for new resources?**
3. **How should NB Power determine the optimal timing of new resource additions?**
4. **How should NB Power's method for determining resource needs align with studies undertaken by the Northeast Power Coordinating Council ("NPCC") and the North American Electric Reliability Council ("NERC")?**

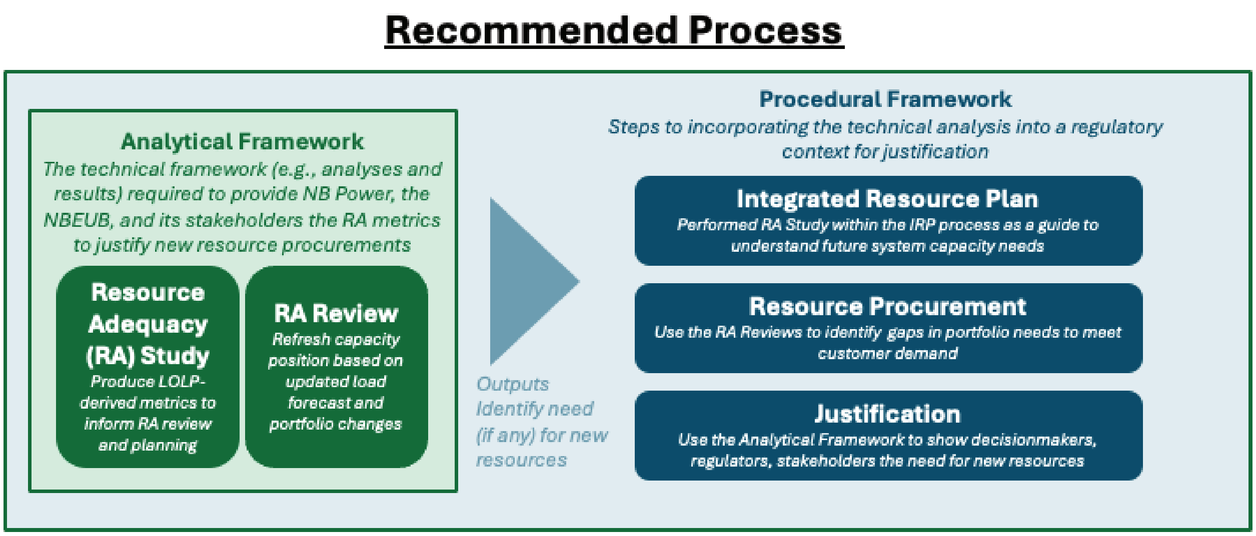
In answering these questions, E3 developed a proposed framework that combines resource adequacy analytical best practices and procedural discipline. The recommended framework is designed to move NB Power toward best practices that are methodologically robust and adaptable to future challenges, while mitigating risk to NB Power customers, minimizing administrative burden, and recognizing the province's regulatory context. By embedding resource adequacy into each stage of planning and procurement, NB Power can ensure that investment decisions are prudent, transparent, and defensible. This provides stakeholders and the regulator with confidence that reliability is being maintained, balancing costs and risks.

Proposed Framework

E3's recommended framework addresses this gap by better integrating RA directly into NB Power's planning and procurement cycle. The following changes are proposed to strengthen NB Power's existing RA analytical ability, along with the connections between RA analysis, planning, and procurement framework. Figure 1 below illustrates the proposed framework.

- **Integrated Process:** Integrating resource adequacy studies, planning studies, procurement, and demonstration together in a regular 3-year cadence.
- **Annual RA Reviews:** Performing annual resource adequacy reviews with updated load forecasts and, if necessary, resource portfolios.
- **Alignment:** Harmonizing inputs and study timelines across NBP's internal resource adequacy reviews and NERC/NPCC RA assessments, to the extent possible.
- **Demonstration:** Presenting analysis and decision criteria to demonstrate the resource need.

Figure 1. Recommended Analytical and Procedural Framework



Key Elements of the Recommended Process

Specifically, E3 recommends the following procedural and analytical enhancements to strengthen NB Power's process. Further detail is provided in later sections of this report. Key elements include:

Procedural Enhancements

- **Milestones for Regulatory Demonstrations** – establish a transparent chain of evidence from RA analysis through procurement to regulatory filings.
- **Annual RA Reviews** – update load forecasts, load–resource balances, and adequacy metrics every year.
- **Alignment with NPCC/NERC** – harmonize inputs and assumptions with regional compliance studies to ensure consistency.
- **Defined Triggers for Off-Cycle Action** – codify quantitative and qualitative thresholds for when supplemental analysis is required.
- **Supplemental Analysis Toolbox** – provide structured, right-sized analysis options to justify procurement between IRP cycles.
- **Managing Risks of Over- or Under-Building** – explicitly evaluate asymmetric risks and potential benefits of early or larger builds.

Analytical Enhancements

- **Institutionalize Loss-of-Load Probability ("LOLP") Modeling** – acquire and apply a New Brunswick-specific probabilistic tool to reflect local conditions.
- **Adopt a Critical Hours Framework** – focus adequacy assessments on periods when reliability risks are greatest.
- **Align Reliability Standards** – translate NPCC/NERC criteria into NB-specific planning margins that reflect provincial realities.

Figure 2. Summary of E3's Proposed Enhancements

Procedural

1. Creating Milestones for Regulatory Justifications
2. Creating an Annual Cadence of RA Reviews
3. Aligning with NERC/NPCC on Inputs / Assumptions
4. Identifying Triggers or Material Changes that May Require Procurement
5. Adding Supplemental Analysis to Material Changes
6. Managing Risks of Under- and Over-Building

Analytical

1. Institutionalizing RA Modeling within NBP
2. Adopting an RA Analytical Framework that Follows a Critical Hours Framework
3. Strengthening the Role of RA Reviews

Implementation Roadmap

This report also translates the above recommendations into a sequenced set of actions for NB Power and its Regulator. Each item is organized by priority and timeframe from immediate steps that establish the foundation, medium-term steps that build integration and governance, to long-term steps that prepare the system for future challenges. Please see Section 5 for details.

1. Introduction

1.1 Context and Chronology

New Brunswick Power ("NB Power") is at an important inflection point in its resource adequacy ("RA"), planning, and procurement practices. For the first time in decades, the utility is seeking approval to add significant new firm generation capacity. In 2025, NB Power announced its plan for the Renewable Integration and Grid Security ("RIGS") project, a 400 MW combustion turbine targeted for 2028, which is the first new firm capacity build since the 1990s.

This need reflects the combined impact of several long-standing system-level RA factors whose risks have intensified in recent years:

- **Load Growth:** The primary reliability challenge in New Brunswick continues to be meeting its peak demand during cold winter periods when heating needs drive the highest system loads, but recent unprecedented growth in population, widespread electrification, and more extreme weather conditions have intensified the pace of electric load growth. In its 2023 Integrated Resource Plan ("IRP"), NB Power identified a potential capacity shortfall projected for the 2030s. However, subsequent forecasts indicate that electricity demand is increasing at a faster rate than initially predicted in the 2023 IRP, and a potential capacity shortfall is now anticipated to occur by 2028.
- **Single-unit Risk:** Furthermore, the reliance on a single, large nuclear unit within a relatively small system, such as the Point Lepreau Nuclear Generating Station (PLNGS), remains a pertinent concern regarding its availability and the necessity for contingency reserves, with availability risks growing more significant as system reliability margins tighten.
- **Aging/Retiring Assets:** Aging large hydroelectric assets, such as the Mactaquac Generating Station, require replacement and maintenance. Additionally, substantial firm capacity is anticipated to face retirements and the phase-out of coal in the future, affecting facilities such as Coleson Cove and Belledune. The approaching of these critical milestones makes their impact on adequacy more pressing than in prior decades.
- **Reliability Standards:** While NB Power currently applies a 20% planning reserve margin ("PRM") consistent with Northeast Power Coordinating Council ("NPCC") standards of the minimum PRM, recent system conditions suggest that this benchmark may not always align with achieving NB Power's stated reliability criterion of 1-day-in-10-years, or 0.1 days/yr. Loss-of-Load Expectation ("LOLE"). A transition toward a PRM that is informed by probabilistic Loss-of-Load Probability ("LOLP") modeling could provide a more tailored reflection of New Brunswick's reliability needs. Further details are available in a later section.

At the same time, the New Brunswick Energy and Utilities Board ("NBEUB" has reviewed major capital projects such as the Bayside Turbine Replacement Capital Project (Matter 552, March 2025[1]), emphasizing the importance of prudence testing, strong evidence, and transparency.

These findings highlighted broader challenges that many utilities face: traditional RA practices, designed for stable load growth and conventional thermal fleets, are no longer sufficient in an environment shaped by electrification, renewables, and extreme weather. Recognizing these gaps, NB Power engaged Energy and Environmental Economics ("E3") to design a structured analytical and procedural RA framework. This work is intended to support both the utility (NB Power) and the Board (NBEUB) with a repeatable, regulator-ready process for determining when new resources are needed and how procurement decisions should be justified.

E3's approach is two-pronged:

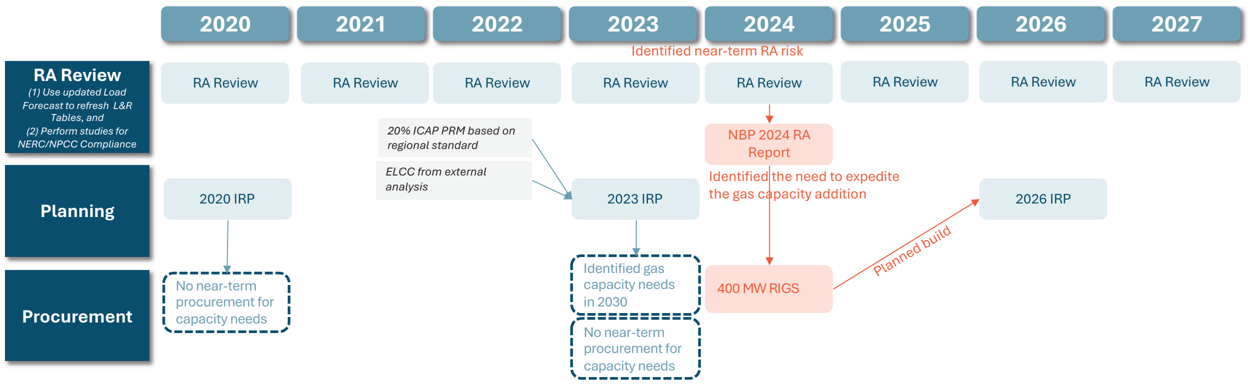
+ **Technical** – technical recommendations related to strengthening RA modeling, need determination, and resource accreditation (e.g., effective load carrying capability for all resources).
+ **Procedural** – Procedural steps clearly outlining what evidence the Board (NBEUB) should require from NB Power for approval of procurement, and defining the process for NB Power to gather and share this information with the Board and other stakeholders.

1.2 NB Power's Current RA, Planning, and Procurement Framework

NB Power's RA, planning, and procurement cycle combines a triennial Integrated Resource Plan (IRP) with annual and seasonal modeling and data submissions to meet NERC and NPCC compliance requirements. In the current process, NBP's RA efforts are less integrated with the rest of the processes, and there are no structured trigger points to do a re-study of resource adequacy. IRP is designed to support the planning and inform portfolio recommendations, but itself does not make any decisions. Procurement is a separate process under different proceedings where actual procurement decisions are made based on separate analyses and bid evaluations to justify specific investment decisions. Figure 3 below summarizes the process of RA, planning, and procurement altogether. Please note that IRP cycles and procurement processes may span multiple years, therefore boxes in these rows represent initiation instead of completion within the single year shown.

[1] New Brunswick Energy and Utilities Board, Matter 552 – Reasons for Decision (March 31, 2025). Available at: https://nbeub.ca/uploads/2025%2003%2031%20-%20Matter%20552%20-%20Reasons%20for%20Decision.pdf

Figure 3. NB Power's Current RA Assessments, Planning, and Procurement Process[2]

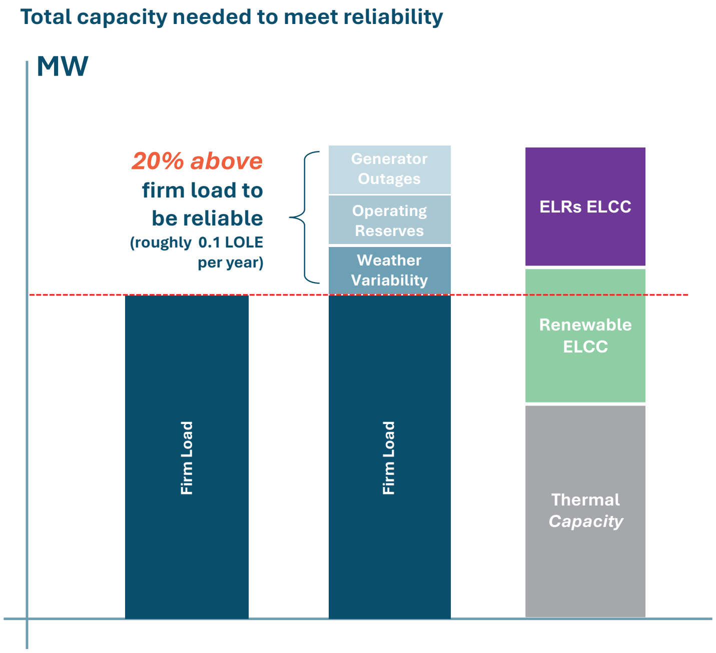


1.2.1 Resource Adequacy: Need Determination and Resource Accreditation

NB Power is a member of the NPCC. NPCC establishes reliability practices that interconnected electricity systems should follow. The benchmark for resource adequacy is no more than one day every ten years (i.e., Loss-of-Load Expectation ("LOLE") of 0.1 days/year). In line with the Maritimes Area assessment, NBP has been using a minimum 20% PRM target. This target is not based on an LOLP model but on historical operating experience. The 20% PRM is calculated on a baseline firm load, which includes in-province demand but excludes firm export commitments. Variable and energy-limited resources ("VERs") are credited with Effective Load Carrying Capacity ("ELCC"), while thermal and hydro resources are credited with installed capacity ("ICAP"). This aligns with the traditional ICAP-based PRM and resource accreditation framework.

[2] NB Power's 2023 IRP did result in wind procurements; however, these additions were driven by energy and decarbonization objectives rather than by resource adequacy requirements.

Figure 4. NB Power's PRM and ELCC Framework



1.2.2 Resource Adequacy: NERC/NPCC Compliance and Internal Review

Under the Electricity Act of New Brunswick, the Reliability Standards Regulation (NB Reg 2013-66) formally designates the North American Electric Reliability Council ("NERC") as the standards-setting body, NPCC as the compliance monitoring body, and the NBEUB as the provincial enforcing authority. Under this Regulation, the NBEUB adopts and enforces NERC/NPCC reliability standards, with full provincial authority for legal enforcement, cost recovery approvals, and oversight of reliability obligations for registered entities.

NB Power is listed in the NBEUB's Compliance Registry with multiple NERC functional roles, including but not limited to Reliability Coordinator ("RC") and Balancing Authority ("BA"). As a member of NPCC, NB Power must comply with both NERC and NPCC procedures. Compliance is demonstrated through a structured schedule of regular RA assessments. Additionally, NB Power also conducts internal load forecast analysis and updates the load and resource tables annually to monitor system reliability.

In practice, NB Power conducts and submits annual LOLP studies for the Maritimes Area[3] and provides the associated seasonal and annual load, resource, and study data that feed into NPCC's regional processes and, ultimately, into NERC's assessments. Specifically, compliance efforts with NERC and NPCC include the following, which are effectively on an annual cadence and have become the established norm of RA review frequency:

[3] The Maritimes Area is a winter peaking NPCC area with separate jurisdictions in New Brunswick (NB), Nova Scotia (NS), Prince Edward Island (PEI), and Northern Maine (NM).

- As the Reliability Coordinator for the Maritimes Area, NB Power leads and coordinates the triennial Comprehensive Review of Resource Adequacy and conducts annual interim updates, using its own probabilistic LOLP modeling to assess reliability for the region.
- These studies provide the baseline data and results that feed into NPCC's compliance processes where the CP-8 Working Group uses the GE-MARS probabilistic model for the Long-Range Adequacy Overview (LRAO), while the CO-12 Working Group layers on deterministic operational analyses for seasonal assessments.
- NERC, in turn, relies on vetted NPCC results and area submissions for its continent-wide Long-Term Reliability Assessment ("LTRA"), Summer Reliability Assessment ("SRA"), and Winter Reliability Assessment ("WRA").

As shown in Figure 5, an annual cadence has become the established norm for NERC and NPCC compliance requirements, providing a structured foundation that NB Power's enhanced RA framework can leverage and build upon. Each of these reports and analyses draws on somewhat different inputs, assumptions, and forecast horizons, which can lead to results that are not always directly comparable.

Figure 5. NBP's RA Assessment for NERC/NPCC Compliance

		2021	2022	2023	2024	2025	2026	*Notes*
NERC	*Deterministic + Probabilistic*	LTRA	LTRA	LTRA	LTRA + ProbA	LTRA + ProbA	LTRA + ProbA	*10 years time horizon*
NERC	*Deterministic*	Summer & Winter Assessments	Summer & Winter Assessments	Summer & Winter Assessments	Summer & Winter Assessments	Summer & Winter Assessments	Summer & Winter Assessments	*Cover upcoming summer or winter period*
NPCC	*Probabilistic (GE-MARS)*	LRAO	LRAO	LRAO	LRAO	LRAO	LRAO	*Based on the same year's NERC LTRA 5 years time horizon*
NPCC	*Probabilistic LOLP Modeling*	Maritimes IRRA	Maritimes CRRA	Maritimes IRRA	Maritimes IRRA	Maritimes CRRA	Maritimes IRRA	*3-5 years time horizon*

Electricity Act of New Brunswick

- Made the Reliability Standards Regulation, which formally designates NERC as the standards body, NPCC as the compliance body, and NBEUB as the enforcing authority (provincial regulator)

NERC (standard body)

- Continent-wide ERO designated by FERC, and recognized in Canada via provincial authorities
- Develops mandatory reliability standards
- Canada provinces formally adopt and enforce standards through legislation/regulation
- In Canada, NERC does not fine entities directly — it has no statutory enforcement power inside a province.

NPCC (compliance body)

- One of NERC's regional entities
- RC at the regional level, administers NERC standards and develops additional NPCC regional standards
- Monitors the compliance under the province's Reliability Standards Regulation
- Does not fine entities

NBEUB (provincial regulator)

- Adopts NERC/NPCC standards under the Reliability Standards Regulation (through provincial gov authority)
- Maintain legal enforcement authority and regulatory oversight on reliability compliance, cost recovery, etc.
- Keeps the Compliance Registry (official list of who must comply)
- Empowered by the Reliability Standards Regulation to impose financial penalties on registered entities (including NB Power)

NBP

- Registered under NBEUB's Compliance Registry with multiple NERC functional roles (RC, BA, etc)
- Member of NPCC and must comply with both NERC/NPCC requirements
- NBP's "good standing" with NPCC/NERC ensures access to the broader system, but compliance obligations (reserve margins, tie benefits, transfer criteria) can sometimes force NBP to forgo or curtail transactions it might otherwise pursue
- Is subject to NBEUB enforcement (including fines)

1.2.3 Planning: On-Cycle Process

NB Power runs an IRP every 3 years, as required by law, which requires provincial government approval. IRP itself is a planning document that provides long-term direction for the utility but does not determine any system procurement decisions. NB Power has a separate process for considering procurement decisions which has its own proceedings and evidentiary standard.

NB Power's RA practices are less integrated with the IRP, as the PRM assumption is based on regional standards, and ELCC assumptions for renewable and storage resources come from external analysis (for example, 2023 IRP).

1.2.4 Recent Resource Procurement Experience: Onshore Wind

In May 2025, NB Power signed 452MW of new wind across four new projects. New wind was identified as one of the many resources needed to achieve a net-zero electricity system in the 2023 IRP. Because the need for new wind resources was demonstrated in the IRP, NB Power paved the road for a smooth solicitation for new wind projects, resulting in NB Power identifying cost competitiveness resources needed to make progress in its net-zero goals.

1.2.5 Recent Procurement: Off-Cycle Identification Firm Capacity Need

The recent proposal for a 400 MW RIGS firm capacity addition represents an off-cycle procurement plan that occurs outside the regular planning and procurement schedule.

In the latest 2023 IRP, NB Power identified a potential capacity shortfall in the 2030s and justified the potential need for additional natural gas firm capacity by then. However, the recent load forecasts projected faster demand growth due to unprecedented population increase, electrification, and more extreme weather. Updated forecasts (e.g., NB Power's March 2024 Resource Adequacy Report) indicate that electricity demand in 2024 and 2025 is tracking above the 2023 IRP projection, advancing the potential capacity shortfall to as early as 2028.[4] Along with the tighter capacity margin observed by NPCC/NERC RA assessments, conducted through collaboration between NB Power planning and operations groups in recent years, a potential near-term RA risk has been identified, prompting further investigations by NBP.[5] NB Power then carried out detailed RA evaluations in 2024, which indicated the need to expedite the procurement of firm capacity (400 MW by 2028), and to begin early pre-development work on an additional 600 MW that may be required by 2030. This leads NB Power to plan the addition of new firm capacity resources for the first time since the 1990s: In July 2025, NB Power announced the RIGS project, which includes approximately 400 MW nameplate capacity planned to come online by 2028.

1.3 How This Report is Structured

The remainder of report is organized as follows:

+ **Section 2: Framework Improvement Recommendations.** Outlines E3's recommended improvements for NB Power, bridging from its current practices to a regulator-ready RA framework that integrates technical rigor with procedural discipline.
+ **Section 3: From Recommendation to Action – Implementation Roadmap.** Provides a sequenced roadmap of immediate, medium-term, and long-term steps to operationalize the framework, clarifying roles for NB Power, the NBEUB, and regional entities.
+ **Section 4: Procedural Framework – A Transparent Decision-Making Process.** Describes how NB Power should structure its processes to ensure timely and regulator-ready

[4] See NB Power, Resource Adequacy Report (March2024), which documents updated load growth and resource balance conditions.
[5] NERC LTRA and NPCC RA Assessment

procurement decisions. Topics include milestones for regulatory demonstrations, annual RA reviews, triggers for off-cycle actions, supplemental analyses, and risk management for premature builds.

+ **Section 5: Analytical Framework – Strengthening RA Concepts and Evidence.** Details improvements to NB Power's analytical capabilities, including adoption of best-practice LOLP modeling, ELCC-based accreditation, updated PRM determination, and frequency of RA reviews.
+ **Appendix: Jurisdictional Insights and Case Studies.** Presents findings from a scan of North American jurisdictions, highlighting how utilities and regulators approach RA need determination, accreditation, and the link between adequacy analysis and procurement. Includes detailed case studies such as Xcel Energy Colorado and Public Service Company of New Mexico ("PNM").

1.4 Scope Limitations

This study concentrated on evaluating NB Power's current resource adequacy (RA) methodology and processes, as well as on developing recommendations for a more comprehensive analytical and procedural RA framework that integrates with planning and procurement. The scope did not include reviewing or validating any results of past RA studies, nor assessing the prudence or cost-effectiveness of specific NB Power projects. Consequently, our recommendations are confined to the design of the framework, and are not intended as findings concerning the adequacy or prudence of any individual procurement decisions.

2. Framework Improvement Recommendations

This section presents the key findings and recommended improvements to NB Power's RA, planning, and procurement framework. This framework is designed to be transparent, evidence-based, and regulator-ready. It is tailored to NB Power's system and regulatory environment to ensure future investments are consistently justified through clear, repeatable, and accountable processes.

Importantly, the framework seeks to move NB Power toward best practices in a methodically robust and future-ready way while balancing integration with its existing processes, minimizing administrative burden, and recognizing the jurisdictional and regulatory context.

2.1 Framing Best Practices for NB Power: Analytical and Procedural Lenses

To define best practices for NB Power's system, it is necessary to evaluate both the analytical framework for resource adequacy and the procedural framework that governs how resource adequacy, planning, and procurement decisions are carried out. These frameworks are assessed using the following perspective:

Procedural Framework – How should the process be structured and implemented?

+ What framework should define the trigger point for RA re-evaluation between IRP cycles?
+ How should NB Power interact with NPCC/NERC given existing compliance flows and discrepancies in methodologies?
+ How should the IRP process connect with RFPs and the actual procurement process?
+ How should NB Power justify "premature" builds (earlier or larger than the minimum necessary) considering costs and risks?
+ What level of stakeholder and regulatory engagement is appropriate at each stage of the process?

RA Analytical Framework – What is the best-practice framework and criteria?

+ What PRM framework should NB Power adopt, and how should it be tied to LOLE outcomes?
+ What resource accreditation framework should be used (e.g., marginal/portfolio vs. average ELCCs)?
+ How frequently should RA reviews be conducted to balance accurate and up-to-date results with administrative burden?

2.2 Bridging NB Power's Current to E3's Recommended RA Framework

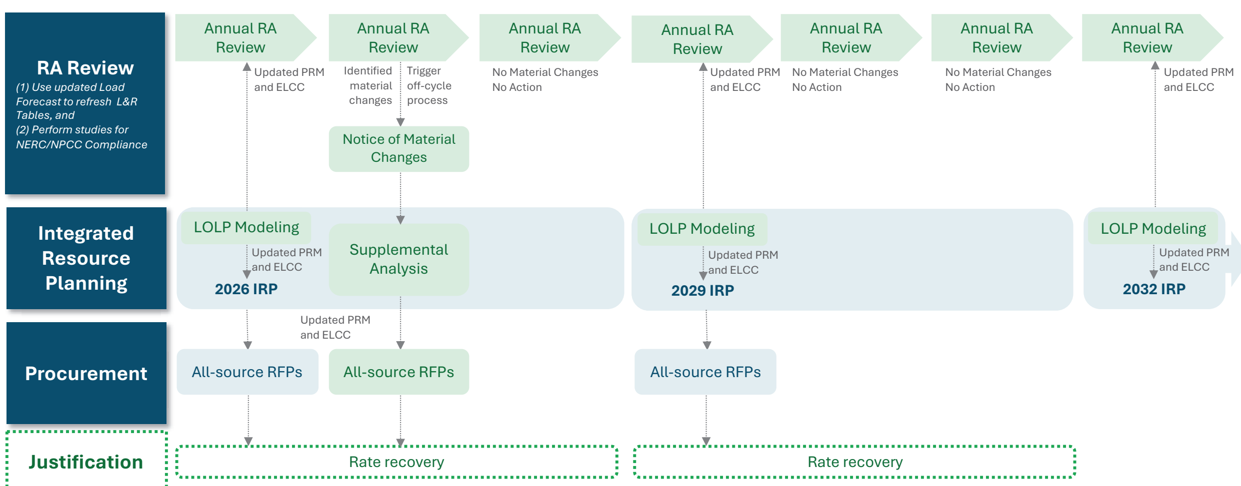
2.2.1 Recommended Analytical and Procedural Framework for NB Power

As summarized above, NB Power's current RA analyses could be enhanced and better integrated with its IRP and procurement processes. Every three years, NB Power conducts an IRP, but relies primarily on NERC and NPCC compliance studies as its principal RA assessment. While these compliance assessments are performed annually on a structured schedule, the process for incorporating their findings into planning and procurement is less formal. As a result, procurement and investment decisions can be harder to justify with a consistent, evidence-based record.

E3's recommended framework addresses this gap by better integrating RA directly into NB Power's planning and procurement cycle. The following changes are proposed to strengthen NB Power's existing RA analytical ability, along with the connections between RA analysis, planning, and procurement framework. Figure 6 below illustrates the proposed framework.

+ **Integrated Process:** Integrating resource adequacy studies, planning studies, procurement, and demonstration together in a regular 3-year cadence.
+ **Annual RA Reviews:** In addition to regular 3-year LOLP analysis, performing annual resource adequacy reviews with updated load forecasts and resource portfolios.
+ **Alignment:** Harmonizing inputs and study timelines across NBP's internal resource adequacy reviews and NERC/NPCC RA assessments, to the extent possible.
+ **Demonstration:** In the procurement phase, ensuring sufficient capacity is procured based off the robust RA analysis performed during the IRP and verified using the same analytical frameworks used in the IRP / RA analysis.

Figure 6. Recommended Analytical and Procedural Framework



This section summarizes E3's recommendation at a high level. The details of recommended procedural framework are described in full in Section 3 and the details of the recommended analytical approach are described in full in Section 4.

2.2.2 *Overview of E3's Recommended Framework*

A well-designed RA framework should clearly show *how* results link to planning and procurement decisions. Best practice is for RA analysis to provide a transparent foundation for investment by connecting quantified needs directly to specific resource contributions, expressed in effective-MW terms. For example, linking the RA shortfall to a resource's incremental ELCC contribution allows

NB Power and the regulator to see not only that the reliability gap is closed, but that it is done cost-effectively and in alignment with the periods when reliability is most at risk. Once the IRP establishes the long-term guide, procurement should then focus on closing near-term shortfalls, with RFPs structured to align with the RA evidence package. Unlike IRPs, which are directional, procurement introduces updated market data and requires demonstrated need for specific resources. This linkage ensures consistency, transparency, and regulator-ready filings.

Building on this principle, E3 recommends that NB Power's RA framework provide the necessary (1) RA metrics, (2) structure, (3) flexibilities, and (4) risk management in addressing its resource adequacy needs.

To understand resource needs, NB Power should perform RA assessments. The output RA metrics include a total reliability need ("TRN") and resource capacity value, using an ELCC methodology. The analysis should give NB Power the short- and long-term view of the system's load and resource balance, thus identifying the total MW need for each year.

For structure, NB Power should perform an RA assessment every year, updating key input, like load forecast. NB Power should perform an RA review, using the target PRM and ELCCs calculated in the detailed RA assessment to inform a load and resource balance table. This ensures NB Power's procurement is based on the most up-to-date load forecasts and potential changes to the portfolio. This step serves as a check for any material changes required in NB Power's existing plans. If no material change is found, NB Power documents "no action". If a material change is identified, NB Power issues a Notice of Material Changes and conducts Supplemental Analysis to quantify the total resource need and recommend the least-cost/least-risk solution. This supplemental analysis sets the procurement path and establishes the demonstrated need for specific resources in the following rate-recovery filing.

For years that line up with the start of an IRP cycle (e.g., 2026, 2029, 2032), RA assessments should include a refresh of the TRN and resource ELCCs and should be performed at the start of the IRP process. Once refreshed, NB Power can continue with its annual RA review with updated need and resource accreditation.

The proposed framework addresses several challenges that have historically complicated NB Power's planning and procurement. By anchoring decisions in probabilistic RA modeling, it replaces ad-hoc procurements with a predictable and repeatable cadence and a structure for the off-cycle process. Finally, the framework provides clear, modular decision points and documentation, strengthening regulatory oversight and supporting transparent approval and rate recovery processes.

2.2.3 Proposed Enhancements to Procedural and Analytical Framework

Specifically, E3 recommends the following procedural and analytical enhancements to strengthen NB Power's RA framework. Further detail is provided in later sections of this report. Key elements include:

Procedural Enhancements

- **Milestones for Regulatory Demonstration** – establish a transparent chain of evidence from RA analysis through procurement to regulatory filings.
- **Annual RA Reviews** – update load forecasts, load–resource balances, and adequacy metrics every year.
- **Alignment with NPCC/NERC** – harmonize inputs and assumptions with regional compliance studies to ensure consistency.
- **Defined Triggers for Off-Cycle Action** – codify quantitative and qualitative thresholds for when supplemental analysis is required.
- **Supplemental Analysis Toolbox** – provide structured, right-sized analysis options to justify procurement between IRP cycles.
- **Managing Risks of Over- and Under-Building** – explicitly evaluate asymmetric risks and potential benefits of early or larger builds.

Analytical Enhancements

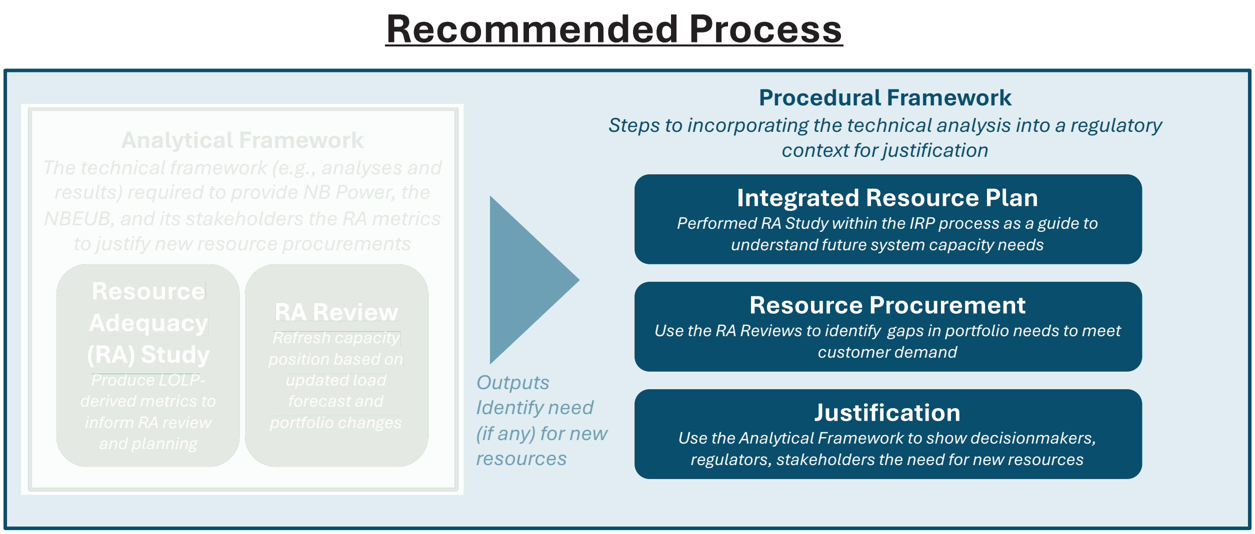
- **Institutionalize LOLP Modeling** – acquire and apply a New Brunswick-specific probabilistic tool to reflect local conditions.
- **Adopt a Critical Hours Framework** – focus adequacy assessments on periods when reliability risks are greatest.
- **Strengthening the Role of RA Reviews** – formalize a process to ensure RA Studies and RA reviews play a role in managing near- and long-term RA risks.

Figure 7. Summary of E3's Proposed Enhancements

Procedural	Analytical
1. Creating Milestones for Regulatory Justifications	1. Institutionalizing RA Modeling within NBP
2. Creating an Annual Cadence of RA Reviews	2. Adopting an RA Analytical Framework that Follows a Critical Hours Framework
3. Aligning with NERC/NPCC on Inputs / Assumptions	3. Strengthening the Role of RA Reviews
4. Identifying Triggers or Material Changes that May Require Procurement	
5. Adding Supplemental Analysis to Material Changes	
6. Managing Risks of Under- and Over-Building	

3. Procedural Framework: A Transparent Decision-Making Process for New Resources

This section provides an expanded explanation of the procedural framework, offering additional details and insights into the proposed enhancements suggested by E3 to improve and refine the existing procedures.



3.1 Principles of a Procedural Framework

Resource adequacy is not only a technical exercise; it also requires a clear, repeatable process to translate analytical results into planning guidance and procurement decisions that are regulator-ready. E3 recommends that NB Power's RA framework provide the necessary (1) RA metrics, (2) structure, (3) flexibilities, and (4) risk management in addressing its resource adequacy needs.

- **Metrics** – clear quantitative outputs that define system need and resource contributions.
- **Structure** – a regular cadence of reviews so planners can identify emerging needs in time to act.
- **Flexibility** – the ability to adjust the process in response to rapid changes in load, resources, or policy.
- **Risk Management** – explicit consideration of reliability and cost trade-offs to reduce exposure to under- or over-building.

These principles provide the foundation for NB Power's procedural framework. The following subsections build on these principles with specific enhancements tailored to NB Power's system and regulatory context.

Figure 8. Summary of E3's Proposed Enhancements

Procedural

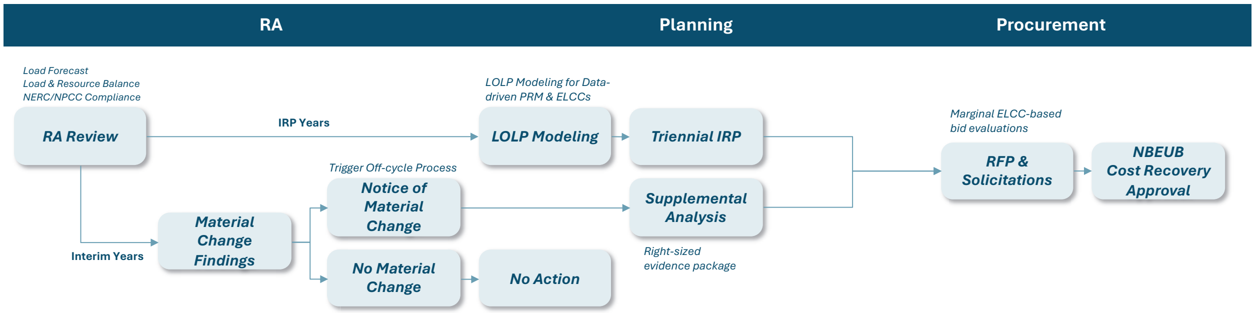
1. Creating Milestones for Regulatory Justifications
2. Creating an Annual Cadence of RA Reviews
3. Aligning with NERC/NPCC on Inputs / Assumptions
4. Identifying Triggers or Material Changes that May Require Procurement
5. Adding Supplemental Analysis to Material Changes
6. Managing Risks of Under- and Over-Building

3.2 Enhancement: Creating Milestones for Regulatory Demonstrations

A central purpose of the proposed RA framework is to create a transparent basis for justifying procurement decisions to the regulator. This means that every resource decision, whether emerging from an on-cycle triennial IRP or an off-cycle Supplemental Analysis following the issuance of Notice of Material Changes, should be backed by a clear chain of evidence: RA review that updates load forecasts and load & resource balance, documents material-change findings, LOLP modeling that quantifies total resource need and defines PRM/ELCC values, and bid evaluation records from RFP and resource solicitations. Together, these milestones provide the EUB with a defensible demonstration for post-hoc cost recovery once contracts are secured. Figure 9 below summarizes the milestones for regulatory demonstrations as an additional lens and perspective in visualizing the recommended analytical and procedural framework.

NB Power is required under Section 107 of the Electricity Act to seek NBEUB approval for capital projects exceeding $50 million, and Power Purchase Agreements (PPAs) are subject to review through general rate applications. The proposed RA framework expands on these requirements by integrating demonstration into the process flow itself, ensuring that resource decisions are regulator-ready and stakeholder-transparent.

Figure 9. Milestones for Regulatory Demonstrations



3.3 Enhancement: Creating an Annual Cadence of RA Reviews

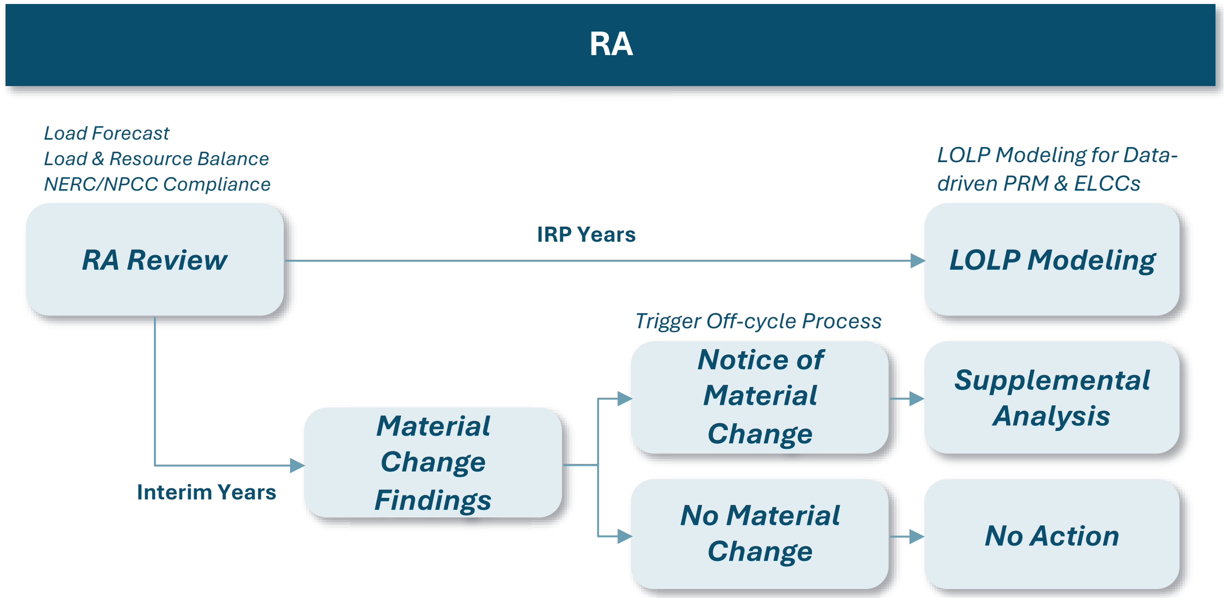
As previously noted, NB Power conducts internal regular load forecast analysis and updates the load and resource tables to monitor system reliability in addition to its regular NERC and NPCC compliance that is demonstrated through a structured schedule of regular RA assessments.

This study recommends that a natural improvement that aligns with this existing process. The process starts with an annual RA review process. This begins with updating load forecasts and L&R, which is then passed or aligned with NERC/NPCC RA studies. Depending on whether the RA review aligns with the start of an IRP cycle, a LOLP modeling step is introduced to refresh the PRM and ELCCs, serving as a bridge to connect and integrate RA with the planning process. Figure 10 shows the interactions between the annual RA review process and the RA study performed as part of the IRP.

The need for performing this LOLP modeling depends on the year of the IRP cycle:

+ **IRP Years (for example, 2023, 2026, 2029):** Total Reliability Need (TRN) which is then translated into a Planning Reserve Margin (PRM) and ELCC results developed through the LOLP modeling will be integrated into the on-cycle IRP process to inform the capacity expansion modeling.
+ **Interim Years (for example, 2024, 2025, 2027, 2028):** An annual process that starts with refreshing load forecasting, portfolio additions and subtractions, and load and resource balance. Depending on the findings in the RA review, material changes may trigger supplemental analysis. If material changes are not observed and no further actions are necessary for additional analysis.

Figure 10. Structured RA Process for NB Power



3.4 Enhancement: Aligning with NERC/NPCC on Inputs and Assumptions

Once NB Power institutionalizes RA modeling, the coordination with the NPCC/NERC RA studies will less be about the results, but more on the inputs. Streamlining inputs between the NERC/NPCC RA studies and NB Power's RA Review is vital to understanding the seams between the region and NB Power. Ideally, two models using the same software, inputs, and methodologies would be available, one RA model for the region and one downscaled for NB Power. Recognizing it may be difficult, ensuring at least the inputs are the same would allow the results of the regional studies to be used more as a check, rather than a planning document to use for the purposes of decision making.

3.5 Enhancement: Identifying Triggers or Material Changes that May Require Procurement

On or between IRP cycles, a properly defined trigger for off-cycle action is essential to make the process structured, transparent, and defensible. The key is establishing what counts as a material change, expressed through a combination of quantitative thresholds and qualitative criteria. Below is a non-exhaustive list of example thresholds and criteria to be considered and further evaluated include:

Quantitative Triggers

+ **Load Forecast Shifts**: Significant variations in forecasted peak demand (e.g., ≥1–2% of winter peak or ≥100 MW) relative to the baseline load forecast presented in the last IRP for the upcoming IRP year.

- **Resource Changes**: Retirement, delay, or loss of effective capacity from the resource portfolio (e.g. ≥100 MW).
- **Timing Risk**: Evidence that additional capacity additions must begin before the next IRP cycle to maintain compliance with regional reliability standards.

Qualitative Triggers

- **Policy or Regulatory Changes**: New government directives, emissions targets, or EUB rulings that materially alter planning assumptions.
- **Market and Intertie Conditions**: Loss of firm imports/exports or changes in neighboring system availability.
- **Operational and Fuel Risks**: Shifts in forced-outage rates, extreme weather patterns, or critical supply chain disruptions.

If any of these triggers are met, NB Power should issue a Notice of Material Change and proceed with a Supplemental Analysis tailored to the scale of the issue, which will be discussed further in the next section. The Notice may be provided to the NBEUB where appropriate, but its primary function is to ensure that material changes are identified and addressed promptly without unnecessary re-opening of prior evaluations.

3.6 Enhancement: Adding Supplemental Analysis to Material Changes

IRP continues to serve as a planning document that guides portfolio planning; however, it does not have decision-making authority. Procurement remains a separate process with its own procedures and evidentiary requirements for justifications.

Once a material change is identified, a Supplemental Analysis process will serve as the analysis for justification. This step relies on similar analytical tools used in the IRP, right-sized for the needs of the Supplemental Analysis phase. For RA, that may mean quantifying an updated total resource need, or demonstrating the set of incremental resources achieve system reliability, and/or justify the timing of actions and resource size.

As suggested by our jurisdictional scan, this type of off-cycle process could range from a relatively cumbersome process like an interim IRP (for example, PSCo), IRP amendments (for example, NV Energy), to a relatively light process like a direct entry into an RFP when the solution is obvious and time-sensitive. The level of analysis is at the discretion of NB Power's judgment on the analysis required to demonstrate the need for resource additions.

3.7 Enhancement: Managing Risks of Under- and Over-Building

NB Power operates in an environment of increasing uncertainty. Load growth is trending upward due to electrification and increasingly extreme weather conditions. While NB Power benefits from interties with neighboring systems, NPCC and NERC assessments show that regional surplus capacity and tie benefits are expected to tighten over time, especially in winter, limiting the extent to which imports can be relied on under stressed conditions. Longer-term proposals such as the

Atlantic Loop may expand options in the future, but until such infrastructure is realized, NB Power must plan conservatively for resource adequacy on its own system. These factors heighten the importance of carefully balancing the risks of both over- and under-building.

The consequences of under-building can be significant, including elevated reliability risks, emergency procurements under time pressure, and potential non-compliance with reliability standards. By contrast, over-building generally results in incremental carrying costs, some of which can be mitigated through exports, reserve sales, or portfolio flexibility. This asymmetry suggests that modestly advancing or enlarging capacity builds may sometimes be a prudent strategy for risk management.

The IRP provides a platform to evaluate these trade-offs by evaluating portfolios under multiple load growth and policy scenarios. This reduces the risk of over- or under-valuing resources in the investment process and strengthens the evidentiary basis for early or larger additions

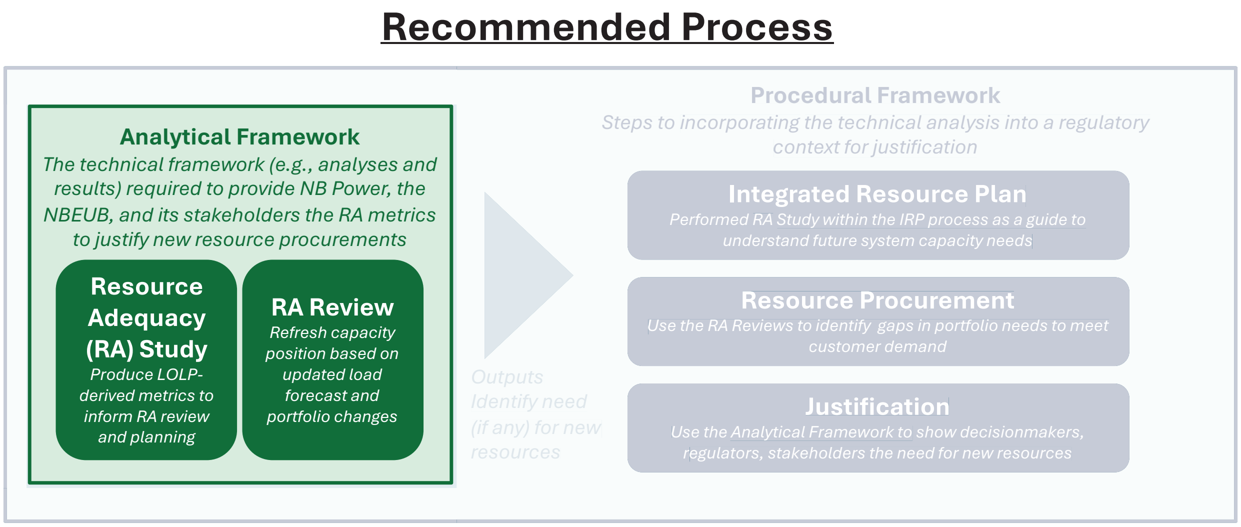
Preemptive builds can also create additional benefits, such as achieving economies of scale, lowering unit costs, and reducing the frequency of procurements. At the same time, these decisions should remain transparent and regulator-ready, with clear documentation of the rationale and supporting metrics.

By explicitly evaluating the asymmetric risks of over- and under-building, NB Power and the regulator can make balanced decisions that prioritize reliability while maintaining cost discipline, ensuring that justifications for earlier or larger additions are evidence-based and defensible.

Together, these procedural enhancements provide NB Power with a structured, transparent pathway for making procurement decisions that are regulator-ready. The next section turns to the analytical foundation of the framework, describing the technical methods, metrics, and adequacy criteria that underpin this process.

4. Analytical Framework: Strengthening RA Concepts and Evidence

To best understand the resource adequacy (RA) needs of the system, planners must have a robust RA planning framework that fits with a modern electricity system. This section details the three key pillars of a robust resource adequacy planning framework and the recommended changes to NB Power's existing resource adequacy practices.



4.1 Principles of an Analytical Framework

Best-practice frameworks emphasize three pillars:

- **Probabilistic modeling (LOLP/LOLE) –** Modern RA planning relies on probabilistic simulations of load and resource availability, replacing static reserve benchmarks.
- **Transparent and actionable metrics –** Adequacy studies must produce clear metrics that link the total system need to resource contributions.
- **Ongoing and system-specific tailoring –** Regular RA reviews and full LOLP studies ensure adequacy criteria reflect NB Power's unique load, weather, and operational conditions.

The subsections that follow describe these principles in more detail (Sections 4.2, 4.3, and 4.4), which provide a high-level summary of a longer technical white paper E3 produced in August 2025. For more details on the technical implementation and application of the RA planning framework, see Appendix A: Resource Adequacy for the Energy Transition: A Critical Periods Reliability Framework and its Applications in Planning and Markets, before NB Power–specific recommendations (Sections 4.5, 4.6, 4.7).

Figure 11. Summary of E3's Proposed Enhancements to NB Power's Analytical Framework

Analytical

1. Institutionalizing RA Modeling within NBP
2. Adopting an RA Analytical Framework that Follows a Critical Hours Framework
3. Strengthening the Role of RA Reviews

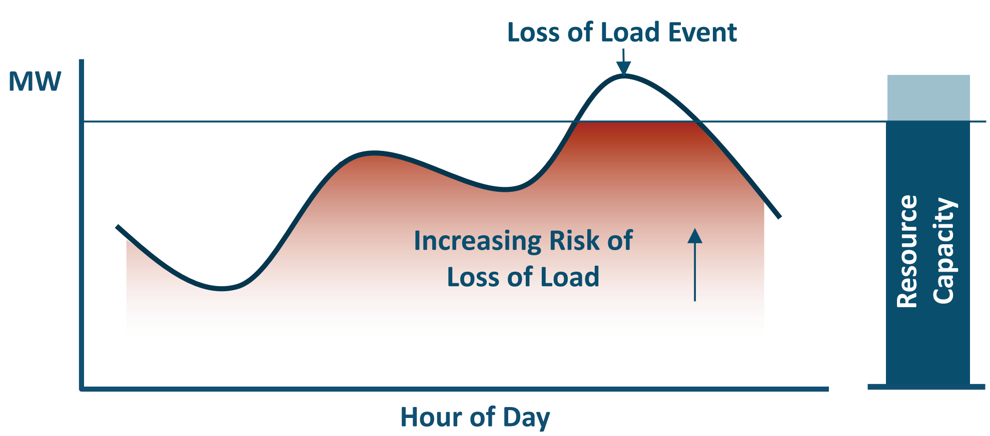
4.2 Defining Resource Adequacy

Resource adequacy is one aspect of electric system reliability. Resource adequacy is the ability of an electric power system to produce sufficient generation to meet loads across a broad range of weather and system operating conditions, subject to a long-run reliability standard that limits the frequency of shortfalls to very rare instances. The resource adequacy of a system thus depends on both the characteristics of its load, such as seasonal trends, weather sensitivity, and hourly patterns, and the attributes of its resources, including size, dispatchability, outage rates, and other limitations on availability. Ensuring resource adequacy is an important goal for utilities seeking to provide reliable service to their customers.

NERC Definition of Resource Adequacy

"The ability of the electric system to supply the aggregate electrical demand and energy requirements of the end-use customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements."

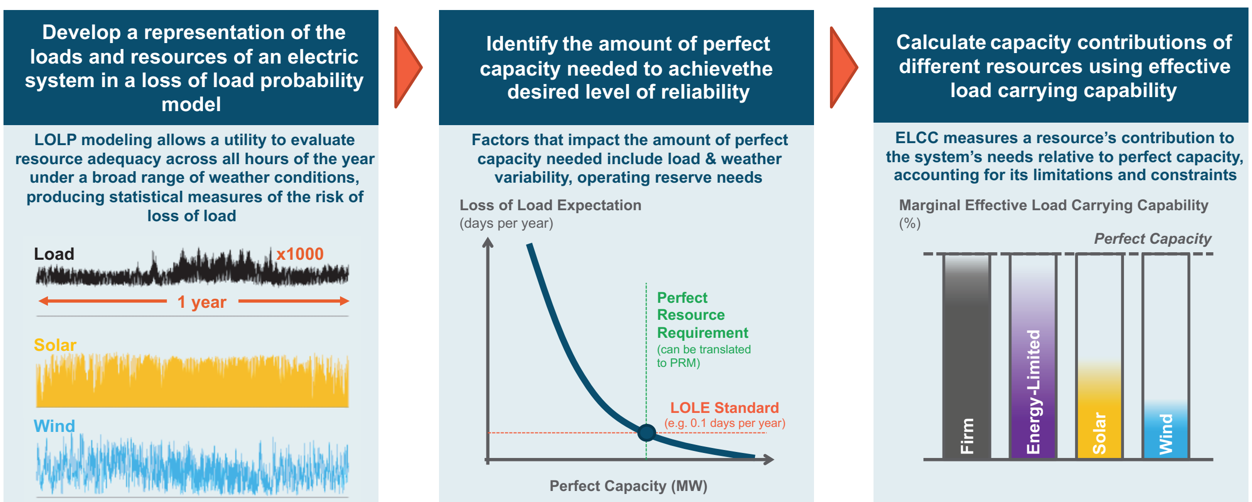
Figure 12. Illustration of a loss of load event due to insufficient generation



4.3 Introduction to RA Best Practice Framework

The growing penetration of variable renewable resources (whose output is constrained by intermittency) and energy-limited resources (whose production is constrained by duration) has exposed important shortcomings in the traditional planning reserve margin approach long used to ensure resource adequacy. At the same time, across North America, conventional thermal generators, long considered dependable during stress events, have performed below expectations in highly scrutinized recent winter storms. Taken together, these developments underscore the need to design the system to perform under the most constrained operating conditions. With improved understanding of these challenges and innovations in probabilistic methods designed to capture the interaction between variable, energy-limited, and other firm resources, utilities and program administrators have begun modernizing their resource adequacy planning practices.

Figure 13. Three foundational pillars underpinning a robust approach to resource adequacy



the robust framework for resource adequacy requires three components:

1. Development of a **loss-of-load-probability (LOLP) model** that can simulate the availability of loads and resources on an hourly basis across a wide variety of weather conditions to identify periods in which an electricity system is vulnerable to reliability risks;
2. Derivation of a **total capacity requirement** that reflects the amount of "perfect capacity" needed to achieve an acceptable standard of reliability; and
3. Application of an **effective load carrying capability (ELCC)** accounting framework to measure the contribution of each resource (or portfolio of resources) towards the total capacity requirement. Under a critical period framework, ELCC will be determined on a marginal basis (marginal ELCC), which can also be understood as representing its expected performance during critical periods.

The following sections will detail the selection criteria for LOLP models and development of inputs and assumptions for LOLP models. For more details on the derivation of the total capacity requirement and the application of ELCCs, please see Appendix A: Resource Adequacy for the

Energy Transition: A Critical Periods Reliability Framework and its Applications in Planning and Markets.

4.4 Running and Using a LOLP model

4.4.1 Choosing a LOLP Model

Modern resource adequacy analysis is grounded in models with capabilities of capturing the increasing complexity of modern power systems. In addition to the conventional complexities of thermal outages, higher penetrations of variable and energy-limited resources has driven the growing adoption of Monte Carlo–based loss-of-load-probability (LOLP) models.

4.4.1.1 Prioritizing Criteria for LOLP Model Selection

To understand the tool landscape, E3 reviewed Electric Power Research Institute's (EPRI) Resource Adequacy Assessment Tool Guide. This guide surveyed the available RA Tools available in the industry and summarized the capabilities of each one.[6] In EPRI's survey, the authors summarize the key factors to consider in terms of the specific system type. Figure 14. LOLP Model Selection Criteria describes the priorities for LOLP model selection.

Figure 14. LOLP Model Selection Criteria

Model selection factors	Importance (low, medium, high)
Availability of detailed models	High
Cost	Medium
Computational speed	High
User interface	Medium
Software support	High
User manual	Medium
Access to nonproprietary databases	Low

In addition to the model selection criteria, the LOLP model needs necessary features to be able to simulate large numbers of random realizations of uncertain inputs, including forced outages, renewable generation variability, and load variability. EPRI's uses the system type to help planners identify the tool needed. Figure 15. Tool Feature Considerations Depends on the System shows the system specific needs and the translation to tool features needed.

[6] https://www.epri.com/research/products/3002027832

Figure 15. Tool Feature Considerations Depends on the System

If modeling a system…	Then prioritize…
… with a large amount of energy limited resources	→ dispatch-based chronological Monte Carlo sampling method → robust storage, hydropower and/or demand response modeling
… at risk of extreme weather events	→ report percentile-based metrics → correlated timeseries data (weather-based resources, load, temperature, etc.) → conditions-based forced outage modeling → start-up failure modeling → coincident outages to represent widespread outages due to fuel shortages
… in the operational planning timeframe	→ chronological Monte Carlo sampling method → multi-stage economic optimization → no forced outage foresight → short-term weather forecast error
… at risk of shoulder season shortfall events	→ a robust maintenance outage modeling methodology

4.4.1.2 Ensuring Statistical Convergence in LOLP Modeling

Another critical consideration in LOLP model selection is the model's ability to achieve statistical convergence of the reliability metrics produced. As mentioned earlier, since LOLP analysis relies on Monte Carlo simulation with various uncertain inputs (e.g., outages, generation variability), the outputs of the model (such as LOLE, LOLH, EUE, etc.) are subject to sampling error. To accurately estimate true system reliability and make it useful for planning, the number of simulations must be sufficiently large for these metrics to stabilize within an acceptable confidence interval. A model with poor convergence properties may yield results that vary significantly across different runs, reducing confidence in the outputs and potentially leading to misleading conclusions about system reliability. Conversely, a model that converges efficiently can not only give planners confidence that the reported reliability characterizations are statistically robust, but also reduce computational requirements. Therefore, choosing a model that can be configured to achieve higher convergence performance (based on simulation design and computational efficiency) is another crucial factor for robust system resource adequacy planning.

For more information and discussion on tool selection, see Appendix C.

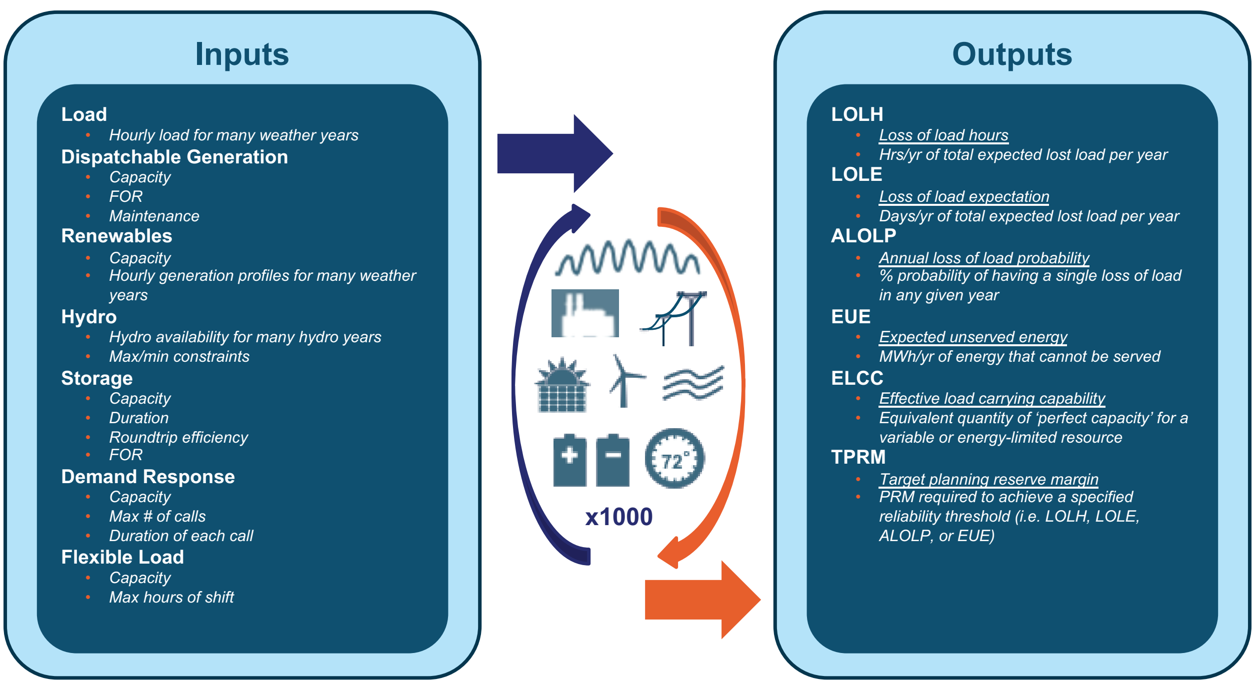
4.4.2 Developing a Data Set for LOLP Modeling

In addition to a capable LOLP model, an accompanying dataset with robust assumptions and inputs is needed for the model to reflect the range of plausible system states that may pose reliability challenges to the system. This includes:

1. **Distributions of extreme weather events:** While planners have long relied on extended samples of historical weather data to inform probability distributions of tail weather events; the assumption that historical conditions provide an accurate representation of the future may no longer be appropriate.

2. **Hourly load and renewable production data:** the adequacy of a system will depend, in part, on how renewables perform during rare extreme load events. For many renewable facilities, little to no historical data is available that can be used directly for this purpose. For this reason, the use of simulated renewable profiles, which rely on historical meteorological data as inputs into simulations of wind and solar plant performance, is common practice.
3. **Performance assumptions for existing and emerging technologies:** generation technologies are quickly advancing, and electricity systems are presented with new resource options to meet their needs that would not have been available a decade ago. This trend is likely to continue, as research, development, and deployment will continue to bring new technologies into the market. While these advances offer long-term promise, planners should also take caution in assumptions made regarding the performance of new resources with limited operational history at commercial scale. Especially during early years of commercialization, new technologies may not perform as expected.
4. **Random and correlations among unit outages:** the assumption that forced outages of generators can be modeled as independent, uncorrelated events is common practice in traditional LOLP modeling; to the extent that underlying factors like weather patterns and fuel supply issues may affect outages at multiple plants simultaneously, a correlated risk that is not often captured may exist. While evidence of this type of correlated relationship exists, it is typically highly geographically specific and difficult to generalize. While capturing these types of relationships would improve the rigorousness of reliability modeling, how to use the limited availability of robust data sets that inform this factor is an emerging area of research within the field.

Figure 16: Key Inputs and Outputs from LOLP modeling



4.5 Enhancement: Institutionalizing RA Modeling within NBP

4.5.1 Standing up an NB Power-Specific RA Model

While NB Power will continue to participate in and comply with NERC/NPCC regional reliability assessments, these probabilistic and deterministic modeling studies are performed at the regional level in nature, supported by data from regional entities. The results of the study may not capture the specific NB Power RA needs and system conditions. This study recommends that NB Power institutionalize its own NB-specific LOLP probabilistic modeling capability by investing in the right modeling tool and the right data. This will allow NB Power to run RA studies to inform their annual, NB-specific RA reviews that reflect its own load shapes, load forecasts, extreme winter weather conditions, and resource performance, while remaining consistent with NERC/NPCC standards. By developing this in-house capability, NB Power reduces dependence on regional models, creates a transparent evidence base for the regulator, and ensures that procurement and planning decisions are informed by the most accurate view of NB Power's reliability needs.

4.5.2 Aligning Reliability Standards

NBEUB adopts and enforces the reliability standards established by NERC and NPCC, such as the requirement to maintain a LOLE of no more than 0.1 days per year and a minimum of 20% PRM. NB Power has adopted a 20% PRM for its integrated resource planning process.

4.5.2.1 LOLE Standard

E3 recommends that NB Power continue to rely on the LOLE standard of no more than 0.1 days per year going forward. At the same time, given the evolving nature of load growth, electrification, and climate risks, it may be worth reevaluating in the future whether this frequency-based metric remains sufficient, or whether a different reliability target that focuses on loss-of-load risk duration or magnitude is warranted to reflect the evolving reliability risk nature of the province.

4.5.2.2 PRM Target

E3 recommends that the PRM target that meets a reliability target set by NB Power should be derived from a data-driven LOLP modeling process and regularly refreshed with each RA study along with the latest load and resource data. This ensures the PRM accurately represents NB Power's system reliability needs and reliably achieves the NPCC/NERC LOLE standard, given New Brunswick's load growth and reliance on a single, large nuclear unit within a relatively small system.

This means that while NB Power must comply with NPCC/NERC standards, it may need to present evidence to the NBEUB that a higher PRM, derived from regularly updated LOLP modeling based on the latest load and resource data, than the regional benchmark is required to satisfy the same reliability obligation while accounting for New Brunswick's unique system characteristics.

4.6 Enhancement: Adopting an RA Analytical Framework that Follows a Critical Hours Framework

A structured RA analytical framework that follows the best practices is needed in New Brunswick to address the evolving needs and challenges in resource adequacy in a decarbonized future where the grid transitions from one dominated by dispatchable thermal resources to one increasingly reliant on variable renewable generation. It becomes more critical to plan not only for peak gross load but also for critical periods when high load coincides with low renewable output or thermal outages. See Appendix A for an explanation in detail of the implementation of the critical hours framework.

The following subsections summarize E3's recommended enhancements to NB Power's RA analytical framework, tailored to NB Power's regulatory and jurisdictional context.

4.6.1 Adopting LOLP-derived PCAP PRM for Need Determination

E3 recommends the following enhancements to NB Power's PRM framework:

+ Calibrate a PCAP PRM once per IRP cycle,
+ Publish an ICAP / PCAP translation with each resource adequacy study to maintain continuity with existing reporting practices.

NB Power consider base its resource need determination on a Perfect Capacity Planning Reserve Margin (PCAP PRM) derived from probabilistic loss-of-load probability (LOLP) modeling. Using PCAP to define the planning reserve margin provides a clear and transparent measure of adequacy that adjusts naturally as load and operating reserve needs evolve.

NB Power currently reports planning reserve margins in terms of installed capacity (ICAP) because a minimum of 20% ICAP PRM is established by NERC and NPCC, and adopted and enforced by NBEUB. This reporting convention can continue, provided that each study also establishes a clear translation between ICAP and PCAP results. For example, when results are expressed in ICAP, NB Power should calculate and report the implied PCAP PRM; when results are expressed in PCAP, the implied ICAP values should also be presented. Maintaining this cross-reference allows NB Power to continue meeting legacy reporting needs while adopting the modern PCAP framework for resource adequacy planning.

By deploying and formalizing these enhancements, NB Power will remain aligned with NPCC and NERC expectations, provide clear and comparable results, and ensure that its planning and procurement decisions are supported by a consistent and defensible analytical framework.

4.6.2 Incorporating Operating Reserves in NB Power's PCAP PRM

The goal of resource adequacy planning is to ensure sufficient resources to provide reliable service, including sufficient operating reserves for real-time balance between supply and demand. To incorporate operating reserves in resource adequacy planning, NB power must account for the minimum level of operating reserves needed to maintain operating reliability in real time. In practice, though, not all operating reserves are treated the same way in planning studies. As shown in the table below, utilities typically include spinning reserves and regulating reserves requirements in LOLP modeling, as these are mandated by NERC and considered essential to maintaining real-time system reliability. Non-spinning reserves and load-following reserves, on the other hand, are generally excluded, as they're likely to be depleted before critical periods when system has to shed load.

Each utility takes its own approaches on deciding which ancillary service should be maintained during a load shed event. NB Power should coordinate closely with its operations group to ensure the treatment of reserves in RA planning is aligned with how reserves would actually be deployed in real time operations.

Table 1. Reserves and Recommended Treatment in LOLP Modeling

Reserves	Description	Example Quantity	Recommended Treatment in LOLP	Notes
Non-Spinning Reserves	Uncertainty in load and generator availability	3% of load	✗	Excluded by most utilities in LOLP studies; likely depleted before shedding firm load
Spinning Reserves	Uncertainty in load and generator availability	3% of load	✓	Included by most utilities in LOLP studies; required by NERC
Ramping / Load Following	Intra-hour deviations	Varies by conditions on system	✗	Not considered by most utilities in LOLP studies; since most EUE events will be after sunset, this component should also be negligible
Regulating	Intra-5-minute deviations	1.5% of load	✓	Included by most utilities in LOLP studies; required by NERC (this differs from the approach taken so far)
Frequency Response	Sub-minute deviations	Varies by conditions	✓	Included in some utilities' LOLP study as a practice for internal operations

Once appropriate reserves are identified, NB Power should implement the reserve type and quantity in its probabilistic loss-of-load models. This results in an LOLP-derived PRM that sufficiently captures the total capacity needs, including operating reserves held during a load shed event.

E3 recommends the following enhancements to NB Power's need determination:

+ Coordinate with the operations group to ensure that assumptions around reserves and load shedding practices in planning are consistent with how the system is actually managed in real time
+ Model operating reserves explicitly within probabilistic LOLP analysis so that adequacy assessments account for the real-world need to hold reserves and reflect both demand- and supply-side risks

4.6.3 Adopting Marginal ELCC Methodology for Resource Accreditation

The next step in the critical period reliability framework is to evaluate the marginal ELCC of individual resources or portfolios, i.e., the amount of perfect capacity displaced from the total reliability need as additional resources are added. E3 recommends that NB Power consider adopting marginal Effective Load Carrying Capability (ELCC) as the consistent methodology for accrediting all resources. Using marginal ELCC aligns resource accreditation with the system's probabilistic need, ensures that resources are valued based on their actual contribution to reliability during critical periods, and creates a level playing field across resource types.

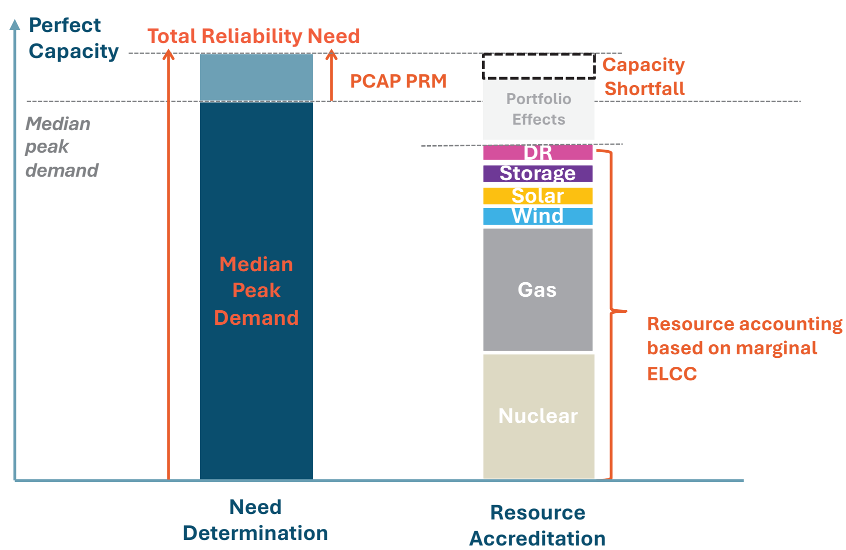
As summarized in Section 1.2.1, currently at NB Power, variable and energy-limited resources (VERs) are credited with Effective Load Carrying Capacity (ELCC), while thermal and hydro resources are credited with installed capacity (ICAP). This aligns with the traditional ICAP-based PRM and resource accreditation framework. Continuing to apply disparate approaches risks distorting procurement choices and under- or over-valuing resources. Moving to a single marginal ELCC methodology across all technologies will improve comparability and transparency, and ensure that procurement decisions are tied to actual contributions to system reliability.

E3 recommends the following enhancements to NB Power's ELCC framework:

- Apply marginal ELCC consistently to new and existing resources, including renewables, storage, demand response, and thermal generation.
- Publish resource-class ELCC results in RA studies so stakeholders see how contributions are derived.
- Use ELCC values in procurement evaluation to avoid bias between tech types.

By adopting marginal ELCC for all resource types, NB Power will strengthen the integrity of its resource adequacy framework, align with leading practice across North America, and avoid biases that can arise from applying different accreditation methods to different technologies.

Figure 17: Using the LOLP Model Outputs to Inform Load and Resource Balance



4.6.4 Refining the Quantification of Non-Firm Import Benefits

There is no standard methodology for incorporating non-firm imports firm neighboring utilities in resource adequacy planning, but reliance on neighboring utilities its typically depends on the combined load and resource diversity. Regions with diverse timing of critical periods (e.g. summer vs winter peaking systems) have increased opportunities to share resources. However, regions with similar timing of critical hours typically have fewer opportunities to share resources (e.g. utilities experience the same regional cold snap). Neighboring entities in the Atlantic Provinces experience similar critical periods, resulting in limited non-firm opportunities to share resources. However, opportunities may arise from neighbors in the south with ISO-NE. Given ISO-NE's critical periods hours occur in the summer, NB Power could consider performing analysis to produce an annual or seasonal MW value from non-firm imports to NB Power.

NB Power should consider robust analysis to measure the MW contribution from non-firm imports to NB Power. There are multiple potential approaches to derive the MW value of non-firm imports. One approach is to models neighboring systems explicitly within a LOLP model, with any excess external generation made available for use. Another approach is to derive an explicit MW assumption on external available support based on historical and/or projected data. While endogenous representation within a LOLP is possible, the latter is preferable due to the level of uncertainty in neighboring utilities' forecasted resources and loads. Below in are some examples of entities and their assumptions in external markets in a RA assessment.

To derive a MW assumption for non-firm imports, NB Power should consider (1) load diversity between neighbors (e.g. coincident load during NB Power's peak compared to non-coincident load), (2) neighbor's historical excess capacity during NB Power's peak periods, (3) neighbor's excess capacity during their own peak load, and (4) historical imports from neighbor's during NB Power's critical periods. Each metric can be pieced together to inform an assumption for an appropriate MW value to assign non-firm imports.

Using analysis, NB Power must demonstrate the value, but also its validity into the future. Given the broader region's future capacity needs, the historical available capacity may shrink and NB Power must decide if historical imports and capacity availability data can be used for future planning.

Table 2. Treatment of Neighboring Markets in Resource Adequacy Assessments

Utility	Are Neighboring Markets Simulated Endogenously?	Cap on Net Imports?	Notes
Public Service of New Mexico (PNM)[7]	Yes	Yes	50 MW cap at net peak based on historical experience
Arizona Public Service (APS)[8]	Yes	Yes	"Limited the aggregate APS imports during the peak season"
Nevada Energy (NVE)[9]	No	Yes	No imports/island
Black Hills Energy - Colorado	No	Yes	No imports/island
California Public Utilities Commission (CPUC)[10]	Yes	Yes	
Portland General Electric (PGE)[11]	No	Yes	Caps developed based on forward-looking assessment (previously done by E3, now done in house)

[7] PNM: https://www.pnmforwardtogether.com/assets/uploads/PNM-2023-IRP-Report-corrected-2023-12-18.pdf

[8] APS: https://www.aps.com/-/media/APS/APSCOM-PDFs/About/Our-Company/Doing-business-with-us/Resource-Planning-and-Management/APS_IRP_2023_PUBLIC.pdf?la=en&sc_lang=en&hash=DF34B49033ED43FF0217FC2F93A0BBE6

[9] NV Energy / Black Hills: E3 Analysis

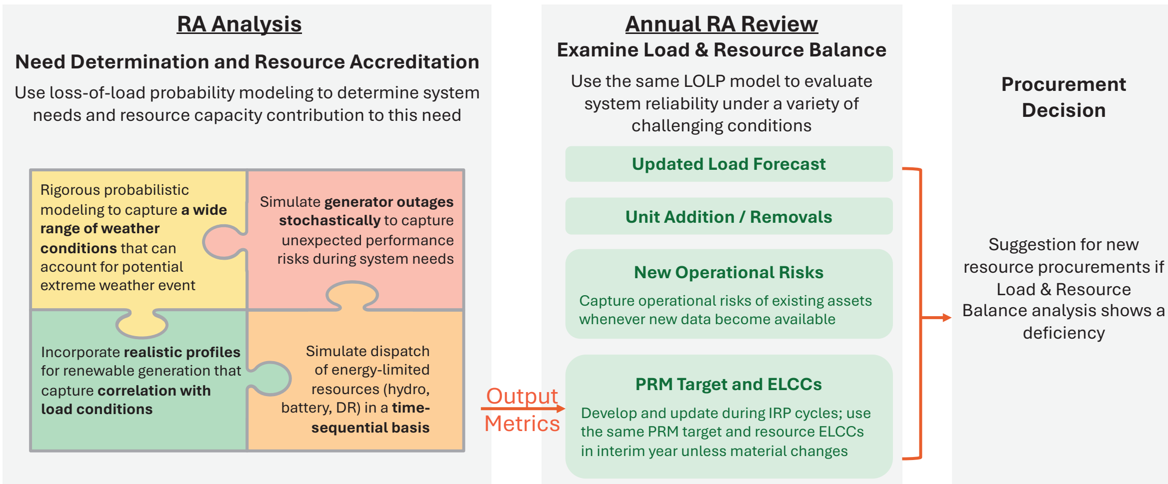
[10] CPUC: https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/20230210_irp_e3_astrape_updated_incremental_elcc_study.pdf

[11] PGE: https://assets.ctfassets.net/416ywc1laqmd/5KGhp7ztJ0EjYguNpPEO62/08ad02fff92d7122c9c85bb33093e677/2023_CEP-IRP_Ch_04.pdf

4.7 Enhancement: Strengthening the Role of RA Reviews

4.7.1 Setting the Right Frequency of RA Studies vs RA Reviews

Figure 18: RA Analysis Output Metrics Used for RA Review



The frequency of RA review has also become a critical consideration in light of rapid system changes and growing climate uncertainties. Historically, many jurisdictions conducted adequacy assessments only once every several years, reflecting the relatively stable load growth and predictable performance of conventional thermal fleets. However, with today's accelerating pace of electrification, increased reliance on variable renewables, and climate-driven extreme weather events, new risks can emerge faster than what multi-year assessment cycles can capture. For example, unanticipated heat waves or winter storms, shifts in seasonal peak timing can all expose risks that were not evident in prior studies, even when those studies used long historical datasets.

Some regions have already moved toward annual RA reviews to better align planning with the pace of system change. Interim assessments may also be triggered by major interruptions such as unexpected plant failures, delayed capacity additions, large load growth, or observable shifts in weather-driven demand. Regular review is especially important in the context of climate change, as historic weather data alone may not capture the frequency or intensity of emerging critical periods.

While performing resource adequacy studies (i.e., running LOLP models to calculate achieved reliability) more frequently helps mitigate risk, constant review can be burdensome and excessive. However, frequent review of loads and resource balance informed by outputs from LOLP models is recommended. Systems that incorporate more granular and recurring reviews are better positioned to account for evolving risk factors, like recalibrating reliability needs in light of updated load forecasts. Recurring RA assessments also act as a feedback mechanism, continuously refining procurement strategies and reliability needs evaluation to match the needs of an electricity system that is evolving faster than ever before. E3 offers a case study from Public Service of Colorado that details how this practice informed the need for new resources and is introduced in Section 7.6.1.

4.7.2 Producing Core Output Metrics from RA Studies

Once a LOLP model is stood up with the appropriate dataset, producing core and detailed outputs from the analysis will feed directly into the RA review and analysis. The core outputs from the model needed aid planners in developing a load and resource balance table for each year. The metrics include:

- Annual or seasonal LOLP-derived target planning reserve margin, and
- Annual or seasonal marginal ELCCs and portfolio effects

These core outputs are typically refreshed during the start of every IRP. For NB Power, this means a detailed RA analysis that produces a target PRM and marginal ELCCs results are performed every 3 years.

In addition to core outputs used for the Annual RA Review, planners use detailed output metrics from the LOLP model to characterize the loss of load risk in a system. These are typically probabilistic metrics like loss of load expectation, average loss of load hours, expected unserved energy. While they are not strictly needed for the purposes of a load and resource balance exercise, each metric provides insights to the potentially frequency, duration, and magnitude of loss of load risk on a system.

For more details on the full scope for integrated planning, see Appendix A.

4.7.3 Refreshing Capacity Position in Annual RA Reviews

Using the two core outputs, PRM and marginal ELCCs, planners can determine the total need for each year or the capacity is needed to meet a reliability target, and incremental resource's capacity contributions to the total need. The output for this analysis identifies the system's capacity position, either in shortfall or surplus of the total reliability need in each year. Using the capacity position is the first step in identifying the need for procurement in both total MW need, but also in timing.

4.7.4 Incorporating Load Forecasting and its Uncertainty in Annual RA Reviews

Load forecasting is a critical element of resource adequacy analysis because the total resource need is directly dependent on both the magnitude and temporal shape of projected load. Having a load forecasting methodology that captures the near- and long-term load component growth is critical but so is the frequency of the load forecast update. The right methodology paired with an appropriate frequency allows NB Power to balance the system's near-term and long-term view of the resource needs. For NB Power, a successful forecast captures near-term population growth, transport electrification, large customer growth, and winter electrification.

To mitigate risks arising from uncertain load growth and evolving load shapes, utilities are adopting a range of strategies. Most now develop multiple load forecast scenarios to capture high and low growth outcomes, reflecting the variability of emerging loads, such as data centers, electrification of heating and transportation, and evolving climate conditions. Utilities also explicitly model demand-side resources, including energy efficiency, distributed solar, and demand response, to refine net system demand forecast.

While it is important for utilities to regularly refresh load forecasts to capture new trends and uncertainties, these updates do not necessarily require recalibration of the PRM target. Once established, a PCAP PRM target derived from rigorous LOLP model is generally durable across different forecast vintages. Unless there are significant structural shifts in the load forecast, e.g., major changes in electrification patterns, peak timing, or overall load composition, the same PRM percentage can typically be applied to updated load forecasts and continue to provide a reasonable guide for system needs.

In addition to regular refresh of load forecasts during annual RA reviews, E3 also recommends that NB Power deploy two complementary approaches to explicitly quantify uncertainty in their load forecasting efforts:

- **Scenario Analysis:** Create a set of 'what-if' scenarios that reflect different long-term futures of New Brunswick, for example, a base case (continuation of current trends), a high growth case (reflecting accelerated electrification or new industrial loads such as data centers) and a low growth case. Running RA studies under these different scenarios help demonstrate how system needs could change if electric load grows either faster or slower than expected. This is a common practice used by many utilities and markets throughout North America, including NB Power (as seen in the 2023 IRP).
- **Probabilistic Analysis:** In addition to load forecast scenarios, simulating possible load distribution outcomes with many years of historical weather year data and different economic conditions should also be considered. This method allows NB Power to calculate not just the 'most likely' reliability need but also the chance of extreme events that could cause shortages.

Specifically, when applying these methods, relevant emerging drivers including large new loads such as data centers, extreme events, and climate change should also be factored in.

- **Modeling New Loads:** These loads can create sudden step-changes in demand that are not captured by gradual population or economic growth. NB Power should develop discrete scenarios that assume earlier, later, or no arrival of these projects that are refreshed annually through the RA review. In addition, potential load flexibility from these new large loads[12] should also be considered and modeled as potential reliability resource, instead of just as additional demand.
- **Modeling Extreme Events:** Conventional load forecasts may not reflect low-probability but high-impact conditions such as multi-week wind or hydro droughts, prolonged cold snaps, heat waves, or simultaneous outages of large generating units (such as Point Lepreau). For load forecasts, NB Power should supplement its load forecast inputs with targeted "stress tests" that represent these tail risks, building "tail risk" load distributions that reflect rare but plausible cold snaps or prolonged weather extremes.

[12] Such as shifting computing tasks, using on-site generation, or curtailing during emergencies

+ **Modeling Climate Change Impacts:** A changing climate is altering both demand and supply. On the demand side, more extreme winter cold snaps and hotter summers will reshape peak profiles, especially as heating and cooling electrification accelerates. Historical weather data alone is not sufficient. NB Power should begin incorporating climate-conditioned weather projections into its forecasting, while showing both historic-based and climate-conditioned results side-by-side for transparency

By combining scenario analysis, probabilistic methods, and explicit treatment of new loads, extreme events, and climate change, NB Power can move beyond a single “most-likely” load forecast to a risk-aware view of future load growth. This approach will provide greater confidence that capacity needs are being measured against a full range of plausible load forecast outcomes, ensuring that procurement decisions are transparent, evidence-based, and resilient to both economic growth and climate uncertainty.

5. From Recommendation to Action: Implementation Roadmap

The roadmap translates these recommendations into a sequenced set of actions for NB Power and the NBEUB. It organizes initiatives by priority and timeframe: immediate steps that establish the foundation, as well as medium- and long-term steps that strengthen integration and governance and then enhance flexibility and prepare the framework for future challenges.

Each item highlights the action, its rationale, the responsible party, and the suggested timeframe. The intent is not to provide a detailed implementation manual, but rather a clear guide to what should be done first, what follows next, and what to plan for later, ensuring steady progress toward a robust, regulator-ready RA framework while keeping administrative burden manageable and aligned with New Brunswick's context.

5.1 Immediate Priorities

From all proposed enhancements, the immediate priority is to establish the minimum viable product (MVP) of NB Power's RA framework. These near-term actions focus on putting in place the essential building blocks for best-practice RA modeling and ensuring results can flow directly into planning and procurement. Specifically, NB Power should: (1) institutionalize its own probabilistic LOLP modeling capability; (2) adopt an analytical framework that applies a critical hours approach to develop data-driven PRM and ELCCs; (3) create an annual cadence of RA reviews to refresh load forecasts and load & resource balance assessments; and (4) align inputs and study timelines with NPCC and NERC processes to the extent possible. Taken together, these steps establish a transparent, repeatable foundation on which later procedural and analytical enhancements can be built. Please note that some of these actions involve multiple sub-steps, and full implementation may extend beyond the first year.

Figure 19. Roadmap for Robust and Future-ready RA Framework: Immediate Steps

Steps	Action / Rationale	Responsibility	Timeframe
Institutionalizing RA Modeling within NBP	Acquire or establish NB-specific probabilistic LOLP modeling tool that supports PRM and ELCC study for each IRP cycle; Align on a reliability standard	NB Power	< 1 year[13]
Adopting an RA Analytical Framework that Follows a Critical Hours Framework	Deploy best-practice LOLP modeling that produces data-driven PRM; Incorporate operating reserves within a PCAP PRM framework; Adopt a marginal ELCCs framework for all resources; Refine the quantification of non-firm import benefits	NB Power	< 1 year[13]
Create an Annual Cadence of RA Reviews	In addition to regular 3-year LOLP analysis, performing annual resource adequacy reviews with updated load forecasts and resource portfolios	NB Power	< 1 year
Aligning with NERC/NPCC on Inputs / Assumptions	Harmonize inputs and study timelines across NBP's internal resource adequacy reviews and NERC/NPCC RA assessments, to the extent possible	NB Power + NPCC + NERCC	< 1year

5.2 Medium- and Long-term Steps

In the 1–3 year horizon by the 2029 IRP cycle, medium- and long-term steps focus on strengthening NB Power's RA, planning, and procurement framework so it becomes more structured, transparent, and regulator-ready to demonstrate to the board the need for new resources. Key priorities include: (1) defining clear triggers for when off-cycle procurement analysis is needed, (2) developing a Supplemental Analysis toolbox that provides structured options without reopening the full IRP, (3) formalizing milestones for regulatory justifications to ensure a consistent chain of evidence, and (4) embedding evaluation of the asymmetric risks of under- and over-building into both IRP and supplemental analysis. Together, these measures will allow NB Power to manage evolving reliability needs with greater discipline, justify procurement decisions on an evidence-based basis, and maintain accountability to the NBEUB and stakeholders.

[13] This bucket may include multiple sub-actions; while initial progress can be made within a year, certain elements (e.g., PCAP conversion, marginal ELCC) may require a longer timeframe to be fully implemented.

Figure 20. Roadmap for Robust and Future-ready RA Framework: Medium- and Long-term Steps

Steps	Action / Rationale	Responsibility	Timeframe
Creating Milestones for Regulatory Demonstrations	Create transparent, repeatable chain of evidence	NB Power	1-3 years
Identifying Triggers or Material Changes that May Require Procurement	Codify quantitative and qualitative criteria to activate off-cycle Supplemental Analysis to provide structured, transparent off-cycle pathway and avoid ad-hoc re-studies	NB Power	1-3 years
Adding Supplemental Analysis to Material Changes	Provides structured off-cycle options without reopening the full IRP, develop Supplemental Analysis toolbox and menu of options (light/medium/heavy pathways)	NB Power	1–3 years
Managing Risks of Under- and Over-Building	Evaluate asymmetric risks of over- and under-building within the IRP process and in Supplement Analysis during off-cycle process if needed to ensure that justifications for earlier or larger additions are evidence-based and defensible	NB Power	1-3 years

6. Appendix A: Resource Adequacy for the Energy Transition: A Critical Periods Reliability Framework and its Applications in Planning and Markets

Electricity systems are under increasing stress related to resource adequacy. Unprecedented load growth, changes in historical weather patterns, retirement of conventional resources, and the rise of variable and energy-limited resources have created new challenges for maintaining resource adequacy. At the same time, recent events have shown that conventional thermal generators often underperform during critical winter conditions. In this context, power system planners and market operators are reevaluating longstanding practices for determining and allocating resource adequacy need. E3's new white paper, Resource Adequacy for the Energy Transition: A Critical Periods Reliability Framework and its Applications in Planning and Markets, describes these challenges and lays out a framework that both formalizes and advances the emerging methodologies for evaluating resource adequacy need.

The paper formalizes a framework for resource adequacy that builds on established methodologies like loss-of-load probability and ELCC. It provides a more precise mathematical formulation of the problem than has previously been put forward, helping to clarify how total system need is defined, how resources are accredited, and how obligations are allocated.

Download the full white paper here

7. Appendix B: Jurisdictional Insights and Case Studies

7.1 Overview

E3 performed a jurisdictional scan of Resource Adequacy (RA) planning processes and associated frameworks in order to support New Brunswick in identifying a system planning process that is supported by industry best practices. This survey was carried out across North American jurisdictions identifying how each entity approaches their resource adequacy planning and highlights gaps relative to established best practices.

This survey aimed to capture a variety of planning practices with a range of geographies, markets, structures and methods around North America. The list of evaluated jurisdictions can be seen below:

- Black Hills Energy - Colorado
- El Paso Electric Co
- Nova Scotia Power, Inc.
- NV Energy
- Puget Sound Energy
- Arizona Public Service Co
- Avista Corporation
- Dominion Energy South Carolina
- Duke Energy Carolinas
- Manitoba Hydro
- Newfoundland Hydro
- Portland General Electric
- TECO
- NorthWestern Energy
- ISO New England
- New York ISO
- Midcontinent ISO

Figure 21. Geographical representation of jurisdictions evaluated

For this analysis, E3 uses three key topics, each contributing to a comprehensive understanding of the industry's current practices in Resource Adequacy Planning. The categories explore how entities use different (1) need determination methodologies, (2) resource accreditation, (3) and RA's Application for Resource Procurement. The first two categories are detailed in length in Appendix A. RA's Application for Resource Procurement explores how regulatory bodies respond to the findings of the RA assessment and provides insight into the associated resource procurement process.

7.2 Resource Adequacy Model

A resource adequacy analysis that adheres to best practices outlined in this report starts with a model with the appropriate features to assess system RA. Table 3 below is a summary of the RA models used by each entity identified to perform their RA analysis as part of their resource planning process. Appendix C (Section 8) covers the requirements of a robust RA model in more detail.

Table 3. Resource Adequacy Model Summary

	Utility/Jurisdiction	Software Provider	Software
Canadian Utilities	Nova Scotia Power, Inc.	Energy Exemplar	PLEXOS
	Manitoba Hydro	N/A	N/A
	Newfoundland Hydro	Energy Exemplar	PLEXOS
Southwest Utilities	Arizona Public Service Co	PowerGEM	SERVM
	El Paso Electric Co	E3	RECAP
Other Western Utilities	Avista Corporation	Avista Corporation	AVAM (Excel-based)
	NorthWestern Energy	N/A	N/A
	Nevada Power Company	E3	RECAP
	Portland General Electric	Portland General Electric	Sequoia
	Black Hills Energy - Colorado	E3	RECAP
	Puget Sound Energy	E3	RECAP
Eastern Utilities	Dominion Energy South Carolina	PowerGEM	SERVM
	Duke Energy Carolinas	PowerGEM	SERVM
	Florida Power and Light	E3	RECAP
RTOs	ISO New England	General Electric	GE-MARS
	New York ISO	General Electric	GE-MARS
	Midcontinent ISO	PowerGEM	SERVM
	PJM	PJM	PRISM

7.3 Need Determination

One of the most fundamental outcomes of a Resource Adequacy analysis is the system's Need Determination. This establishes how much capacity is needed across the pool to meet resource adequacy standard. As such, it is very important to establish a resource adequacy metric that will ensure system reliability within the given constraints. The table below summarizes the Need Determination framework employed by various jurisdictions across North America. This includes their preferred resource adequacy metric and a statistical standard which to solve for. One of the most common industry standards today is the "one day in ten years" or "0.1 days per year". This need determination process is then carried at different frequencies across jurisdictions, as can be seen in the final column where the frequency of IRP (or equivalent) is noted.

Table 4. Need Determination Summary

	Utility/Jurisdiction	PRM Framework	Resource Adequacy Metric	Current Standard	Time Period of IRP Review
Canadian Utilities	Nova Scotia Power, Inc.	UCAP	LOLE	0.1 days per year	Every 2 years
	Manitoba Hydro	Historical PRM of 12%	LOLE	0.1 days per year	Every 2 years

	Newfoundland Hydro	UCAP	LOLH	2.8 hours per year	Every 2 years
Southwest Utilities	Arizona Public Service Co	UCAP	LOLE	0.1 days per year	Every 3 years
	El Paso Electric Co	PCAP	LOLE	0.1 days per year	Every 3 years
Other Western Utilities	Avista Corporation	ICAP	aLOLP /LOLE	5% per year + 0.1 days per year	Every 2 years
	NorthWestern Energy	UCAP	LOLE	0.1 days per year	Every bid evaluation
	Nevada Power Company	UCAP	LOLE	0.1 days per year	Every 3 years
	Portland General Electric	UCAP	LOLH	2.4 hours per year	Every 2 years
	Black Hills Energy - Colorado	UCAP	LOLE	0.1 days per year	Every 3 years
	Puget Sound Energy	PCAP	LOLE	0.1 days per year	Every 2 years
Eastern Utilities	Dominion Energy South Carolina	UCAP	LOLE	0.1 days per year	Every 3 years with annual updates
	Duke Energy Carolinas	UCAP	LOLE	0.1 days per year	Every 2 years
	Florida Power and Light	ICAP	LOLP	0.1 days per year	Every year
RTOs & Resource Adequacy Programs	ISO New England	ICAP (seasonal)	LOLE	0.1 days per year	Every 2 years
	New York ISO	UCAP	LOLE	0.1 days per year	Every 2 years
	Midcontinent ISO	UCAP	LOLE	0.1 days per year	Every 2 years
	PJM	UCAP	LOLE	0.1 days per year	Every year

7.4 Resource Accreditation

Several markets already rely on ELCC for accreditation of at least one technology, and most others are in the process of transitioning towards ELCC or are actively considering its implementation.

The table below summarizes the current status and framework of ELCC across the various organized capacity markets and resource adequacy programs throughout North America.

While most uses of ELCC to date have focused on renewables (and, to a lesser extent, energy storage), the conceptual framework is broadly applicable to all resource types. No resource is truly perfect, but all resources' contribution to reliability can be measured using an ELCC framework. The broad application of ELCC for resource accreditation across all types of resources provides the strongest foundation for a robust resource adequacy planning framework into the future, as it would treat all resources on an equitable basis.

Table 5. Resource Accreditation Summary

	Utility/Jurisdiction	Resource Accreditation Framework
Canadian Utilities	Nova Scotia Power, Inc.	• ELCC for renewable resources (wind, solar and hydro) • Proposed ELCC methodology for storage and demand response in their next capacity value study • UCAP for thermal

	Manitoba Hydro	• Variable resources are assigned a seasonal partial credit for their firm capacity contribution • UCAP for thermal
	Newfoundland Hydro	• ELCC for solar • UCAP for thermal
Southwest Utilities	Arizona Public Service Co	• ELCC for solar, storage, wind, and demand response • UCAP for thermal (expects to move to ELCC for 2026)
	El Paso Electric Co	• Currently using ELCC methods to value capacity from all resources, including renewables, storage, and firm in 2021 IRP
Other Western Utilities	Avista Corporation	• Qualifying Capacity Credits (QCC) for solar, wind, storage and DR • ICAP for thermal
	NorthWestern Energy	• ELCC for dispatch limited resources (solar, storage and wind)
	Nevada Power Company	• adopted ELCC method for valuing renewables in Fourth Amendment to 2018 Joint Triennial Integrated Resource Plan filed in 2020 • UCAP for thermal
	Portland General Electric	• Currently using ELCC methods to measure capacity value of renewables and storage resources in IRP planning • Using UCAP accounting for thermal resources
	Black Hills Energy - Colorado	• ELCC for dispatch limited resources (solar, storage and wind) • ICAP for thermal
	Puget Sound Energy	• ELCC for solar, wind, storage and demand response • ELCC for new generic thermal, ICAP for existing thermal
Eastern Utilities	Dominion Energy South Carolina	• ELCC methodology for solar and storage • Using UCAP accounting for thermal resources
	Duke Energy Carolinas	• ELCC for dispatch limited resources (solar, storage and wind) • Using UCAP accounting for thermal resources
	Florida Power and Light	• Firm capacity value calculated for summer and winter peak hours depending on site location, technology, design, and the total amount of solar that is operating on FPL' system
RTOs & Resource Adequacy Programs	New York ISO	• ELCC for solar, storage and wind • UCAP for thermal (EFORd-based)
	Midcontinent ISO	• DLOL • UCAP for thermal (EFORd-based)
	PJM	• Average ELCC for wind, solar and storage • UCAP for thermal (EFORd-based) Marginal ELCC for all resources

7.5 RA's Application for Resource Procurement

Resource procurement refers to the processes and mechanisms through which utilities secure enough energy supply to meet the current and future demand. This need determination is typically identified through a resource adequacy study, however the way in which it is utilized can differ across jurisdictions and there is no one defined way to approach. This section examines the application of RA in the resource procurement process.

This scan is based on a review of publicly available utility findings, regulatory decisions and industry reports. The comparative assessment provides a high-level overview of the commonalities, divergences and emerging trends in procurement frameworks across jurisdictions.

Table 6. RA application for Resource Procurement

	Utility/Jurisdiction	Use of RA Analysis in Resource Procurement Process
Canadian Utilities	Nova Scotia Power, Inc.	Yes, the 2024 10-Year System outlook report included 600 MW of new fast-acting generation to be installed by 2030 to maintain supply reliability while meeting growing demand requirements. Procurement responsibility transferred to Nova Scotia Independent Energy System Operator (NSIESO) in Fall 2024.
	Manitoba Hydro	Yes, the 2023 IRP identified a system need to meet reliability requirements as demand is expected to double in the next 20 years. Manitoba Hydro is in the process of procuring 600 MW of new wind energy , having issued an EOI in June 2025 and in the process of issuing an RFP. Expecting construction schedules to begin as early as spring 2027 and be commercially operable by 2029.
	Newfoundland Hydro	Yes, the 2024 Resource Adequacy Plan identified the Minimum Investment Required to ensure adequate system supply. In June 2025, it issued a request for expression of interest (RFEI) for up to 150 MW of firm capacity
Southwest Utilities	Arizona Public Service Co	Yes, the 2023 IRP identified a system need to meet reliability requirements and add renewable energy resources to the system, this was followed by an All-Source RFP published in June 2023.
	El Paso Electric Co	Yes, the 2017 Load Forecast showed EPE would need additional capacity beginning 2022 as a result of firm resource retirements. EPE published an All Source RFP in June 2017, which selected Newman Unit 6 and was approved a CCN by the PUCT in 2020. NM6 became commercially operational in December 2023.
Other Western Utilities	Avista Corporation	Yes, the 2025 IRP identified an energy resource shortfall within the next four years, this triggered an All-Source RFP in May 2025 to procure the necessary resources.
	NorthWestern Energy	Yes, the 2024 South Dakota IRP identified a capacity deficit in the near term. In August 2025, it published an All-Source RFP to procure this capacity and be available for delivery by the end of 2029.
	Nevada Power Company	Yes, defined future resource need in 2024 IRP and subsequently published an RFP to procure the needed resources.

	Portland General Electric	Yes, PGE published an RFP in July 2025 to contract resources necessary to meet its long-term energy and capacity needs as identified in PGE's 2023 Clean Energy Plan/IRP action plan.
	Black Hills Energy - Colorado	Yes, as part of the Electric Resource Plan (ERP) , BHE published a 2030 Clean Energy Plan in 2022 which identified resource needs for the near future. In July 2023, it filed a competitive bid solicitation by issuing a 2030 Ready RFP for resources to come online in 2026 and 2027. In 2024 it submitted it's 120-Day report with the preferred portfolio for review and approval by the Colorado PUC.
	Puget Sound Energy	Yes, Pursuant to Washington Utilities and Transportation Commission Purchases of Resources rules (WAC 480-107), PSE must file an All-Source Request for Proposals when the Integrated Resource Plan identifies a resource need within the next four years. PSE may also issue targeted and voluntary RFPs on an as-needed basis.
Eastern Utilities	Dominion Energy South Carolina	Yes, DESC identifies system needs in the IRP by comparing forecast load + required reserve margin against the expected capacity of its fleet, adjusted for retirements and resource performance. This is anchored in the Reserve Margin Study but not yet a full probabilistic LOLP standard. Once a gap is identified, that triggers consideration of new resources and potentially competitive solicitations. Dominion SC is in the process of replacing aging thermal resources in order to maintain system reliability.
	Duke Energy Carolinas	Yes, the 2022 IRP identified the need for new capacity to reliably serve Duke Energy's projected customer load. In 2023, Duke Energy published an RFP for new solar capacity to be in service by 2028.
	Florida Power and Light	Partially, while RA is considered during FPL's Resource Planning work, resource procurement decisions have historically been based on an economic analysis.
RTOs & Resource Adequacy Programs	ISO New England	For all ISOs in this table, each uses the total reliability need and the resource capacity values from LOLP analysis to inform a centrally-cleared capacity auction.
	New York ISO	
	Midcontinent ISO	
	PJM	

7.6 Detailed Case Studies

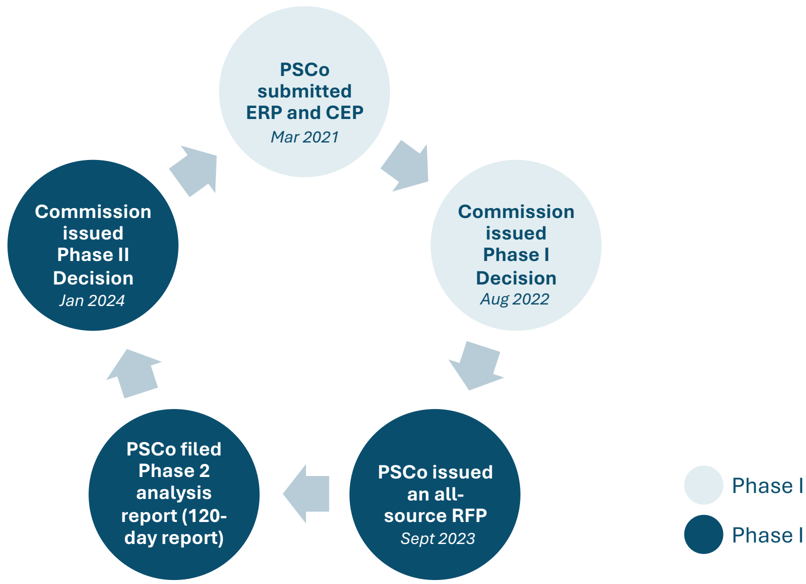
The section below chooses a few of the jurisdictions above to illustrate the use of resource adequacy justification for new resource capacity. These examples are meant to illustrate the different processes in North America and provide insight into the pros and cons of each process.

7.6.1 Xcel Energy Colorado ("PSCo")

7.6.1.1 Why This Case Matters

This PSCo example demonstrates how a quantified RA shortfall moved the Commission from long-term planning to procuring new capacity and then prompted an additional interim solicitation when long-term RA risk persisted.

Figure 22. PSCo ERP & CEP Process Cycle (with 2021 Cycle Procedural Timeline)



7.6.1.2 Existing Planning Practices

In Colorado, the planning and procurement phase is tied together in a two-phase approach. In Phase 1, The Colorado Public Utilities Commission (PUC) directs Colorado utilities to file an Electric Resource Plan (ERP) and Clean Energy Plan (CEP) every 4-5 years. When Phase 1 is approved, Phase 2 directly follows in the form of a request for proposal (RFP), with the results from the ERP and CEP informing the incremental resource procurement need.

Like many integrated resource planning processes, Phase 1 is a long-term planning exercise where Xcel Energy Colorado (PSCo) produces a set of inputs and assumptions and uses energy systems modeling to inform the future resource needs. To inform the incremental resource needs, PSCo performs a variety of technical analyses, including:

- **Long-term capacity expansion modeling:** Producing multiple optimized portfolios under different fuel price, carbon, and technology cost scenarios, while satisfying reliability and policy constraints.
- **Resource adequacy modeling:** Perform both before and after the capacity expansion portfolio modeling to 1) develop TRN and ELCC assumptions, and 2) ensure each portfolio meets a reliability target of 0.1 LOLE.

- **Transmission planning:** Identifying transmission upgrades needed to integrate new resources.
- **Policy Compliance:** Ensuring portfolios meet statutory clean energy targets

This analytical process typically takes 2-3 years to develop an ERP and CEP. Once completed, PSCo files their ERP and CEP with the commission and is litigated through several testimony and discovery, phases, and ultimately ending with either a settlement or final hearing at the PUC. At the end, the PUC issues a Phase 1 decision, which, if approved, authorizes Phase 2, a competitive solicitation for new resources, including demand-side resources.

Phase 2 is monitored by an independent monitor, and the utility applies similar technical analysis in Phase 1, but tests specific bids received in the RFP. The bid evaluation, portfolio analysis, and stakeholder review typically take 12–18 months. After all the technical analysis, final approval from the PUC on the selected portfolio (the "Preferred Plan") usually comes about 2–3 years after the initial ERP filing.

7.6.1.3 Chronology and Results of the 2021 ERP/CEP

7.6.1.3.1 Phase I

In March 2021, PSCo submitted its 2021 Electric Resource Plan and Clean Energy Plan to the Colorado (PUC).[14] In the ERP, PSCo's resource need was driven by the State of Colorado's 80% carbon emission reductions by 2030 and an identified 1,521 MW firm capacity need by 2028.[15] On August 3, 2022, the Commission issued Decision No. C22-0459 ("Phase I Decision") and approved the findings from Phase 1. This authorized PSCo to implement a competitive bidding process for acquiring cost-effective resources to meet its projected resource needs from 2022 through 2028.

7.6.1.3.2 Phase II

In September 2023, following Phase 1 approval, PSCo issued an all-source RFP and later filed its Phase 2 analysis report, known as the 120-day Report. In January 2024, the Colorado PUC issued its Phase II Decision and approved a modified resource portfolio and associated transmission investments.

The commission authorized PSCo to pursue the acquisition of more than 5,800 MW of new resources that were included in the approved resource portfolio. The approved resource bids comprised 9 company-owned resources and 11 contracted projects, covering the following:

- **Solar**: 1,720 MW
- **Wind**: 2,053 MW
- **Storage**: 1,848 MW
- **Natural Gas**: 669 MW

[14] https://www.dora.state.co.us/pls/efi/efi_p2_v2_demo.show_document?p_dms_document_id=949918
[15] https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20%26%20Regulations/PUBLIC%202021%20ERP%20%26%20CEP_120-Day%20Report_FINAL.pdf

According the PSCo's modeling, the combined resource MW contribution to the load and resource balance procured was 1,621MW in 2028, 100MW over the incremental need identified.

7.6.1.4 Role of Resource Adequacy in Procurement

The incremental 5.8GW portfolio of approved resources surpasses the state's 2030 clean energy target. While meeting carbon reduction targets was a large consideration of the resource procured, PSCo projects a capacity shortfall with the preferred portfolio in the 2030 system. Despite the large procurement, the remaining resource procurement needs in 2030 will require PSCo to continue to procure enough to maintain an adequate position.

Figure 23: 2021 ERP/CEP Phase 2 Load & Resource Balance Table (Post-Commission Approval)

Table 3 - Load and Resources Table, Preferred Plan 2023-2030[10]

PSCo L&R Table (MW) for Summer Peak	2024	2025	2026	2027	2028	2029	2030	
Existing Resources	7,911	7,948	7,323	6,764	6,109	5,943	5,960	
Preferred Plan Resources	-	-	352	1,354	1,621	1,649	1,626	
TOTAL ACCREDITED CAPACITY	**7,911**	**7,948**	**7,675**	**8,118**	**7,730**	**7,592**	**7,586**	A
Native Load Forecast	7,157	7,224	6,960	7,037	7,136	7,247	7,374	
Demand Response	(593)	(618)	(652)	(631)	(679)	(725)	(767)	
FIRM OBLIGATION LOAD	**6,564**	**6,606**	**6,308**	**6,406**	**6,457**	**6,522**	**6,607**	B
Target Planning Reserve Margin %	*19.2%*	*19.2%*	*19.1%*	*18.0%*	*18.0%*	*18.0%*	*18.0%*	
Target Planning Reserve Margin	1,260	1,268	1,205	1,153	1,162	1,174	1,189	
IREA & HCEA Backup Reserves	48	48	11	11	11	11	11	
TOTAL PLANNING RESERVE MARGIN TARGET	**1,308**	**1,316**	**1,216**	**1,164**	**1,173**	**1,185**	**1,200**	C
CAPACITY NEED	7,873	7,923	7,524	7,570	7,630	7,707	7,807	B+C
ACTUAL RESERVE MARGIN	1,347	1,342	1,367	1,712	1,273	1,070	979	A-B
Actual Reserve Margin %	*20.5%*	*20.3%*	*21.7%*	*26.7%*	*19.7%*			
CAPACITY POSITION: LONG/(SHORT)	**39**	**26**	**151**	**548**	**100**	**(115)**	**(221)**	A-B-C

Due to the shortfall identified in 2030, the Commission further authorized PSCo to initiate an interim ERP called the Just Transition Solicitation ("JTS") focused on meeting the projected resource needs for the years 2029, 2030, and 2031. The Phase 1 report for the JTS is currently being litigated (as of Aug 2025), and the findings from the Phase 1 report have not been approved. The main findings show that the capacity needed has grown further due to an increase in large loads and their initial inadequate position.[16]

[16] JTS Report: https://www.dora.state.co.us/pls/efi/efi_p2_v2_demo.show_document?p_dms_document_id=1029504&p_session_id=

Figure 24: JTS Phase 1 Reported Summer Resource Capacity Need (MW)

Table JTL-D-2 Summer Resource Capacity Need (MW)
(needs as of summer of year shown)

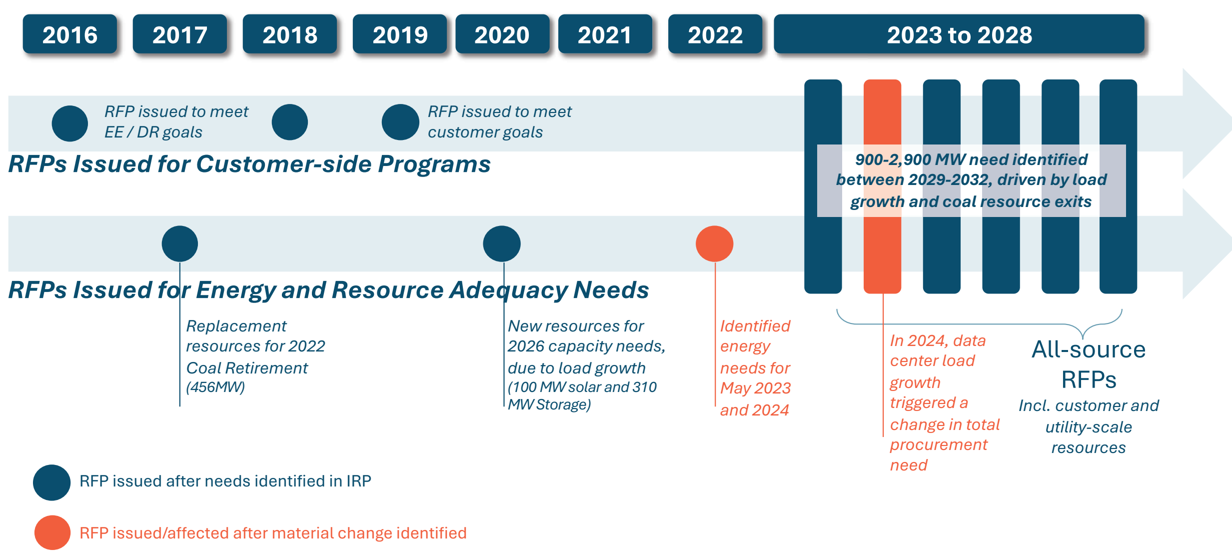
Summer	2024	2025	2026	2027	2028	2029	2030	2031
Capacity Need (MW)	378	646	534	237	631	1,517	2,253	3,177

7.6.2 Public Service of New Mexico ("PNM")

7.6.2.1 Why This Case Matters

This PNM example demonstrates how analysis to justify multiple and successive RFPs. The focus for each RFP differ but all aim to position PNM to transition its portfolio to cleaner energy to meet its 2045 100% carbon-free target and meet growing customer demand. In the past decade, PNM has issued a multiple RFPs, below is a chronology of the various RFPs issued between 2016 and today.

Figure 25. Chronology of RFPs Issued by PNM (Since 2016)



7.6.2.2 Brief Description and Chronology of each RFP

- **2016:** PNM sought bids for their Commercial & Industrial (C&I) Demand Response (DR) Program. The program was intended to be part of the utility's broader portfolio of energy efficiency initiatives. 17
- **2017:** PNM issued an RFP for 456 megawatts (MW) of new resources. This was part of the company's plan to replace generation from the coal-fired San Juan Generating Station,

[17] https://www.pnm.com/documents/28767612/28792746/PNM+CI+DR+RFP_Jan+25+2016v2.pdf/b669c9aa-7b03-4700-8556-08751dfaccb7?t=1453768593219

which was scheduled to close by the end of 2022. In addition, a separate RFP was issued for its Demand Response Program. 18

- **2018 and 2019:** PNM issued an RFP for additional MW for their C&I Demand Response Program.
- **2020:** In preparation for its 2026 peak load requirements, PNM's competitive RFP for new utility-scale resources, resulting in 100 MW of solar energy and 310 MW of battery storage. The selection aimed to ensure system reliability and align with goals set in the 2020 Integrated Resource Plan (IRP). 19
- **2022:** PNM filed a Material Change with the NM Public Service Commission after identifying an energy shortage Short- and Long-Term Resources: A formal RFP was issued for up to 700 MW of new resources to come online by May 2023 or May 2024 to address concerns about a potential energy shortage.20
- **2024-28:** PNM issued an All-Source RFP for 2029–2032 after identifying needs from its findings from the 2023 IRP, the all-source RFP for 900–2,900 MW of new capacity to come online between 2029 and 2032. These resources were primarily intended to replace power from the Four Corners Power Plant, which PNM is exiting in 2031. These are expected to be

7.6.2.3 RFPs are signaled through IRP and reviewed by the NMPRC

Before each RFP is officially released, PNM files a plan document with the NMPRC seeking authorization for the procurement. For the purposes of this report, E3 focuses on understand the the 2024 RFP for resources coming online 2029–2032.

- **Public notice:** When PNM releases an RFP, a formal notice is posted on its website. It also files information with the NMPRC, making the procurement a matter of public record.
- **Independent evaluation and selection:** An independent evaluator typically oversees the RFP process to ensure a fair and competitive selection. The evaluator assists in developing the evaluation methodology and determines a shortlist of bids.
- **Post-selection application:** After proposals are received and evaluated, the final selected resources are filed with the NMPRC for review and approval. This application includes details on the chosen resources and may require a Certificate of Public Convenience and Necessity (CCN) for utility-owned assets.
- **Regulatory hearing:** The NMPRC conducts a public proceeding on the application. This can include hearings where intervenors and NMPRC staff review the selected resources, the bidding process, and potential cost implications for customers.
- **Commission order:** The commission ultimately issues an order either approving, denying, or modifying PNM's application. The process can take more than a year

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[18] https://www.utilitydive.com/news/pnm-issues-rfp-for-456-mw-of-resources-pushing-for-renewables-and-storage/509846/#:~:text=Dive%20Brief:,Palo%20Verde%20Nuclear%20Generating%20Station.

[19] https://www.txnmenergy.com/~/media/Files/P/PNM-Resources/rates-and-filings/2026%20Resource%20Filing/Application/2%20%20Executive_Summary.pdf

[20] https://www.pnm.com/documents/28767612/29865400/NEWS+RELEASE+-+PNM+issues+request+for+new+resources+to+manage+combined+impact+of+climate+change+regulatory+delays+and+supply+chain+issues.pdf/cedb47cf-04fc-ca77-fcc0-2cb1adcb567f?t=1653331187224

8. Appendix C: Resource Adequacy Assessment Tool Guide: EPRI Resource Adequacy Assessment Framework

This EPRI report focuses on understanding the main options available in commercial and research RA tools and aims to develop an understanding of existing RA tool gaps. It is not meant to be a comparison or cataloging of each adequacy tool or software, but rather an opportunity to understand where the industry stands as a whole in 2024. Responses to a request for information put forward as part of the initiative, in addition to subsequent discussions with both participating tool providers and participating members, form the basis for the analysis presented here.

Download the technical report here

9. Appendix D: Expert Witness Information

This appendix includes the Expert Witness Acknowledgement Form and the curriculum vitae of Mr. Arne Olson, Senior Partner at Energy and Environmental Economics (E3). Mr. Olson served as the lead technical advisor for this study and will appear as an expert witness before the New Brunswick Energy and Utilities Board (NBEUB) in support of this report and its conclusions.

Information begins on the following page.

Matter No. EL-002-2025

NEW BRUNSWICK ENERGY AND UTILITIES BOARD

EXPERT WITNESS ACKNOWLEDGEMENT
(Rule 6.3)

In Relation to an Application by: New Brunswick Power Corporation

In Accordance with: Subsection 107(2) of the Electricity Act, SNB 2013 c. E-7 (the *"Electricity Act"* or the *"Act"*).

I, Arne Olson, of San Francisco, CA, USA hereby confirm that:

1. I have been engaged by or on behalf of New Brunswick Power Corporation to provide evidence in relation to the above-noted proceeding before the New Brunswick Energy and Utilities Board.
2. I acknowledge that it is my duty to provide evidence in relation to this proceeding as follows:
   a) to provide opinion evidence that is fair, objective and non-partisan;
   b) to provide opinion evidence that is related only to matters that are within my area of expertise; and
   c) to provide such additional assistance as the Board may reasonably require, to determine a matter in issue in this proceeding.
3. I acknowledge that the duty referred to above prevails over any obligation which I may owe to any party by whom or on whose behalf I am engaged.

Dated the 3rd day of August, 2025.

Arne Olson

Arne Olson

44 Montgomery Street, Suite 1500, San Francisco, CA 94104
arne@ethree.com

ENERGY AND ENVIRONMENTAL ECONOMICS, INC. San Francisco, CA
Senior Partner

Mr. Olson has over 30 years of experience in energy analysis. He joined E3 in 2002 and became a partner in 2010. Mr. Olson leads E3's Integrated System Planning practice area helping clients navigate changes to bulk electric system operations and investment needs brought about by increasing policy and market interest in clean and renewable energy sources. He has led a number of landmark studies of the feasibility and cost of achieving deep decarbonization and high renewable penetration goals, including studies of 100% renewable and net zero energy systems in New England, California, the Pacific Northwest and the Midwest. He consults extensively for utilities, asset owners, project developers and electricity consumers in support of resource planning and commercial transactions involving renewable, conventional and energy storage resources. He also provides technical and strategic support to numerous utility regulators, state agencies and environmental organizations. He is a frequent conference speaker and has provided expert witness testimony in regulatory and legal proceedings in California, Oregon, Montana, Colorado, New Mexico, North Carolina, South Carolina, Georgia, Alberta, Nova Scotia and Ontario. Prior to joining E3 in 2002, he served for six years in the Energy Policy Division of the Washington State Energy Office and its successor agencies.

Mr. Olson has led the development of E3's industry-leading resource planning software including the RESOLVE model that develops optimal portfolios of renewable, conventional and energy storage resources and the RECAP model that calculates Loss-of-Load Probability and related statistics to ensure that power systems can meet load reliably under high renewable penetrations. His clients have included major utilities and market participants across North America including the California Independent System Operator, Pacific Gas and Electric, Southern California Edison, Sacramento Municipal Utilities District, Los Angeles Department of Water and Power, Puget Sound Energy, PacifiCorp, Portland General Electric, the Bonneville Power Administration, NorthWestern Energy, Arizona Public Service, Salt River Project, El Paso Electric, Omaha Public Power District, Xcel Energy, Florida Power & Light, Tampa Electric Company, Nova Scotia Power, NB Power, Manitoba Hydro, SaskPower, Hydro-Quebec TransEnergie, TransElect, Long Island Power Authority, Calpine, NextEra, NRG, TransAlta, and others. He also works extensively with government agencies and industry organizations such as the California Public Utilities Commission, California Energy Commission, Oregon Public Utilities Commission, the Western Electric Coordinating Council, the Western Interstate Energy Board, the New York State Research and Development Authority, Illinois Power Authority, National Association of Regulatory Utility Commissioners, and others.

Electricity Resource Adequacy:

Mr. Olson is a prominent expert on resource adequacy issues and has led many projects that evaluate the need for effective capacity to ensure resource adequacy during the clean energy transition. Examples include:

- Led a team that prepared a Planning Reserve Margin and Effective Load-Carrying Capability study for FPL and testified on behalf of the company in 2025 in an electric rate case on the company's capacity needs and the contribution of solar, batteries, and thermal generation toward those needs.
- Led a team that prepared an ELCC study for NorthWestern Energy and testified on behalf of the company in 2025 in an electric rate case on the capacity contribution of wind, solar and energy storage resources.
- Led a team that performed a Planning Reserve Margin and ELCC study on behalf of Yukon Energy.
- Led a team that performed a Planning Reserve Margin and ELCC study on behalf of New Brunswick power and utilized those outputs to evaluate the potential value of new nuclear and other forms of generation for the company in the future.
- Led a team that performed a Planning Reserve Margin and ELCC study on behalf of El Paso Electric and used the study to inform its resource planning and procurement activities.
- Advised MISO on need determination and resource accreditation as part of a package of reforms to MISO's Planning Resource Auction.
- Advising the California Public Utilities Commission in developing a proposed Reliable Clean Power Procurement Program that would reform the way the state's Load-Serving Entities procure reliability and clean energy attributes.
- Advised the Public Utilities Commission of Texas on proposed reforms to the ERCOT market to address resource adequacy needs.
- Advised Calpine Corporation on generator accreditation issues for capacity markets in ISO-NE and PJM including addressing thermal generator limitations associated with lack of fuel availability.
- Developed new resource adequacy standards and models for the Hawaiian Electric Company's five island systems.
- Advised the New York Independent System Operator on application of ELCC concepts to renewable resources within the context of NYISO's Installed Capacity (ICAP) market.
- Prepared the study *Resource Adequacy in the Desert Southwest* on behalf of a consortium of Southwest utilities that concluded urgent action is needed to develop new resources to ensure the region can continue to provide reliable power supplies in response to returning electric load growth, planned and anticipated resource retirements, and a changing supply mix.
- Led a team that was retained by NRG and Exelon to develop a concrete proposal for a Load-Serving Entity Reliability Obligation to provide forward price signals necessary to ensure resource adequacy in the Electric Reliability Council of Texas (ERCOT) market.
- Led a team including former U.S. Energy Secretary Ernest Moniz and the Energy Futures Initiative that published *Net Zero New England*, a study of electricity system reliability under economy-wide target of net zero carbon emissions. The study included significant electric load growth due to electrification of transportation and building sector end uses along with the incorporation of vast quantities of solar and wind generation.
- Advised PJM Interconnection on application of ELCC concepts to renewable resources within the context of PJM's Reliability Pricing Model (RPM) forward capacity market.

- Leads a multi-company team that supports the California Public Utilities Commission (CPUC) staff for the Integrated Resource Planning (IRP) Proceeding. The IRP proceeding is considering the need for new capacity resources to ensure resource adequacy in California.
- Prepared a report on regional resource adequacy programs in support of the Northwest Power Pool's effort to stand up such a program in the Pacific Northwest. The study evaluated regional programs operated by each of the major market operators in North America for their potential application to the unique circumstances of the Pacific Northwest.
- Led a team that developed the Renewable Energy Capacity Planning (RECAP) Model, a loss-of-load probability (LOLP) model designed explicitly to measure the need for capacity on highly renewable electricity systems, as well as the contribution of dispatch-limited resources such as wind, solar, energy storage and demand response toward meeting those needs.
- Has led numerous teams that utilized RECAP to calculate resource needs, Planning Reserve Margins (PRMs), and Effective Load-Carrying Capability (ELCC) values for dispatch-limited resources for clients including the California ISO, California PUC, Western Electric Coordinating Councils, Portland General Electric, Hawaiian Electric Company, Los Angeles Department of Water and Power, Sacramento Municipal Utilities District, NorthWestern Energy, Northwest Power Pool, Xcel Energy, NV Energy, El Paso Electric, Nova Scotia Power, Calpine Corporation, and others.
- Evaluated the need for "clean firm" capacity to ensure reliable electric service under 100% carbon reduction scenarios for California, sponsored by the Environmental Defense Fund and the Clean Air Task Force.
- Reviewed Duke Energy Carolinas and Duke Energy Progress's IRPs on behalf of Cypress Creek Renewables and Carolinas Clean Energy Business Association and provided expert witness testimony in North Carolina and South Carolina regarding Duke's resource adequacy studies, the capacity value attributed to solar and battery storage resources, and their incorporation in Duke's capacity expansion modeling.
- Led a project team that evaluated alternative methods for calculating the capacity value of solar resources on behalf of the Oregon Public Utilities Commission staff.
- Led a team in 2019-2020 that utilized RECAP to calculate the capacity contribution of demand response and energy storage resources in California using the ELCC method on behalf of the California ISO.
- Served as expert witness in a wholesale market tariffs case for Nova Scotia Power, considering issues related to effective capacity determination for third-party resources.
- Led a team in 2019 that evaluated what types of resources would be needed to maintain resource adequacy in a deeply-decarbonized, 2050 California electricity system, in a study sponsored by the Calpine Corporation.
- For a group of 13 utilities in the Pacific Northwest, led studies in 2017 and 2018 that examined scenarios achieving 50% renewables and up to 100% carbon reductions across the region, focusing on policy mechanisms to achieve the goals at least cost and on the nature and quantity of complementary resources that are needed to maintain reliable electric service.
- For the Los Angeles Department of Water and Power, led a study that evaluated the reliability implications of closing three in-city natural gas-fired generating stations and replacing them with alternative resource portfolios including new gas, demand response, solar energy, energy storage and new transmission.
- Evaluated flexible capacity needs under high renewable penetration across the Western Interconnection on behalf of the Western Electric Coordinating Council and the Western Interstate Energy Board. The team included technical contributions from E3, NREL and Energy Exemplar.

- Performed analysis on behalf of Calpine and presented to the California Public Utilities Commission (CPUC) to recommend the use of the effective load carrying capability (ELCC) metric in the Resource Adequacy (RA) program for wind and solar resources. The CPUC ultimately adopted this recommendation along with several market design features proposed by E3.

Electricity Resource Planning and Decarbonization:

Mr. Olson has led numerous projects supporting utility system integrated resource planning efforts. Many of these projects have considered the cost, reliability and operational implications of achieving very high levels of renewables. Examples include:

- Led a team that performed a Planning Reserve Margin and ELCC study on behalf of New Brunswick power and utilized those outputs to evaluate the potential value of new nuclear and other forms of generation for the company in the future.
- Leading a team that is evaluating the potential role of offshore wind in the future energy mix of the Atlantic Canada region on behalf of Net Zero Atlantic.
- Leading a team that is providing a variety of integrated resource planning support for El Paso Electric including a PRM and ELCC study, portfolio optimization and production cost modeling in PLEXOS, RFP and bid evaluation support, resource planning to serve new large loads, and others.
- Advising SaskPower in developing their first integrated system planning process.
- Advising Manitoba Hydro in conducting their first integrated resource plan.
- Advised the Salt River Project in 2023-2024 in conducting their first integrated system plan consisting of generation, transmission, distribution and customer resource planning. E3 helped SRP design and implement the ISP process.
- Evaluated alternative policy options for achieving a deep decarbonization and high penetrations of clean energy resources across the PJM system. The study considers alternative clean energy policy mechanisms and geographic footprints.
- Led a team including former U.S. Energy Secretary Ernest Moniz and the Energy Futures Initiative that evaluated economy-wide deep decarbonization pathways for New England. The *Net Zero New England* study considers alternative scenarios for building decarbonization including High Fuels and High Electrification scenarios, as well as optimal portfolios of electricity resources to meet electric demand reliably while reducing carbon emissions to 2-3 MMT by 2050. Alternative resources considered include onshore and offshore wind, ground-mounted and rooftop solar, imported hydroelectric power, conventional and advanced nuclear power, fossil generation with carbon capture and sequestration, and hydrogen.
- Provided full modeling support for El Paso Electric Company's 2021 IRP including loss-of-load probability modeling to determine EPE's planning reserve margin, portfolio modeling using RESOLVE and PLEXOS, and evaluation of bids from EPE's subsequent all-source RFP.
- Led a team that studied regional transmission and clean energy projects on behalf of four Atlantic Canada provinces, several utilities, and Natural Resources Canada.
- Leads a team that is developed an economy-wide deep decarbonization study for a large, dual-fueled Midwestern utility.
- Provided extensive support for Nova Scotia Power's 2020 Integrated Resource Plan, which seeks to reduce carbon emissions by over 90% by replacing coal generation with a combination of in-province clean energy resources as well as potential clean imports.

- Leads a team at E3 that has supported the California Public Utilities Commission staff since 2014 in developing an electricity Reference System Plan for California and designing and implementing integrated resource planning standards for California load-serving entities.
- For the Sacramento Municipal Utilities District, led the development of their 2018 IRP which considered scenarios and resource portfolios for meeting California's and SMUD's own aggressive renewables goals including 100% renewables by 2040 and provides ongoing IRP and strategic planning support.
- For Xcel Energy, led an effort to support development of Northern States Power's 2018-19 IRP examining high renewable scenarios within the context of the company's stated goal of completely decarbonizing their electric resource portfolio by 2050.
- In 2018, led a study of the value of partially- and fully-dispatchable solar and solar+storage power plants on the Tampa Electric Company (TECO) system. The study was funded by First Solar but it involved extensive participation by a wide range of TECO staff and included detailed TECO power system data. The study was recognized by Public Utilities Fortnightly as among its 2018 Top Innovators and nominated as a finalist for the Smart Electric Power Alliance 2019 Power Players Award in the Change Agent of the Year category, and for the 2019 Platts Global Energy Awards in the Grid Edge category.
- For a group comprising the five largest utilities in California (Los Angeles Department of Water and Power, Pacific Gas and Electric Company, Sacramento Municipal Utilities District, San Diego Gas & Electric Company, and Southern California Edison), I led a landmark 2014 study of the feasibility, cost implications and complementary measures for achieving 50% renewables by 2030.
- Participated in several other E3 resource planning studies of achieving very high renewable penetrations for the Hawaiian Electric Company, the New York State Energy Research and Development Authority, and several electric utilities in the Southwest.
- For Portland Generic Electric, led a team that evaluated the need for resource adequacy capacity and flexible generation capacity in 2014-2016.
- For the Western Electric Coordinating Council and Western Interstate Energy Board, led teams that assessed electricity-natural gas infrastructure issues with regards to electric sector reliability under a changing resource mix including reduced reliance on coal generation and increased reliance on variable renewables and natural gas generation.
- For the Sacramento Municipal Utilities District, led a team that investigated the capacity contribution of new wind, solar and demand response (DR) resources.
- For the Colorado Public Utilities Commission, assisted in developing long-term scenarios to use across a range of energy infrastructure planning dockets.
- Provided expert testimony in front of the California Public Utilities Commission on rates and revenue requirements associated with several alternative portfolios of demand-side and supply-side resources, on behalf of Pacific Gas and Electric Company, Southern California Edison, and San Diego Gas & Electric.
- Served as lead investigator in assisting the California Public Utilities Commission (CPUC) in its efforts to reform the long-term procurement planning process in order to allow California to meet its aggressive renewable energy and greenhouse gas reduction policy goals.
- On behalf of the CPUC, investigated a number of strategies for achieving a 33% Renewables Portfolio Standard in California by 2020, and estimated their likely cost and rate impacts using the 33% RPS Calculator, a publicly-available spreadsheet model developed for this project.
- Served as lead investigator in developing integrated resource plans for numerous publicly-owned utilities including PNGC Power, Lower Valley Energy, Umatilla Electric Cooperative and Platte River Power Authority.

- Investigated for Bonneville Power Administration (BPA) the economics and feasibility of investing in new, long-line transmission facilities connecting load centers in the Pacific Northwest with remote areas that contain large concentrations of high-quality renewable energy resources. The study informed BPA about cost-effective strategies for procuring renewable energy supplies in order to meet current and potential future renewable renewables portfolio standards and greenhouse gas reduction targets.

Asset Valuation:

- Provides market evaluation and strategic advisory services for numerous asset owners and developers in California, the Southwest and the Pacific Northwest.
- Leads a team that develops medium- and long-term market price forecasts for energy, capacity, ancillary services and renewable energy credits (RECs) under very high renewable energy penetration at various market pricing points in the Western Interconnection.
- Led the team that developed renewable and conventional resource cost and performance characteristics for use in the WECC's Regional Transmission Expansion Planning process.
- On behalf of the Wyoming Governor's Office, developed a model of the cost of developing wind resources in Wyoming relative to neighboring states to inform policy debate regarding taxation. The model included detailed representations of state-specific taxes and capacity factors.

Transmission Planning and Pricing:

- Performed economic studies for a consortium of entities in Atlantic Canada including utilities, provincial government ministries, and Natural Resources Canada evaluating the potential economic benefits of the Atlantic Loop, a new HVDC transmission project connecting Quebec, New Brunswick and Nova Scotia.
- Provided educational and strategic advisory services to the Natural Resources Defense Council to inform their advocacy around environmentally beneficial transmission in California and the Western Interconnection.
- Provided generation and transmission asset valuation services to a number of utility and independent developer clients.
- Advising transmission developers seeking approval for projects through the CAISO's Transmission Planning Process.
- Served as technical support to the Western Electric Coordinating Council's Scenario Planning Steering Group (SPSG). The SPSG is developing scenarios for long-term transmission planning in the Western Interconnection.
- Led a team that investigated the use of Production Cost Modeling for the purpose of allocating costs of new transmission facilities on behalf of the Northern Tier Transmission Group and contributed to NTTG's Order 1000 compliance filing.
- Served as an expert witness in front of the Alberta Utilities Commission in a case regarding the Alberta Electric System Operator's proposed methodology for allocating Available Transmission Capacity among interties during times of congestion.
- Retained by a consortium of southwestern utilities and state agencies including the Wyoming Infrastructure Authority, Xcel Colorado, Public Service Company of New Mexico, and the Salt River Project to perform an economic feasibility study of the proposed High Plains Express (HPX) transmission project, a roadmap for transmission development in the Desert Southwest and Rocky Mountain regions.

- Conducted numerous screening studies of long-distance transmission lines connecting to remote renewable energy zones for multiple western utilities.
- Assisted in the development of a methodology for evaluating the renewable energy benefits of the Sunrise Powerlink transmission project in support of expert testimony on behalf of the California ISO.
- Assisted British Columbia Transmission Corporation and Hydro-Quebec TransEnergie with open access transmission tariff design.
- Provided assistance to the Seattle City Council to develop guidelines for the evaluation of large electric distribution and transmission projects by Seattle City Light (SCL). Guidelines specified the types of evaluations SCL should perform and the information the utility should present to the City Council when it seeks approval for large distribution or transmission projects.
- Led several periodic studies between 2009 and 2019 to develop generation and transmission capital cost assumptions for use in WECC's Transmission Expansion Planning and Policy Committee (TEPPC) studies.
- Contributed to a study of the benefits of North-South transmission expansion in Alberta on behalf of AltaLink.
- Performed economic studies on behalf of the BC Energy Ministry evaluating the potential benefits of a new transmission path connecting BC to the Pacific Northwest and California.
- Co-authored *Load-Resource Balance in the Western Interconnection: Towards 2020*, a study of west-wide infrastructure needs for achieving aggressive RPS and greenhouse gas reduction goals in 2020 for the Western Electric Industry Leaders (WEIL) Group, comprised of CEOs and executives from a number of utilities through the West, and presented results indicating that developing new transmission infrastructure to integrate remote renewable resources can result in cost savings for consumers under aggressive policy assumptions.

Market Analysis:

- Leads a team that is conducting an extensive modeling effort for a large group of western utilities to evaluate alternative market options available to them including CAISO's Extended Day-Ahead Market (EDAM), SPP's Markets+, and other configurations.
- Supported an effort by Pacific Northwest utilities to evaluate the benefits and costs of regional capacity planning reserve sharing mechanisms.
- Co-led a study for the California Independent System Operator in 2017 to estimate the benefits of forming an organized regional electricity market across much of the Western Interconnection. The study estimated benefits from more efficient capacity expansion, reduced operating reserves, reduced fuel and O&M costs, reduced renewable curtailment, reduced planning reserve margins, and others.
- Led a study for WECC to estimate the benefits of developing a centralized Energy Imbalance Market (EIM) across the Western Interconnection. The study estimated benefits due to increased generation dispatch efficiency resulting from reduced market barriers and increased load and resource diversity among western Balancing Authorities. Led several follow-up studies of alternative Western EIM footprints for potential EIM participants.
- Led a study to estimate the benefits of EIM participation for Seattle City Light and Chelan County Public Utilities District.
- Participated in studies of the benefits of joining the Western EIM for numerous utilities including PacifiCorp, Portland Generical Electric, Idaho Power, NorthWestern Energy, the Balancing Area of Northern California, Tucson Electric Power, Public Service Company of New Mexico, and the Bonneville Power Administration.

- Represented BC Hydro in RTO West market design process in areas of congestion management, ancillary services, and transmission pricing.

Cost of Service and Rate Design:

- Testified on behalf of Nova Scotia Power on rate designs for the Company's Back-up and Top-up service provided to wholesale customers who procure a portion of their supplies, including the appropriate rates for such service as well as the terms and conditions under which third-party supplies are deemed "firm" and therefore eligible for demand charge reductions.
- For a medium-sized Northwest public utility district, led a team that analyzed financial risks to native ratepayers of fulfilling service requests for significant new quantities of industrial electric loads.
- For a large Northwest rural electric cooperative, developed a new large load policy to provide electricity service at cost-of-service rates while minimizing upward rate pressure on existing customers.
- For a large Northwest rural electric cooperative, developed a cost-of-service model and redesigned retail electric rates to provide customers with incentives to manage growth in electric loads while equitably allocating benefits from low-cost federal hydropower resources.
- For the British Columbia Hydro and Power Authority, assisted with the developed of Stepped Rates for BC Hydro's large industrial customer class.
- For a medium-sized Northwest rural electric cooperative, led a team that evaluated the rate benefits and rate design options of merging its operations with a neighboring utility.
- For a Northwest generation and transmission cooperative, led a team that evaluated alternative options for structuring pooled generation investments, including design of the pool's wholesale rates to its member cooperatives.
- For a Northwest rural electric cooperative, evaluated the benefits of membership in alternative power pool options, including an evaluation of which design's wholesale rate structure was best suited to the utility's load characteristics.

Energy and Climate Policy:

- Developed policy themes and integrated them into the four long-term planning scenarios under consideration by WECC's Scenario Planning Steering Group.
- Led a team that developed a model of deep carbon dioxide emissions reductions scenarios in the western United States and Canada on behalf of the State-Provincial Steering Committee, a body of western state and provincial officials that provides oversight for WECC.
- Led a study of likely changes to power flows and market prices at western electricity trading hubs following California's adoption of a cap-and-trade system for regulating greenhouse gas emissions in 2013.
- For BC Hydro, evaluated the impact of BC's provincial greenhouse gas reduction policies on future electric load as part of BC Hydro's 2011 Integrated Resource Plan.
- Served as advisor, facilitator and drafter to the Interim Committee in developing Idaho's first comprehensive, statewide energy plan in 25 years. The Interim Committee and subcommittees held 18 days of public meetings and received input from dozens of members of the public in developing state-level energy policy recommendations. This process culminated in Mr. Olson drafting the 2007 Idaho Energy Plan, which was approved by the Legislature and adopted as the official state energy plan in March 2007.

- Developed a model that forecasted renewable and conventional generating resources in the WECC region in 2020 as part of an E3 project to advise the California Public Utilities Commission, California Energy Commission and California Air Resources Board about the cost and feasibility of reducing greenhouse gas emissions in the electricity and natural gas sectors.

WASHINGTON OFFICE OF TRADE AND ECONOMIC DEVELOPMENT Olympia, WA
Senior Energy Policy Specialist 1996-2002

- **Electricity Transmission**: Lead responsibility for developing and representing agency policy interests in a variety of regional forums, with a primary focus on pricing and congestion management issues. Lead negotiator on behalf of agency in IndeGO and RTO West negotiations in areas of Congestion Management, Ancillary Services, and Transmission Planning. Participated in numerous subgroups developing issues including congestion zone definition, nature of long-term transmission rights, and RTO role in transmission grid expansion.
- **Western Regional Transmission Association, 1996-2001:** Member, WRTA Board of Directors. Participated in WRTA Tariff, Access and Pricing Committee. Participated in sub-groups examining “seams” issues among multiple independent system operators in the West and developing a proposal for tradable firm transmission rights in the Western interconnection.
- **Wholesale Energy Markets:** Monitored and analyzed trends in electricity, natural gas and petroleum markets. Editor and principal author of Convergence: Natural Gas and Electricity in Washington, a survey of the Northwest’s natural gas industry in the wake of the extreme price events of winter 2000-2001, and on the eve of a significant increase in demand due to gas-fired power plants. Authored legislative testimony on the ability of the Northwest’s natural gas industry to meet the demand from new, gas-fired power plants.
- **Electricity Restructuring:** Co-authored Washington Electricity System Study, legislatively-mandated study of Washington’s electricity system in the context of ongoing trends and potential methods of electric industry restructuring. Authored legislative testimony on the impact of restructuring on retail electricity prices in Washington, electric industry restructuring and Washington’s tax system, and the interactions between restructured electricity and natural gas markets.
- **Energy Data:** Managed three-person energy data team that collected and maintained a repository of state energy data. Developed Washington’s Energy Indicators, a series of policy benchmarks and key trends for Washington’s energy system; second edition published in January 2001.

DECISION ANALYSIS CORPORATION OF VIRGINIA Vienna, VA
Associate 1993-1996

- **Energy Modeling and Analysis:** Developed energy demand forecasting models for Energy Information Administration’s National Energy Modeling System. Results are published each year in EIA’s Annual Energy Outlook.

Education

University of Pennsylvania Philadelphia, PA

Institut de Francais du Petrole — Rueil-Malmaison, France
M.S., International Energy Management & Policy

University of Washington — Seattle, WA
B.S., Mathematical Sciences, B.S. Statistics

Awards and Recognition

Energy Systems Integration Group, 2024 Excellence Award "for a broad range of innovative pathways to align customer pricing with grid needs."

Energy Systems Integration Group, 2023 Excellence Award "for leadership in the evolution and applications of tools and methodologies to enable utilities to decarbonize their systems."

Public Utilities Fortnightly Top Innovators 2018. E3's 2018 study *Investigating the Economic Benefits of Flexible Solar Power Plant Operation* was recognized by Public Utilities Fortnightly leading to an award for the project sponsors.

Expert Witness Testimony

1. *Montana Public Service Commission, 2025, testified on behalf of NorthWestern Energy regarding loss-of-load probability modeling conducted by E3 to calculate the capacity contribution of various resource types toward meeting the company's resource adequacy needs, in support of a rate case application.*

2. *Montana Public Service Commission, 2024, testified on behalf of NorthWestern Energy regarding avoided capacity costs from Qualifying Facilities in a Public Utility Regulatory Policies Act (PURPA) tariff application.*

3. *Georgia Public Service Commission, 2024, testified on behalf of the Southern Renewable Energy Alliance regarding capacity accreditation, capacity expansion modeling, and transmission planning for Georgia Power's 2023 Integrated Resource Plan Update.*

4. *South Carolina Public Service Commission, 2023, testified on behalf of Carolinas Clean Energy Business Association regarding capacity accreditation and integration costs of solar and storage resources for Santee Cooper's 2023 Integrated Resource Plan.*

5. *District Court of Denver, Colorado, 2023, testified on behalf of Xcel Energy in a civil case related to Xcel's planned early closure of the Comanche 3 coal-fired power plant in Pueblo, Colorado.*

6. *Colorado Public Utilities Commission, 2023, testified on behalf of Black Hills Energy regarding resource adequacy and resource portfolio modeling in support of its Energy Resource Plan.*

7. *Georgia Public Service Commission, 2022, testified on behalf of the Georgia Large-Scale Solar Association regarding capacity credits and integration costs attributable to solar and hybrid solar-storage resources in Georgia Power's 2022 Integrated Resource Plan.*

8. *Colorado Public Utilities Commission, 2021, testified on behalf of the Colorado Independent Energy Association regarding the benefits of Xcel Energy's proposed Colorado Pathways Project, and new transmission investment in general, for Colorado electric ratepayers in achieving Colorado's clean energy goals. The Commission approved Xcel's application to construct the project.*

9. *Nova Scotia Utility and Review Board, 2021, testified on behalf of Nova Scotia Power regarding rate designs for the Company's Back-up and Top-up service provided to wholesale customers who procure a portion of their supplies, including the appropriate rates for such service as well as the terms and conditions under which third-party supplies are deemed "firm" and therefore eligible for demand charge reductions. The Board adopted Nova Scotia Power's position in each of the areas in which I testified.*

10. *South Carolina Public Service Commissions, 2021, testified on behalf of the Carolinas Clean Energy Business Association regarding Duke Energy Carolinas and Duke Energy Progress's resource adequacy studies, the capacity value attributed to solar and battery storage resources, and their incorporation in Duke's capacity expansion modeling in their 2020 IRP processes.*

11. *Ontario Superior Court of Justice, 2021, testified on behalf of the Province of Ontario regarding Ontario's Feed-in Tariff policies and the resulting renewable energy contracts. The Court found on behalf of the Province in each area.*

12. *Georgia Public Service Commission, 2020, testified on behalf of the Georgia Large-Scale Solar Association, Georgia Power's Capacity and Energy Payments to Cogenerators Under PURPA and Georgia Power Company's Green Energy Program.*

13. *New Mexico Public Regulation Commission, 2020, testified on behalf of El Paso Electric Company regarding independent analysis that E3 performed of the Company's selection of solar, energy storage and new gas resources stemming from its 2018 all-source capacity solicitation.*

14. *Georgia Public Service Commission, 2019, testified on behalf of the Georgia Large-Scale Solar Association in Georgia Power's Integrated Resource Plan (IRP) proceeding regarding the quantity of large-scale solar energy that Georgia Power could procure in order to maximize customer benefits.*

15. *Oregon Public Utilities Commission, 2017, testified on behalf of Commission staff regarding methodologies for assessing the value of customer-owned solar resources.*

16. *Oregon Public Utilities Commission, 2016, testified on behalf of Portland General Electric Company regarding methodologies for assessing the capacity contribution of variable renewable energy resources.*

17. *Province of Ontario, Commercial Arbitration, 2015, testified regarding policies related to renewable energy procurement and determination of available transmission capacity. The Arbitrator found on behalf of the Province in each of the areas in which I testified.*

18. *California Energy Commission, 2014, testified on behalf of Abengoa and BrightSource Energy regarding the cost and feasibility of distributed generation and energy storage alternatives to a large, concentrating solar power plant project in the context of a power plant siting case.*

19. *California Energy Commission, 2013, testified on behalf of BrightSource Energy regarding the cost and feasibility of distributed generation alternatives to a large, concentrating solar power plant project in the context of a power plant siting case.*

20. *Alberta Electric Utilities Commission, 2012, testified on behalf of Powerex Corporation reviewing industry practices regarding treatment of existing transmission capacity, in the case when new transmission lines are interconnected.*

21. *California Public Utilities Commission, 2011, provided testimony on behalf of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company regarding cost, revenue requirement, average retail rates, and cost of carbon reductions from alternative resource portfolios in the Long-Term Procurement Planning Proceeding.*

22. *California Public Utilities Commission, 2010, testified on behalf of BrightSource Energy and First Solar regarding the need for the he Eldorado-Ivanpah Transmission Project (EITP) proposed by Southern California Edison (SCE) to help integrate over 1000 MW of utility-scale solar generation.*

23. *California Energy Commission, 2010, testified on behalf of BrightSource Energy regarding the cost and feasibility of distributed generation alternatives to a large, concentrating solar power plant project in the context of a power plant siting case. The case successfully resulted in a site license for the Ivanpah Solar Generating Station.*

Publications

1. *Energy Systems Integration Group. 2025. Foundations of Integrated Planning: Defining a Framework for Comprehensive Energy System Planning. A report by the Integrated Planning Task Force. https://www.esig.energy/integrated-planning/, Aaron Burdick, Arne Olson, Madeline McMillan, Debra Lew and Matt Schuerger*

2. *Energy Systems Integration Group. 2025. Optimization for Integrated Electricity System Planning: Opportunities for Integrated Planning in Capacity Expansion Models. A report by the Integrated Planning Task Force. https://www.esig.energy/integrated-planning/, Aaron Burdick, Arne Olson, Madeline McMillan, Debra Lew and Matt Schuerger*

3. *Ari Gold-Parker, Dan Aas, Arne Olson and Amber Mahone, "How targeted electrification can support a managed transition for the gas system," Utility Dive, March 15, 2024, https://www.utilitydive.com/news/targeted-electrification-natural-gas-pipeline-system-transition/710115/*

4. *Arne Olson, Nick Schlag, Greg Gangelhoff and Anthony Fratto, "Every load an island: Requiring hourly matching of clean electricity purchases would raise emissions", Utility Dive, August 29,*

2023, https://www.utilitydive.com/news/hourly-matching-clean-electricity-renewable-energy-purchases-e3/692099/

5. *Olson, A., E. Cutter, L. Bertrand, V. Venugopal, S. Spencer, K. Walter, and A. Gold-Parker. 2023. "Rate Design for the Energy Transition: Getting the Most out of Flexible Loads on a Changing Grid." A White Paper from the Retail Pricing Task Force. Reston, VA: Energy Systems Integration Group. https://www.esig.energy/aligning-retail-pricing-with-grid-needs.*

6. *Sun, Yuchi, James H. Nelson, John C. Stevens, Adrian H. Au, Vignesh Venugopal, Charles Gulian, Saamrat Kasina, Patrick O'Neill, Mengyao Yuan, and Arne Olson, "Machine learning derived dynamic operating reserve requirements in high-renewable power systems," Journal of Renewable and Sustainable Energy; Volume 14, Issue 3; June 24, 2022; https://doi.org/10.1063/5.0087144*

7. *Burdick, Aaron, Nick Schlag, Adrian Au, Roderick Go, Zachary Ming, and Arne Olson, "Lighting a Reliable Path to 100% Clean Electricity: Evolving Resource Adequacy Practices for a Decarbonizing Grid", IEEE Power and Energy Magazine; Volume: 20; Issue: 4; June 22, 2022, https://ieeexplore.ieee.org/document/9804183*

8. *Baik, Ejeong, Kiran P. Chawla, Jesse D. Jenkins, Clea Kolster, Neha S. Patankar, Arne Olson, Sally M. Benson, Jane C.S. Long, "What is different about different net-zero carbon electricity systems", Energy and Climate Change, Volume 2, December 2021, https://www.sciencedirect.com/science/article/pii/S2666278721000234*

9. *Arne Olson and Adam Simpson, "Greening the Microgrid: Moving beyond backup with cleaner sources of firm energy", Power Engineering, June 21, 2021, https://www.power-eng.com/on-site-power/greening-the-microgrid-moving-beyond-backup-with-cleaner-sources-of-firm-energy/#gref*

10. *Long, Jane C.S., Ejeong Baik, Jesse D. Jenkins, Clea Kolster, Kiran Chawla, Arne Olson, Armond Cohen, Michael Colvin, Sally M. Benson, Robert B. Jackson, David G. Victor, and Steven P. Hamburg. "Clean Firm Power is the Key to California's Carbon-Free Energy Future." Issues in Science and Technology, March 24, 2021, https://issues.org/california-decarbonizing-power-wind-solar-nuclear-gas/*

11. *Scott Burger, Marco Ferrara, Roderick Go, and Arne Olson, "To build a zero-carbon grid, we first need to model it accurately", Utility Dive, December 23, 2020, https://www.utilitydive.com/news/to-build-a-zero-carbon-grid-we-first-need-to-model-it-accurately/592704/*

12. *Nick Schlag, Zachary Ming and Arne Olson, "Adding it all up: Counting the capacity contribution of variable and duration-limited resources", Utility Dive, September 10. 2020, https://www.utilitydive.com/news/adding-it-all-up-counting-the-capacity-contribution-of-variable-and-durati/584843/*

13. *Wu, Grace; Leslie, Emily; Sawyerr, Oluwafemi; Cameron, D. Richard; Brand, Erica; Cohen, Brian; Allen, Douglas; Ochoa, Marcela; Olson, Arne, "Low-impact land use pathways to deep*

decarbonization of electricity", Environmental Research Letters, Volume 15, Number 7, 10 July 2020

14. *Arne Olson and Dan Mullen, "For a smart transition to 100% clean energy: Renewables, storage and, in some cases, new gas", Utility Dive, December 18, 2019,* https://www.utilitydive.com/news/for-a-smart-transition-to-100-clean-energy-renewables-storage-and-in-so/569279/

15. *Woo, C.K., J. Zarnikau, Y. Chen, A. Olson, J. Moore, T. Ho, Y. Liu, and X. Luo (2017) "An empirical analysis of California's hybrid capacity options" The Electricity Journal, Volume 31, Issue 2, March 2018, Pages 7-12*

16. *Woo, C.K., A. Olson, Y. Chen, J. Moore, N. Schlag, A. Ong, and T. Ho (2017) "Does California's CO2 price affect wholesale electricity prices in the Western U.S.A.?" Energy Policy, 110, 9–19*

17. *Olson, A., C.K. Woo, N. Schlag and A. Ong (2016) "What Happens in California Does Not Always Stay in California: The Effect of California's Cap-and-Trade Program on Wholesale Electricity Prices in the Western Interconnection," The Electricity Journal, 29(7), 18-22*

18. *Woo, C.K., J. Moore, B. Schneiderman, T. Ho, A. Olson, L. Alagappan, K. Chawla, N. Toyama, J. Zarnikau (2016) "Merit-order effects of renewable energy and price divergence in California's day-ahead and real-time electricity markets," Energy Policy, 92, 299-312*

19. *Woo, C.K., J. Moore, B. Schneiderman; A. Olson; R. Jones; T. Ho; N. Toyama; J. Wang; and J. Zarnikau, "Merit-order Effects of Day-ahead Wind Generation Forecast in the Hydro-rich Pacific Northwest", The Electricity Journal, Vol. 28, Issue 9, November 2015*

20. *Olson, A., A. Mahone, E. Hart, J. Hargreaves, R. Jones, N. Schlag, G. Kwok, N. Ryan, R. Orans and R. Frowd, "Halfway There: Can California Achieve a 50% Renewable Grid?", IEEE Power and Energy Magazine, Volume:13, Issue: 4, pp. 41-52, July-Aug. 2015*

21. *Olson, A., R. Jones, E. Hart and J. Hargreaves, "Renewable Curtailment as a Power System Flexibility Resource," The Electricity Journal, Volume 27, Issue 9, November 2014, pages 49-61*

22. *Hargreaves, J., E. Hart, R. Jones and A. Olson, "REFLEX: An Adapted Production Simulation Methodology for Flexible Capacity Planning," IEEE Transactions on Power Systems, Volume:30, Issue: 3, September 2014, pages 1306 - 1315*

23. *Woo, C.K., T. Hob, J. Zarnikau, A. Olson, R. Jones, M. Chait, I. Horowitz, J. Wang, "Electricity-market price and nuclear power plant shutdown: Evidence from California", Energy Policy,* 2014, vol. 73, issue C, pages 234-244

24. *Woo, C.K., Zarnikau J, Kadish J, Horowitz I, Wang J, Olson A. (2013) "The Impact of Wind Generation on Wholesale Electricity Prices in the Hydro-Rich Pacific Northwest," IEEE Transactions on Power Systems, 28(4), 4245-4253.*

25. *Orans, R., A. Olson, J. Moore, J. Hargreaves, R. Jones, G. Kwok, F. Kahrl, and C.K. Woo (2013) "Energy Imbalance Market Benefits in the West: A Case Study of PacifiCorp and CAISO," Electricity Journal, 26:5, 26-36.*

26. *Olson A., R. Jones (2012) "Chasing Grid Parity: Understanding the Dynamic Value of Renewable Energy," Electricity Journal, 25:3, 17-27.*

27. *Woo, C.K., H. Liu, F. Kahrl, N. Schlag, J. Moore and A. Olson (2012) "Assessing the economic value of transmission in Alberta's restructured electricity market," Electricity Journal, 25(3): 68-80.*

28. *DeBenedictis, A., D. Miller, J. Moore, A. Olson, C.K. Woo (2011) "How Big is the Risk Premium in an Electricity Forward Price? Evidence from the Pacific Northwest," Electricity Journal, 24:3, 72-76.*

29. *Woo, C.K., I. Horowitz, A. Olson, A. DeBenedictis, D. Miller and J. Moore (2011) "Cross-Hedging and Forward-Contract Pricing of Electricity in the Pacific Northwest," Managerial and Decision Economics, 32, 265-279.*

30. *Moore, J., C.K. Woo, B. Horii, S. Price and A. Olson (2010) "Estimating the Option Value of a Non-firm Electricity Tariff," Energy, 35, 1609-1614.*

31. *Olson A., R. Orans, D. Allen, J. Moore, and C.K. Woo (2009) "Renewable Portfolio Standards, Greenhouse Gas Reduction, and Long-line Transmission Investments in the WECC," Electricity Journal, 22:9, 38-46.*

32. *Moore, J., C.K. Woo, B. Horii, S. Price, A. Olson (2009) "Estimating the Option Value of a Non-firm Electricity Tariff," Energy, 35, 1609-1614.*

33. *Woo, C.K., I. Horowitz, N. Toyama, A. Olson, A. Lai, and R. Wan (2007) "Fundamental Drivers of Electricity Prices in the Pacific Northwest," Advances in Quantitative Analysis of Finance and Accounting, 5, 299-323.*

34. *Lusztig, C., P. Feldberg, R. Orans, and A. Olson (2006) "A survey of transmission tariffs in North America," Energy-The International Journal 31, 1017-1039.*

35. *Woo, C.K., A. Olson, I. Horowitz and S. Luk (2006) "Bi-directional Causality in California's Electricity and Natural-Gas Markets," Energy Policy, 34, 2060-2070.*

36. *Woo, C.K., I. Horowitz, A. Olson, B. Horii and C. Baskette (2006) "Efficient Frontiers for Electricity Procurement by an LDC with Multiple Purchase Options," OMEGA, 34:1, 70-80.*

37. *Woo, C.K., A. Olson and I. Horowitz (2006) "Market Efficiency, Cross Hedging and Price Forecasts: California's Natural-Gas Markets," Energy, 31, 1290-1304.*

38. *Woo, C.K., A. Olson and R. Orans (2004) "Benchmarking the Price Reasonableness of an Electricity Tolling Agreement," Electricity Journal, 17:5, 65-75.*

39. *Orans, R., A. Olson, C. Opatrny, Market Power Mitigation and Energy Limited Resources, Electricity Journal, March 2003.*

Research Reports

1. *Consequential Impacts of Voluntary Clean Energy Procurement, June 2024, https://www.ethree.com/meta-voluntary-clean-energy/*

2. *Benefits and Costs of Net Energy Metering in Washington, December 2023, https://www.ethree.com/wp-content/uploads/2023/12/E3_Benefits-and-Costs-of-Net-Energy-Metering-in-Washington_2023-12-21.pdf*

3. *"The Economics of Electrification in Nova Scotia", December 2023, https://www.ethree.com/wp-content/uploads/2023/12/E3_NS-Power_Electrification-Report.pdf*

4. *Resilience in planning: Its relationship to Reliability and a practical implementation guide, July 2023, https://www.ethree.com/wp-content/uploads/2024/02/Resilience-in-planning-Its-relationship-to-Reliability-and-a-practical-implementation-guide-1.pdf*

5. *"Analysis of Hourly & Annual GHG Emissions: Accounting for Hydrogen Production", April 2023, https://www.ethree.com/wp-content/uploads/2023/04/2023.04.19_E3-ACORE_Report_vFF_20230421update.pdf*

6. *"Assessment of Market Reform Options to Enhance Reliability of the ERCOT System", November 2022, https://www.ethree.com/wp-content/uploads/2023/05/E3-PUCT_Assessment-of-Market-Reform-Options-to-Enhance-Reliability-of-the-ERCOT-System_11.10.22-Sent.pdf*

7. *Electricity Resource Compensation Under a Net Zero Future, September 2022, https://www.ethree.com/wp-content/uploads/2020/08/E3-whitepaper_Electricity-Resource-Compensation-Under-a-Net-Zero-Future.pdf*

8. *"BPA Lower Snake River Dams Power Replacement Study", July 2022, https://www.ethree.com/wp-content/uploads/2022/07/e3-bpa-lower-snake-river-dams-power-replacement-study.pdf*

9. *Resource Adequacy in the Desert Southwest, co-author, February 2022, https://www.ethree.com/projects/resource-adequacy-in-the-desert-southwest/*

10. *Quantifying the Air Quality Impacts of Decarbonization and Distributed Energy Programs in California, January 2022, https://www.ethree.com/wp-content/uploads/2022/01/CPUC-Air-Quality-Report-FINAL.pdf*

11. *Societal Cost Test Impact Evaluation: CPUC Staff Report on the Impact of a Societal Cost Test on Resource Procurement, January 2022, https://www.ethree.com/wp-content/uploads/2022/01/CPUC-SCT-Report-FINAL.pdf*

12. *The Load-Serving Entity Reliability Obligation: A Market Design Reform to Ensure Electric Reliability in Texas, co-author, September 2021, https://www.ethree.com/new-e3-whitepaper-proposes-reform-for-texas-electricity-market/*

13. *Oregon Renewable Energy Market and Industry Assessment Report, Oregon Department of Energy, co-author, June 2021, https://www.oregon.gov/energy/energy-oregon/Documents/2022-RE-Market-Industry-Assessment-Report.pdf*

14. *Scalable Markets for the Energy Transition: A Blueprint for Wholesale Electricity Market Reform, lead author, May 2021, https://www.ethree.com/wp-content/uploads/2021/05/E3-Scalable-Clean-Energy-Market-Design-2021-05-24-vFinal.pdf*

15. *Powering a Green Nova Scotia, Together: 2020 Integrated Resource Plan, E3 project lead and contributing author, November 2020, https://irp.nspower.ca/files/key-documents/E3_NS-Power_2020_IRP_Report_final_Nov-27-2020.pdf*

16. *Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future, Energy and Environmental Economics, Inc. and Energy Futures Initiative, project lead and contributing author, November 2020, https://www.ethree.com/wp-content/uploads/2020/11/E3-EFI_Report-New-England-Reliability-Under-Deep-Decarbonization_Full-Report_11-17-2020_Release.pdf*

17. *Pacific Northwest Zero-Emitting Resources Study, prepared for Energy Northwest, project lead and contributing author, January 2020, https://www.ethree.com/wp-content/uploads/2020/02/E3-Pacific-Northwest-Zero-Emitting-Resources-Study-Jan-2020.pdf*

18. *Least Cost Carbon Reduction Policies in PJM, project lead and contributing author, October 2020, https://www.ethree.com/wp-content/uploads/2020/10/E3-Least_Cost_Carbon_Reduction_Policies_in_PJM-1.pdf*

19. *"Capacity and Reliability Planning in the Era of Decarbonization: Practical Application of Effective Load Carrying Capability in Resource Adequacy", E3 White Paper, contributing author, August 2020, https://www.ethree.com/wp-content/uploads/2020/08/E3-Practical-Application-of-ELCC.pdf*

20. *Hydrogen Opportunities in a Low-Carbon Future: An Assessment of Long-Term Market Potential in the Western United States, June 2020, https://www.ethree.com/wp-content/uploads/2021/11/E3_MHPS_Hydrogen-in-the-West-Report_Final_June2020.pdf*

21. *Minnesota Energy Storage Cost-Benefit Analysis, December 2019, prepared for the Minnesota Department of Commerce, Division of Energy Resources, https://www.ethree.com/wp-content/uploads/2020/01/E3-Minnesota-energy-storage-cost-benefit-study-2020.pdf*

22. *Capacity Needs of the Pacific Northwest, December 2019, prepared for National Grid, https://www.ethree.com/wp-content/uploads/2019/12/E3-PNW-Capacity-Need-FINAL-Dec-2019.pdf*

23. *Exploring a Resource Adequacy Program for the Pacific Northwest, October 2019, prepared on behalf of the Northwest Power Pool, project lead and contributing author, https://www.nwpp.org/private-media/documents/2019.11.12_NWPP_RA_Assessment_Review_Final_10-23.2019.pdf*

24. *California Offshore Wind: Workforce Impacts and Grid Integration, September 2019, with the University of California – Berkeley Labor Center, contributing author, https://laborcenter.berkeley.edu/offshore-wind-workforce-grid/*

25. *Xcel Energy Low Carbon Scenario Analysis: Decarbonizing the Generation Portfolio of Xcel Energy's Upper Midwest System, July 2019, prepared on behalf of Xcel Energy, project lead and contributing author, https://www.ethree.com/wp-content/uploads/2019/08/E3_Xcel_MN_IRP_Report_2019-07_FINAL.pdf*

26. *Grace C. Wu, D. Richard Cameron, Emily Leslie, Douglas Allen, Oluwafemi Sawyerr, Erica Brand, Brian Cohen, Marcela Ochoa and Arne Olson, "Power of Place: Land Conservation and Clean Energy Pathways for California", prepared for The Nature Conservancy, San Francisco, June 2019, https://www.scienceforconservation.org/assets/downloads/Technical_Report_Power_of_Place.pdf*

27. *Electricity System Reliability Under Long-Run Deep Decarbonization Pathways in California, June 2019, prepared on behalf of the Calpine Corporation, project lead and contributing author, https://www.ethree.com/wp-content/uploads/2019/06/E3_Long_Run_Resource_Adequacy_CA_Deep-Decarbonization_Final.pdf*

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29. *Investigating the Economic Value of Flexible Solar Power Plants, October 2018, prepared on behalf of First Solar with the assistance of Tampa Electric Company, project lead and contributing author, https://www.ethree.com/projects/investigating-the-economic-value-of-flexible-solar-plants/*

30. *Western Interconnection Gas-Electric Interface Study, June 2018, prepared on behalf of the Western Electric Coordinating Council, contributing author, https://www.wecc.org/Administrative/WECC%20Gas-Electric%20Study%20Public%20Report.pdf*

31. *Pacific Northwest Low Carbon Scenario Analysis, December 2017, prepared on behalf of the Public Generating Pool, project lead and contributing author, https://www.ethree.com/projects/study-policies-decarbonize-electric-sector-northwest-public-generating-pool-2017-present/*

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33. *The Future of Electricity Resource Planning, Volume 6 of the Lawrence Berkeley National Laboratory Electricity Markets and Policy Group's Future Electric Utility Regulation Report Series, September 2016, https://emp.lbl.gov/publications/future-electricity-resource-planning*

34. *Senate Bill 350 Study: The Impacts of a Regional ISO-Operated Power Market on California, July 2016, prepared on behalf of the California Independent System Operator, project lead and contributing author, https://www.caiso.com/informed/Pages/RegionalEnergyMarket/BenefitsofaRegionalEnergyMarket.aspx*

35. *Western Interconnection Flexibility Assessment, December 2015, prepared on behalf of the Western Electric Coordinating Council and the Western Interstate Energy Board, project lead and contributing author, https://ethree.com/public_projects/western_interconnection_study.php*

36. *Natural Gas Infrastructure Adequacy in the Western Interconnection: An Electric Sector Perspective, July 2014, prepared on behalf of the Western Interstate Energy Board, project lead and contributing author, https://ethree.com/public_projects/wieb.php*

37. *"Capital Cost Review of Power Generation Technologies: Recommendations for WECC's 10- and 20-Year Studies, March 2014, prepared for the Western Electric Coordinating Council*

38. *Investigating a Higher Renewables Portfolio Standard for California, January 2014, prepared on behalf of the Los Angeles Department of Water and Power, Pacific Gas and Electric Company, Sacramento Municipal Utilities District, San Diego Gas & Electric, and Southern California Edison, technical lead and lead author, http://www.ethree.com/public_projects/renewables_portfolio_standard.php*

39. *Optimal Investment in Power System Flexibility, E3 White Paper, December 2013, https://ethree.com/documents/Olson_Flexibility_Investment_2013-12-23.pdf*

40. *PacifiCorp-ISO Energy Imbalance Market Benefits, March 2013, https://www.ethree.com/wp-content/uploads/2017/02/PacifiCorp-ISOEnergyImbalanceMarketBenefits-1.pdf*

41. *Cost and Performance Review of Generation Technologies: Recommendations for WECC 10- and 20-Year Study Process, October 2012, prepared on behalf of the Western Electric Coordinating Council, editor and contributing author, http://www.wecc.biz/committees/BOD/TEPPC/TAS/121012/Lists/Minutes/1/121005_GenCapCostReport_finaldraft.pdf.*

42. *Economic Assessment of North/South Transmission Capacity Expansion in Alberta, January 2012, prepared on behalf of AltaLink, contributing author.*

43. *Energy Imbalance Market Benefits Study, October 2011, prepared on behalf of the Western Electric Coordinating Council, project lead and contributing author, http://www.wecc.biz/committees/EDT/EDT%20Results/EDT%20Cost%20Benefit%20Analysis%20Report%20-%20REVISED.pdf*

44. *High Plains Express Initiative, Stage 2 Feasibility Report, April 2011, project lead and contributing author, http://www.highplainsexpress.com/site/stakeholderMeetingDocuments/HPX_Stage-2_Feasibility-report.pdf*

45. *State of Wyoming Wind Energy Costing Model, June 2010, prepared on behalf of the Wyoming Infrastructure Authority and Governor's office, author, http://legisweb.state.wy.us/2010/WyomingWindModel_7_01_2010.pdf*

46. *Recommendations for Documentation of Seattle City Light Energy Delivery Capital Expenditures, February 2010, prepared on behalf of the Seattle City Council, project lead and contributing author, http://clerk.seattle.gov/~ordpics/31219exA.pdf*

47. *California Public Utilities Commission, 33% Renewables Portfolio Standard Implementation Analysis, Preliminary Results, June 2009, project lead and contributing author, http://www.cpuc.ca.gov/NR/rdonlyres/1865C207-FEB5-43CF-99EB-A212B78467F6/0/33PercentRPSImplementationAnalysisInterimReport.pdf*

48. *California Public Utilities Commission, Energy Division Straw Proposal on LTPP Planning Standards, June 2009, project lead and contributing author, http://www.cpuc.ca.gov/NR/rdonlyres/1865C207-FEB5-43CF-99EB-A212B78467F6/0/33PercentRPSImplementationAnalysisInterimReport.pdf*

49. *California Public Utilities Commission, Survey of Utility Resource Planning and Procurement Practices for Application to Long-Term Procurement Planning in California, September 2008, http://www.cpuc.ca.gov/NR/rdonlyres/029611EA-D7C7-4ACC-84D6-D6BA8515723A/0/ConsultantsReportonUtilityPlanningPracticesandAppendices09172008.pdf.*

50. *Remote Renewable and Low-Carbon Resource Options for BPA, May 2008, prepared on behalf of the Bonneville Power Administration, author, http://www.ethree.com/public_projects/BPA_options.html*

51. *Load-Resource Balance in the Western Interconnection: Towards 2020, prepared on behalf of the Western Electric Industry Leaders Group, January 2008, contributing author, http://www.weilgroup.org/E3_WEIL_Complete_Study_2008_082508.pdf*

52. *Umatilla Electric Cooperative 2008 Integrated Resource Plan, January 2009, contributing author.*

53. *Lower Valley Energy 2007 Integrated Resource Plan Update, February 2007, contributing author.*

54. *2007 Idaho Energy Plan, January 2007, prepared on behalf of the Idaho Legislative Council Interim Committee on Energy and Technology, http://www.legislature.idaho.gov/sessioninfo/2007/energy_plan_0126.pdf*

55. *Base Case Integrated Resource Plan for PNGC Power, April 2006, author.*

56. *Integrated Resource Planning for Coos-Curry Electric Cooperative, August 2005, author.*

57. *Integrated Resource Planning for Lower Valley Energy, December 2004, author.*

58. *"A Forecast Of Cost Effectiveness: Avoided Costs and Externality Adders", prepared for the California Public Utilities Commission, February 2004, contributing author.*

59. *Stepped Rate Design Report, prepared for BC Hydro and filed with the BCUC, May 2003, contributing author.*

60. *Convergence: Natural Gas and Electricity in Washington, editor and principal author. Washington Office of Trade and Economic Development, May 2001. http://www.energy.cted.wa.gov/Papers/Convergence.htm*

61. *2001 Biennial Energy Report: Issues and Analyses for the Washington State Legislature, contributing author. Washington Office of Trade and Economic Development, February 2001. http://www.energy.cted.wa.gov/BR2001/default.htm*

62. *Study of Electricity Taxation, contributing author. Washington Department of Revenue, December 1999. http://www.energy.cted.wa.gov/papers/taxstudy.doc*

63. *Washington Energy Indicators, author. Washington Department of Community, Trade and Economic Development, February 1999. http://www.energy.cted.wa.gov/Indicators99/Contents.htm*

64. *Washington State Electricity Study, contributing author. Washington Department of Community, Trade and Economic Development and Washington Utilities and Transportation Commission, January 1999. http://www.energy.cted.wa.gov/6560/finalapp.htm*

65. *Our Energy Future: At a Crossroads. 1997 Biennial Energy Report, contributing author. Washington Department of Community, Trade and Economic Development, January 1997. http://www.energy.cted.wa.gov/BIENREPO/CONTENTS.HTM*

66. *Washington State Energy Use Profile 1996, contributing author. Washington State Energy Office, June 1996. http://www.energy.cted.wa.gov/FILES/PRFL/BASE02.HTM*

67. *Model Documentation Report: Transportation Sector Model of the National Energy Modeling System, contributing author. Decision Analysis Corporation of Virginia. Prepared for Energy Information Administration, March 1994.*

Selected Public Presentations

1. *A "Critical Periods" Reliability Framework, North American Electric Reliability Corporation, Evaluating Resource Contributions for Reliability and Capacity Supply Workshop, Washington, DC, June 5, 2025*
2. *Renewables Portfolio Standards: What are They Good For? New England Conference of Public Utilities Commissioners Symposium, Mystic, Connecticut, May 19, 2025*
3. *Capacity Accreditation and Forward Hedging, Future Power Markets Forum, May 8, 2025*
4. *California CCAs: Celebrating Success and Preparing for an Uncertain Future, Keynote address, CalCCA Annual Meeting, Irvine, California, April 29, 2025*
5. *Unlocking the Flexibility Value of Dispatchable Resources with multi-stage PLEXOS ST modeling, Xcelerate Case Study Presentation, Phoenix, Arizona, April 8, 2025*
6. *Decarb and Dams: Environmental Tradeoffs in Meeting the Northwest's Clean Energy Goals, Whitman College Community Event, Walla Walla, Washington, February 13, 2025*
7. *State of the Market: Pacific Northwest, Electric Power in the West, Law Seminars International, Seattle, Washington, January 24, 2025*
8. *The Role of Clean Energy Attribute Certificates in Reducing Carbon Emissions, GHG Accounting and Reporting in Western States, Western Interstate Energy Board Webinar, December 16, 2024*
9. *Consequential Impacts of Voluntary Clean Energy Procurement, American Council On Renewable Energy (ACORE), October 24, 2024*
10. *The Increasing Importance of Integrating System Planning, Breakthrough Energy/Energy Systems Integration Group/Global Power System Transformation Consortium, Integrated Planning Workshop, Providence, Rhode Island, October 21, 2024*
11. *State of the Market: Pacific Northwest, Renewable Northwest Fall Member Retreat, Skamania Lodge, Washington, October 15, 2024*
12. *Integrated System Planning: From Vision to Reality, ISP Webinar Series, Energy and Environmental Economics (E3), September 26, 2024*
13. *State of the California Electricity Market, Independent Energy Producers Association Annual Meeting, Fallen Leaf Lake, California, September 24, 2024*
14. *Consequential Impacts of Voluntary Clean Energy Procurement, Clean Energy Buyers Association, September 10, 2024*
15. *Consequential Impacts of Voluntary Clean Energy Procurement, Mid-Columbia Seminar, Wenatchee, Washington, July 31, 2024*

16. *Integrated System Planning: A New Planning Paradigm, ISP Webinar Series, Energy and Environmental Economics (E3) and Salt River Project (SRP), July 29, 2024*

17. *Scalable Markets for the Energy Transition: A Blueprint for Wholesale Electricity Market Reform, Energy Systems Integration Group Forecasting and Markets Workshop, Salt Lake City, Utah, June 12, 2024*

18. *Planning a Smooth Transition: How to Achieve Deep Decarbonization While Keeping the Lights on, the Heaters Cranking, and Electricity Bills Affordable, North American Energy Marketers Association 2024 Spring Conference, Palm Springs, California, April 24, 2024*

19. *"Perfect Capacity" and Other Design Considerations for Accreditation, NARUC Bulk Power System Learning Module Accounting for a Changing Resource Mix: The Latest Developments in Capacity Accreditation, April 2, 2024*

20. *"Accounting for Clean Energy and Carbon: Why Simpler is Sometimes Better, or In Defense of the Humble REC", The Energy Authority 2024 Energy Symposium, Atlantic Beach, Florida, March 6, 2024*

21. *"Accounting for Clean Energy and Carbon: Why Simpler is Sometimes Better, or In Defense of the Humble REC", Pacific Northwest Utility Conference Committee, Portland, Oregon, February 9, 2024*

22. *"Supply and Demand in the Western Interconnection", Law Seminars International, Electric Power in the West, Seattle, Washington, January 26, 2024*

23. *"California's Pathway to 2045", Silicon Valley Clean Energy Reflect and Recharge Event, Cupertino, California, December 13, 2023*

24. *"Are Markets Up to the Decarbonization Challenge?", Energy Bar Association Annual Economics and Law Forum, October 27, 2023, Calgary, Alberta*

25. *"Realistic modeling of sub-hourly flexibility and energy storage in resource planning", Energy Systems Integration Group 2023 Fall Technical Workshop, October 25, 2023, La Jolla, California*

26. *"Clean and Reliable: Ensuring Reliability During the Energy Transition", CREPC/WIRAB Meeting, Seattle, Washington, October 5, 2023*

27. *"Western Regional Markets: The Long and Winding Roads", CREPC/WIRAB Meeting, Seattle, Washington, October 4, 2023*

28. *"Electric Utility Integrated Resource Planning Best Practices", Montana Legislature, Select Committee on Energy Resource Planning and Acquisition, September 29, 2023*

29. *"Variability, Uncertainty, and Climate: Turning Up the Heat on Electric Utilities", Idaho Power Board of Directors, Boise, Idaho, September 21, 2023*

30. *"State of the California Market", Independent Energy Producers Association Annual Meeting, invited speaker, Fallen Leaf Lake, California, September 18, 2023*

31. *"The Clean Energy Frontier: Exploring Innovative Solutions", panel discussion, 3CE Annual Meeting, Paso Robles, California, September 13, 2023*

32. *"WRAP And the Role of Resource Adequacy Markets", Western Power Pool Board Workshop, July 31, 2023*

33. *"Supply and Demand in the Western Interconnection: The Impact of Climate and Climate Policy", Northwest Gas Association/Association of Western Energy Consumers, Sunriver, Oregon, June 8, 2023*

34. *"Resource Adequacy in a Decarbonizing Electricity Grid", Organization of MISO States Resource Adequacy Summit 2.0, St. Louis, Missouri, May 16, 2023*

35. *"Resource Accreditation Best Practices", ESIG Market Design Workshop, Arlington, Virginia, February 28, 2023*

36. *"Supply and Demand in the Western Interconnection: The Impact of Climate and Climate Policy", Law Seminars International, Electric Power in the West, Seattle, Washington, January 26, 2023*

37. *"Risks, Uncertainties, and Planning Focal Points", Northwest Public Power Association Power Supply Conference, Portland, Oregon, December 7, 2022*

38. *"Maintaining Resource Adequacy on a Changing Electricity System", California Energy Commission, Western Electricity System Integration Workshop, Sacramento, California, December 2, 2022*

39. *"Reliability in a Decarbonizing Electricity Grid", Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research, Fall 2022 Research Workshop, Cambridge, Massachusetts, November 18, 2022*

40. *"Resource Adequacy Challenges and Their Application in Capacity Expansion Modeling", Energy Exemplar Xcelerate 2022, Dallas, Texas, November 3, 2022*

41. *"Aligning Retail Rates with the Needs of Transitioning Power Systems", Energy Systems Integration Group, Minneapolis, Minnesota, October 25, 2022*

42. *"Capacity Expansion Modeling and Transmission Planning – the E3 Experience", Energy Systems Integration Group, Minneapolis, Minnesota, October 24, 2022*

43. *"State of the California Market", Independent Energy Producers Association Annual Meeting, invited speaker, Fallen Leaf Lake, California, September 27, 2022*

44. *"Capacity Markets in the Western Context", Northwest and Independent Power Producer Coalition Annual Meeting, invited panelist, Alderbrook Resort, Washington, September 13, 2022*

45. *Federal Energy Regulatory Commission Technical Conference on Increasing Real-time and Day-ahead Market and Planning Efficiency Through Improved Software, "Using E3's RESERVE Machine Learning Model to Advance the Calculation of Subhourly Ancillary Services Needs in Deeply Renewable Grids", June 23, 2022*

46. *"Dynamic Reserve Calculation with E3's RESERVE Model," Energy Systems Integration Group: Meteorology and Market Design for Grid Services Workshop, Denver, Colorado, June 8, 2022*

47. *"Transmission Planning Overview", Washington Transmission Corridors Working Group, June 8, 2022*

48. *"Scalable Markets for the Energy Transition: A Blueprint for Wholesale Electricity Market Reform", NewsData and CJB Energy Economics, Western Electric System Transformation: Connecting The WEST, February 25, 2022*

49. *Federal Energy Regulatory Commission, Technical Conference Regarding Energy and Ancillary Services Markets, invited panelist on "Revising RTO/ISO market models, optimization, and other software elements to address operational flexibility needs", October 12, 2021*

50. *"All Hands on Deck: State of the Market in California", Independent Energy Producers Association Annual Meeting, invited speaker, Fallen Leaf Lake, California, September 21, 2021*

51. *"Scalable Markets for the Energy Transition: A Blueprint for Wholesale Electricity Market Reform", Northwest and Intermountain Power Producer Coalition Annual Meeting, Union, Washington, September 13, 2021*

52. *"Climate Change and the Energy Transition: Our Energy Infrastructure at a Crossroads", Pacific Northwest Economic Region Annual Summit Plenary Session: Overview of our Regional Infrastructure and Policy Landscape, invited speaker, August 17, 2021*

53. *"Benefits of Nuclear Energy in Achieving Zero Emissions in the Pacific Northwest", National Association of Regulatory Utility Commissioners Nuclear Energy Partnership August Webinar, invited speaker, August 6, 2021*

54. *Northwest Power Pool Resource Adequacy Symposium, "Report From the Region", invited panelist, August 3, 2021*

55. *"Scalable Markets for the Energy Transition: A Blueprint for Wholesale Electricity Market Reform", IEEE Power and Energy Society General Meeting Super Session, Impact of Climate Change on the Power Grid, invited panelist, July 29, 2021*

56. *OurEnergyPolicy Energy Leaders Webinar Series: Proposed Federal Clean Energy Standards, invited panelist, July 28, 2021, https://www.ourenergypolicy.org/the-proposed-federal-clean-energy-standard/*

57. *"Opportunities and Challenges in Achieving Pacific Northwest Climate Goals", Oregon Rural Electric Cooperative Association, invited speaker, July 13, 2021*

58. *"Rethinking Resource Adequacy in a Decarbonized World", GridForward Building the Decarbonized Grid Summit, invited panelist, June 9, 2021*

59. *"Green Hydrogen: How Production, Infrastructure and End Uses Will Power an Economic Revolution", Infocast webinar, invited panelist, June 3, 2021*

60. *"Resource Adequacy Challenges in 2021 and Beyond", Energy Systems Integration Group Spring Meeting Plenary Session, invited panelist, April 8, 2001*

61. *"Opportunities and Challenges in Achieving Pacific Northwest Climate Goals", Pacific Northwest Economic Region Forum, invited panelist, March 24, 2021*

62. *"Wholesale Electricity Market Reforms for the Clean Energy Transition: an E3 Perspective", PJM Interconnection Capacity Market Workshop, March 12, 2021*

63. *"Electric Resource Adequacy: California and the West", NewsData and CJB Energy Economics Webinar, invited speaker, January 28, 2021*

64. *"Keeping the Lights on in California", Power Markets Today Webinar, invited panelist, December 2, 2020*

65. *"Resource Adequacy: Now and in the Future", Western Electric Coordinating Council Resource Adequacy Forum, invited speaker, November 18, 2020*

66. *"Accreditation of Dispatch-Limited Resources in Organized Capacity Markets", Organization of PJM States, invited panelist, October 20, 2020*

67. *"The Role of Electricity in Meeting Economy-wide Carbon Goals", Centre for Energy Advancement through Technological Innovation (CEATI), invited panelist, October 15, 2020*

68. *Federal Energy Regulatory Commission, Technical Conference regarding Carbon Pricing in Organized Wholesale Electricity Markets, invited panelist, September 30, 2020*

69. *"California and the Western Market: Trends and Opportunities", opening speaker, Independent Energy Producers Association Annual Meeting, September 23, 2020*

70. *"Decarbonizing the Power System: Summary of Lessons Learned", opening speaker, Columbia University – Johns Hopkins University Future Power Markets Forum, Session 1, June 2, 2020*

71. *"Decarbonizing Electric Power Systems", invited speaker, Minnesota Rural Electric Association Annual Meeting, April 8, 2020*

72. *"Resource Adequacy under High Renewable Penetration", Austin Electricity Conference, invited speaker, Austin, Texas, March 5, 2020*

73. *"Long-Run Resource Adequacy under Deep Decarbonization Pathways for California", invited speaker, California Energy Commission, California Public Utilities Commission and California Air Resources Board SB100 Technologies & Scenarios Workshop, San Francisco, California, November 18, 2019*

74. *"Resource Adequacy in the Pacific Northwest: Summary of existing studies and benefits of a regional program", invited speaker, Northwest Power Pool Resource Adequacy Symposium, Portland, Oregon, October 2, 2019*

75. *"California Energy Outlook: Where Are We?", invited speaker, California Independent Energy Producers Association Annual Meeting, Fallen Leaf Lake, California, September 23, 2019*

76. *"Resource Adequacy in the Pacific Northwest", invited speaker, Northwest and Intermountain Power Producer Coalition Annual Meeting, Union, Washington, September 10, 2019*

77. *"Northwest Resource Adequacy Outlook", invited speaker, Oregon Public Utilities Commission, NW Resource Adequacy Outlook Workshop, Salem, Oregon, May 28, 2019*

78. *"Achieving New York's "Green New Deal" And Deep Decarbonization Of the Electric Sector", invited speaker, Independent Power Producers of New York 33rd Annual Spring Conference, May 8, 2019, Albany, New York*

79. *"Grid Flexible Solar: Leveraging Utility-Scale Solar for Flexible Dispatch & Operations" invited speaker, Committee on Regional Electric Cooperation and Western Interconnection Regional Advisory Board, Salt Lake City, Utah, April 18, 2019*

80. *"Resource Adequacy in a Postmodern World", invited speaker, Committee on Regional Electric Cooperation and Western Interconnection Regional Advisory Board, Salt Lake City, Utah, April 18, 2019*

81. *"The Economic & Business Implications of Energy Storage", invited panelist, Austin Electricity Conference, Austin, Texas, April 4, 2019*

82. *"Resource Adequacy and Planning Reserve Sharing in Bilateral and Organized Markets", invited speaker, Northwest Power Markets Design Informational Seminar, Portland, Oregon, October 24, 2018*

83. *"Future Energy Systems: The Role for Natural Gas in a High-Renewables, Decarbonizing World", invited speaker, Stanford Natural Gas Initiative Symposium, Palo Alto, California, October 16, 2018*

84. *"Charged, Smart and Ready: Getting the most out of new consumer technologies", invited speaker, Northwest and Intermountain Power Producers Coalition Annual Meeting, Alderbrook Resort, Union, Washington, October 9, 2018*

85. *"Getting to 100% 'Clean Energy'", invited speaker, Independent Energy Producers Association's 37th Annual Meeting, Fallen Leaf Lake, South Lake Tahoe, California, October 3, 2018*

86. *"Pacific Northwest Low Carbon Scenario Analyses: Achieving Least-Cost Carbon Emissions Reductions in the Electricity Sector", invited appearance before the Washington State Legislature Energy Supply & Energy Conservation Joint Committee, September 24, 2018*

87. *"Achieving High Renewable Penetration with Grid-Friendly Operations", invited panelist, Austin Electricity Conference, Austin, Texas, April 12, 2018*

88. *"Electric industry trends and their impacts on hydropower", invited speaker, Bonneville Power Administration Strategic Plan Implementation Public Workshop, Portland, Oregon, March 2, 2018*

89. *"Customer Engagement: An Adaptive Survival Strategy for Electric Utilities", invited speaker, Energy NewsData Utility Customer Engagement Conference, Portland, Oregon, November 17, 2017*

90. *"Grid of the Future, Industry of the Future", Platinum Seminar at the Northwest and Intermountain Power Producer Coalition Annual Meeting, Union, Washington, September 11, 2017*

91. *"California's Solar Buildout: Implications for Electricity Markets in the West", invited speaker, EPIS Electric Market Forecasting Conference, Las Vegas, Nevada, September 7, 2017*

92. *"Value of Hydro in a GHG-Constrained World", invited panelist, HydroVision International, Session 1A: How Does Hydro 'Play' in the Energy Playground? Welcome to the New Wild West, Denver, Colorado, June 28, 2017*

93. *"Resource Adequacy and Planning Reserve Margins", invited speaker, Technical Conference on Capacity Planning and Resource Adequacy, Montana Public Service Commission, Helena, Montana, June 8, 2017*

94. *"That Faint Whooshing Sound: California Solar and Changing Western Power Markets", invited speaker, Northwest Power Markets: Mapping the Road Ahead, presented by Energy NewsData and CJB Energy, Portland, Oregon, May 24, 2017*

95. *"Observations on Current Resource Adequacy Practices", invited speaker, Committee for Regional Electric Power Cooperation/Western Interconnection Regional Advisory Body, Boise, Idaho, April 13, 2017*

96. *"Assessing Flexibility Needs in Highly Renewable Systems," invited speaker, Wärtsilä Symposium, Portland, Oregon, September 27, 2016*

97. *"Review: Natural Gas Infrastructure Adequacy in the Western Interconnection," invited speaker, Committee for Regional Electric Power Cooperation/Western Interconnection Regional Advisory Body, San Diego, California, October 31, 2016*

98. *"PATHWAYS to Deep Decarbonization: California", Western Electric Coordinating Council, Transmission Expansion Planning and Policy Committee, Salt Lake City, Utah, August 17, 2016*

99. *"Renewable Euphoria and the 'Big Long': How Renewable Energy Will Impact Western Markets", invited speaker, Mid-C Seminar, Wenatchee, Washington, July 27, 2016*

100. *"The Role of Renewables in Meeting California's Greenhouse Gas Goals", invited speaker, Renewable Energy Integration Summit, San Diego Regional Chamber of Commerce, July 18, 2016*

101. *"Essential Reliability Services", invited panelist, Western Electric Coordinating Council, Western Reliability Summit, Salt Lake City, Utah, May 18, 2016*

102. *"Meeting a 50% RPS for California", invited panelist, Infocast California Energy Summit, Santa Monica, California, May 11, 2016*

103. *"The Future of Resource Planning", invited keynote speaker, Great Plains Institute's e21 Initiative, St. Paul, Minnesota, April 5, 2016*

104. *"Market Driven Distributed Generation in the Western Interconnection", invited panelist, Committee on Regional Electric Power Cooperation biennial meeting, Salt Lake City, Utah, March 22, 2016*

105. *"Is Solar the New Hydro?", invited panelist, Northwest Hydroelectric Association 2016 Annual Conference, Portland, Oregon, February 17, 2016*

106. *"The Role of Energy Storage as a Renewable Integration Solution under a 50% RPS", invited panelist, Joint California Energy Commission and California Public Utilities Commission Long-Term Procurement Plan Workshop on Bulk Energy Storage, Sacramento, California, November 20, 2015*

107. *"Planning for Variable Generation Integration Needs", invited panelist, Utility Variable-generation Integration Group, Operating Impact And Integration Studies Users Group Meeting, San Diego, California, October 13, 2015*

108. *"The Role of Renewables in a Post-Coal World", invited panelist, Energy Foundation, Beyond Coal to Clean Energy Conference, San Francisco, California, October 9, 2015,*

109. *"Implications of a 50% RPS for California", invited panelist, Argus Carbon Summit, Napa, California, October 6, 2015*

110. *"Western EIM: Status Report and Implications for Public Power", Keynote speaker, Large Public Power Council meeting, Seattle, Washington, September 16, 2015*

111. *"California's 50% RPS Goal: Opportunities for Western Wind Developers", Keynote speaker at a meeting of the Wyoming Infrastructure Authority, Berkeley, California, July 28, 2015*

112. "Western Interconnection Flexibility Assessment", Western Electric Coordinating Council Board of Directors, Salt Lake City, Utah, June 24, 2015

113. "California's New GHG Goals: Implications for the Western Electricity Grid", invited panelist, National Association of State Energy Officials, Western Regional State and Territory Energy Office Meeting, Portland, Oregon, May 14, 2015

114. "Replacing Aging Fossil Generation," invited panelist, Northwest Energy Coalition NW Clean & Affordable Energy Conference, Portland, Oregon, November 7, 2014

115. "Investing in Power System Flexibility," invited panelist, State/Provincial Steering Committee & Committee on Regional Electric Power Cooperation System Flexibility Forum, San Diego, California, October 20, 2014

116. "Opportunities and Challenges for Higher Renewable Penetration in California", invited panelist, Beyond 33%: University of California at Davis Policy Forum Series, Sacramento, California, October 17, 2014

117. "Renewable Curtailment as a Power System Flexibility Resource," Boise State University Energy Policy Research Conference, San Francisco, California, September 4, 2014

118. "Natural Gas Infrastructure Adequacy: An Electric System Perspective", Pacific Northwest Utilities Conference Committee Board of Directors, Portland, Oregon, August 8, 2014

119. "The Future of Renewables in the American West," invited panelist, Geothermal Energy Association Annual Meeting, Reno, Nevada, August 6, 2014

120. "Long-Term Natural Gas Infrastructure Needs", invited panelist, U.S. Department of Energy Quadrennial Energy Review, Public Meeting #7, Denver, Colorado, July 28, 2014

121. "Meeting the Demands of Renewables Integration—New Needs, New Technologies, Emerging Opportunities", invited panelist, InfoCast 2nd Annual California Energy Summit, San Francisco, California, May 28, 2014

122. "Power System Flexibility Needs under High Renewables", EUCI Utility Resource Planning Conference, Chicago, Illinois, May 14, 2014

123. "Natural Gas Infrastructure Adequacy: An Electric System Perspective", Western Interstate Energy Board Annual Meeting, Denver, Colorado, April 24, 2014

124. "Power System Flexibility Needs under High RPS", invited panelist, joint meeting of the Committee on Regional Electric Power Cooperation, State-Provincial Steering Committee and Western Interconnection Regional Advisory Body, Tempe, Arizona, March 26, 2014

125. *"Natural Gas Infrastructure Adequacy: An Electric System Perspective", joint meeting of the Committee on Regional Electric Power Cooperation, State-Provincial Steering Committee and Western Interconnection Regional Advisory Body, Tempe, Arizona, March 25, 2014*

126. *"Investigating a Higher Renewables Portfolio Standard for California", 19th Annual Power Conference on Energy Research and Policy, University of California Energy Institute, Berkeley, California, March 17, 2014*

127. *"Investigating a 50 Percent Renewables Portfolio Standard in California", invited panelist, Northwest Power and Conservation Council, Portland, Oregon, March 12, 2014*

128. *"Investigating a 50 Percent Renewables Portfolio Standard in California", invited panelist, Western Systems Power Pool, Spring Operating Committee Meeting, Whistler, B.C., March 5, 2014*

129. *"Investigating a Higher Renewables Portfolio Standard for California", invited speaker, Western Electric Coordinating Council, Transmission Expansion Planning and Policy Committee, Salt Lake City, Utah, February 25, 2014*

130. *"Investigating a 50 Percent Renewables Portfolio Standard in California", invited speaker, Committee on Regional Electric Power Cooperation, State-Provincial Steering Committee and Western Interconnection Regional Advisory Body, Webinar, February 12, 2014*

131. *"Flexibility Planning: Lessons From E3's REFLEX Model", EUCI Conference on Fast Ramp and Intra-Hour Market Incentives, San Francisco, California, January 29-30, 2014*

132. *"The Effect of High Renewable Penetration on California Markets and Carbon Balance", EUCI Conference on California Carbon Policy Impacts on Western Power Markets, January 27-28, San Francisco, California, 2014*

133. *"Reliance on Renewables: A California Perspective", invited panelist at Harvard Electricity Policy Group, Seventy-Third Plenary Session, Tucson, Arizona, December 13, 2013*

134. *"The Role of Renewables in Meeting Long-Term Greenhouse Gas Reduction Goals", State Bar of California, Energy and Climate Change Conference, Berkeley, California, November 14, 2013*

135. *"Benefits, Costs and Cost Shifts from Net Energy Metering", invited expert panelist at Washington Utilities and Transportation Commission Workshop on Distributed Generation, Olympia, Washington, November 13, 2013*

136. *Pacific Northwest Utilities Conference Committee (PNUCC) California Power Industry Roundtable, invited panelist, Portland, Oregon, September 6, 2013*

137. *"After 2020: Prospects for Higher RPS Levels in California", invited speaker at Northwest Power and Conservation Council's California Power Markets Symposium, Portland, Oregon, September 5, 2013*

138. *"Determining Flexible Capacity Needs for the CAISO Area", invited speaker at Northwest Power and Conservation Council's California Power Markets Symposium, Portland, Oregon, September 5, 2013*

139. *"California Climate Policy and the Western Energy System", invited speaker at the Western Interstate Energy Board annual meeting, Reno, Nevada, June 13, 2013*

140. *"Determining Power System Flexibility Need", EUCI Conference on Resource Planning and Asset Valuation, Westminster, Colorado, May 21, 2013*

141. *"California Policy Landscape and Impact on Electricity Markets", EUCI Conference on Resource Planning and Asset Valuation, Westminster, Colorado, May 21, 2013*

142. *"Determining Power System Flexibility Need", EUCI Conference on Fast and Flexi-ramp Resources, Chicago, Illinois, April 23, 2013*

143. *"State-Provincial Steering Committee WECC Low Carbon Scenarios Tool", 3 Interconnections Meeting, Washington, DC, February 6, 2013*

144. *"Distributed Generation Benefits and Planning Challenges", Committee on Regional Electric Power Cooperation/State-Provincial Steering Committee, Resource Planners' Forum, San Diego, California, October 3, 2012*

145. *"Thoughts on the Flexibility Procurement Modeling Challenge", invited speaker at the California Public Utilities Commission, Long-Term Procurement Planning Workshop, San Francisco, California, September 19, 2012*

146. *"Generation Capital Cost Recommendations for WECC 10- and 20-Year Studies", Western Electric Coordinating Council, Transmission Expansion Planning and Policy Committee, Technical Advisory Subcommittee, Webinar, August 15, 2012*

147. *"Renewable Energy Benefits", California Energy Commission, Integrated Energy Policy Report Workshop, Sacramento, California, April 12, 2012*

148. *"The Role of Policy in WECC Scenario Planning", Western Electric Coordinating Council, Scenario Planning Steering Group, San Diego, CA, November 1, 2011*

149. *"WECC Energy Imbalance Market Benefit Study", Western Electric Coordinating Council, Board of Directors, Scottsdale, Arizona, June 22, 2011*

150. *"Renewable Portfolio Standard Model Methodology and Draft Results", California Public Utilities Commission Workshop, San Francisco, California, June 17, 2010*

151. *"Draft Results from 33% Renewable Energy Standard Economic Modeling", California Air Resources Board Workshop, Sacramento, California, May 20, 2010*

152. "Market Opportunities for IPPs in the WECC", invited speaker at the Independent Power Producers of British Columbia Annual Meeting, Vancouver, British Columbia, November 2, 2009

153. "A Low-Transmission Alternative for Meeting California's 33% RPS Target", EUCI Webinar, July 31, 2009

154. "Remote Renewable and Low-Carbon Resource Options for the Pacific Northwest", Center for Research on Regulated Industries Conference, Monterey, California, June 19, 2009

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