

INTRODUCING INNOVATE

**Alternative modeling approaches
to inform energy system planning**

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Taylor McNair
GridLab

Nick Pappas
NP Energy LLC

Priya Sreedharan
GridLab

GridLAB
NP Energy LLC



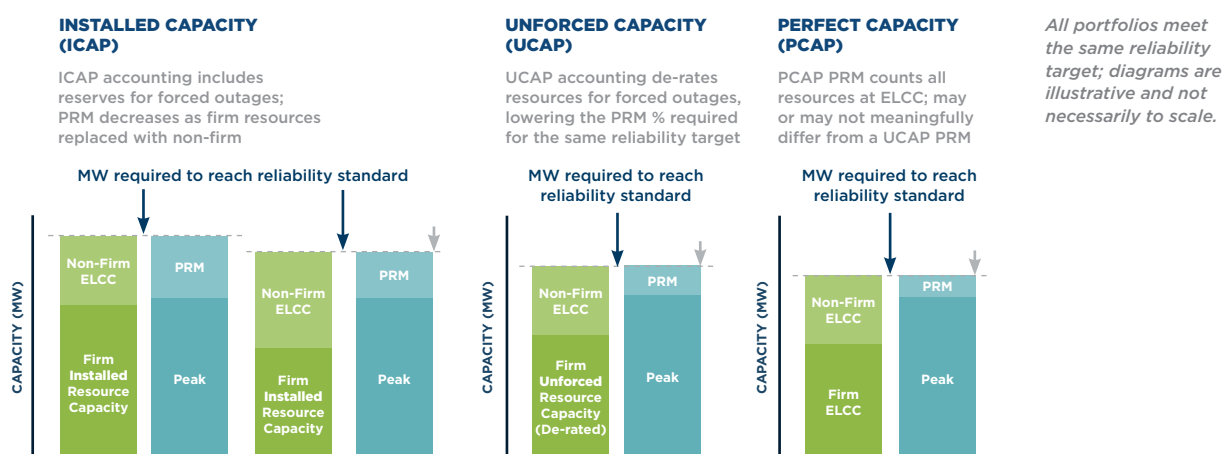
Power system planning has grown in both importance and challenges in recent years. In parallel with rapid integration of variable renewable energy sources and storage, the electric industry is facing rising load growth, evolving weather and natural disaster risks, and increasing operational complexity. These trends have stretched current planning methods and modeling tools to their limits. Planners typically rely on a variety of software tools to help them plan for both near- and long-term energy needs. Policymakers now have multiple objectives—reliability, emissions, cost, equity, land use—not all of which are easily accounted for in current modeling tools.

In this article, we introduce current trends, challenges and opportunities for modeling the future grid, drawing heavily from reviews of recent utility integrated resource plans (IRPs). Articles 2 and 3 in this series launch showcase innovative modeling approaches, developed by power systems modeling experts that target some of these challenges. Article 2 is by Telos Energy Group, and Article 3 is by Sylvan Energy Analytics. As part of this ongoing initiative from GridLab, we hope experts will develop and test additional innovative modeling approaches.

THE DYNAMIC PRM: MOVING FROM RULE-OF-THUMB PLANNING RESERVE MARGINS TO PROBABILISTIC MODELING APPROACHES

The most common practitioner method for designing a resource adequate and reliable portfolio is to compare a portfolio of resources against peak demand plus a Planning Reserve Margin (PRM). PRM derivations and methodologies vary in rigor. The simplest approach to derivation is a rule-of-thumb margin above peak demand (e.g., 15%). More rigorous methods involve deriving the PRM using a loss of load expectation (LOLE) model, which is a probabilistic analytical approach to determine the portfolio of resources that meets a desired reliability standard, from which a PRM can be calculated. Once the PRM is derived, the way in which resources are measured against the PRM requirement may vary (Figure 1), which has implications for how meaningful the PRM is towards ensuring a reliable portfolio.

FIGURE 1. Various PRM methodologies as described by E3 (Hawaiian Electric IRP, 2023).



While many planners have adopted some level of probabilistic modeling for defining resource capacity contributions (i.e., deriving effective load carrying capability (ELCC) values from LOLE modeling), the application of probabilistic modeling across IRPs is far from uniform and is sometimes implemented in problematic ways. Even among utilities applying probabilistic methods and ELCC values, these methods are often limited to solar, wind, and storage, obfuscating risk in thermal¹ and hydroelectric fleets. ELCC values may be based on a single snapshot in time or omit the interactive effects between resources, missing key synergistic reliability impacts as the portfolio evolves.² Finally, utilities may fail to update ELCC values after making material changes to the underlying data, such as refreshed load forecasts, undermining the accuracy and completeness of modeling results using those *ELCC values*.³

Two primary concerns may result from this practice. First, ELCC values play a significant role in how capacity expansion models solve. Overstated ELCC values can lead to portfolios that may not reach the desired reliability target. Understated ELCC values can lead to overbuilt portfolios that include unnecessary ‘backup’ capacity. Second, the inherent limitations of ELCC estimation necessitates an ex-post check of the resource plan through resource adequacy analysis to ensure it is reliable, a practice we refer to in this article as “roundtrip modeling”.

ROUNDRIP MODELING HAS EMERGED AS A UTILITY PLANNING BEST PRACTICE

Incorporating a portfolio reliability check through roundtrip modeling⁴ is becoming an emerging best practice. For purposes of this article, roundtrip modeling is defined as an iterative process between capacity expansion and resource adequacy modeling. Initial resource capacity values (possibly ELCC based) are fed into the capacity expansion model. The derived portfolio is then evaluated in a probabilistic resource adequacy model—highlighting the first step in the “roundtrip” approach. The results from the capacity expansion model (i.e., portfolio composition) are then returned to the resource adequacy model which had initially generated the capacity expansion model ELCC inputs. If this verification step fails certain reliability thresholds, the portfolio can be further iterated between the two models until certain thresholds are attained. The roundtrip approach refers to regular iteration between capacity expansion and resource adequacy models to incorporate additions or retirements until the desired reliability criterion are met.

In practice, utilities perform these steps with varying levels of effectiveness. Figure 2 illustrates how Duke Energy Carolina incorporates roundtrip modeling into its IRP analysis. It is important to distinguish between roundtrip modeling for reliability verification versus processing the portfolio through a production cost model, which may test each future year’s portfolio against a single (often normalized) weather year, a process which is helpful for developing portfolio insights and quantifying operational costs, but does not test its robustness against resource adequacy risk under multiple weather conditions. In contrast, resource adequacy modeling evaluates a portfolio’s performance

1 For additional discussion of the importance of applying probabilistic analysis to thermal resources, see, e.g., Accrediting Resource Adequacy Value to Thermal Generation, Astrape Consulting on behalf of Advanced Energy United, March 30, 2022, astrape.com/wp-content/uploads/2022/10/Accrediting-Resource-Adequacy-Value-to-Thermal-Generation-1.pdf

2 See, e.g., discussion of the need to consider portfolio effects in Comments of Renewable Northwest on the 2023 Portland General Electric Integrated Resource Plan, July 27, 2023, p. 14-15, edocs.puc.state.or.us/efdocs/HAC/lc80hac152229.pdf; discussion of Capacity Factor Method limitations in Comments of Renewable Northwest on the 2023 PacifiCorp Integrated Resource Plan, October 25, 2023, p. 48-53, edocs.puc.state.or.us/efdocs/HAC/lc82hac17443.pdf

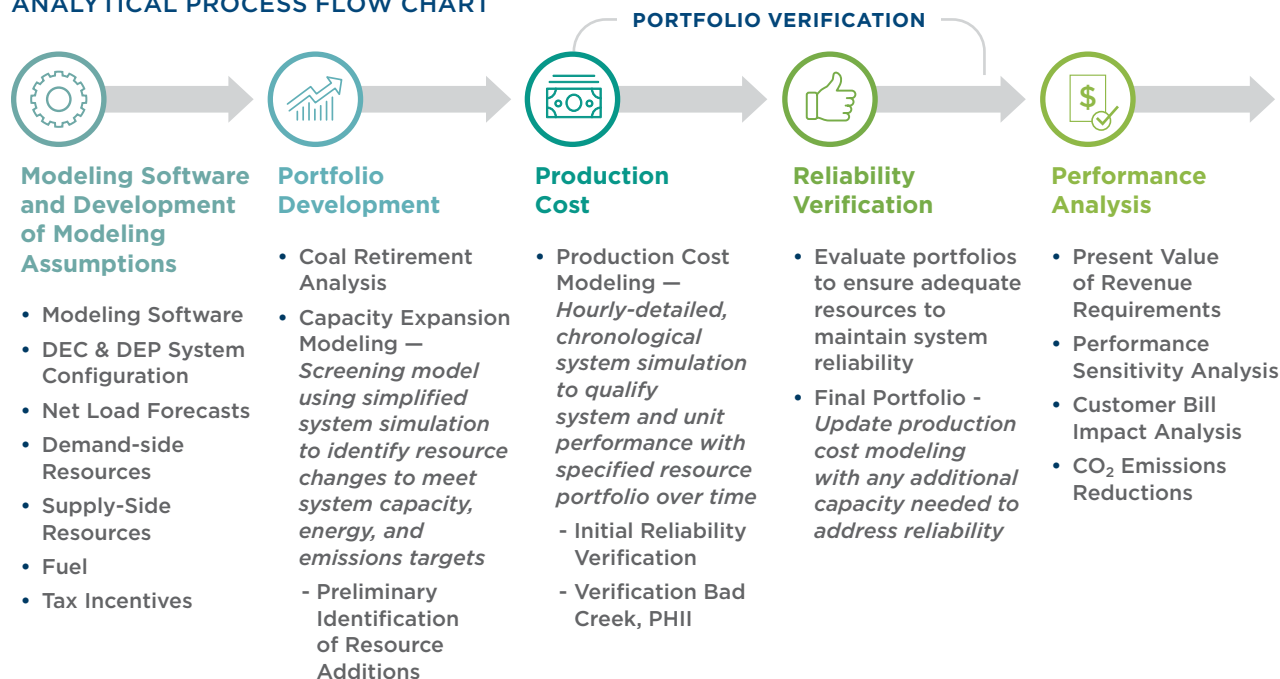
3 See, e.g., discussion of the intersection between load forecasts and ELCC results in Comments of Western Resource Advocates on the Fourth Amendment to the 2021 NV Energy Integrated Resource Plan, March 17, 2023, p. 20-27, pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2020_THRU_PRESENT/2022-11/25487.pdf

4 See page 30 of Ensuring Efficient Reliability: New design principles for capacity accreditation. Energy System Integration Group. February 2023. www.esig.energy/new-design-principles-for-capacity-accreditation/

across a range of weather years (evaluating risk to interannual weather variability), assessing the impacts of weather on renewable resource performance, thermal outages, drought, and load.

FIGURE 2. An illustrative example of a roundtrip modeling approach (Duke Energy Carolinas IRP, 2023).

CAROLINAS RESOURCE PLAN ANALYTICAL PROCESS FLOW CHART



CAPACITY EXPANSION MODELING MUST PLAN FOR A RANGE OF UNCERTAIN FUTURES

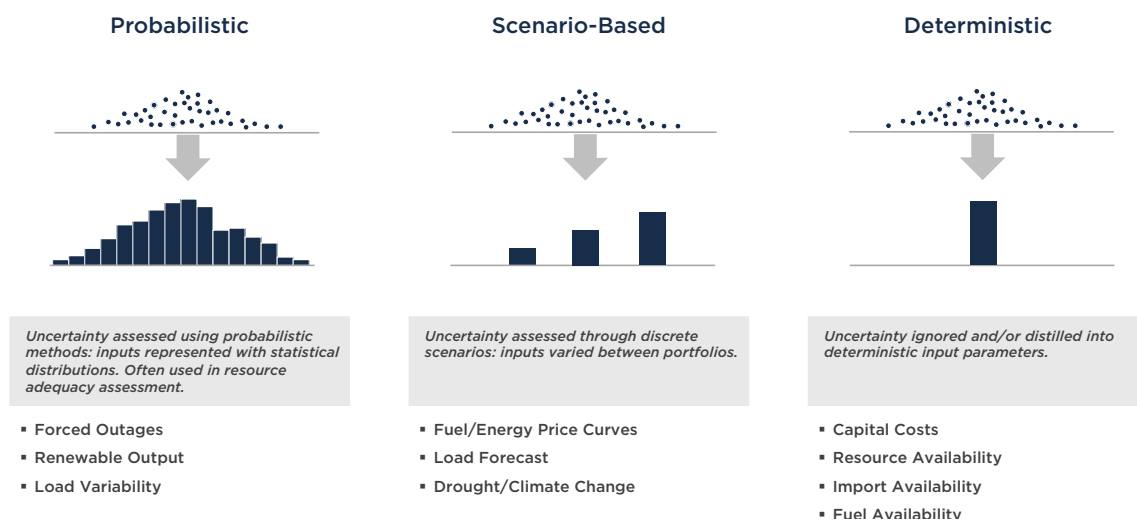
Utility IRPs exist in a paradigm of both aspiration and uncertainty. While uncertainty has long been an important consideration in planning, the transformations reshaping the utility industry necessitate uncertainty taking a more central role for planners.

The past few years are an indication that uncertainties are increasing. As utilities fundamentally reshape and rebuild their portfolios with clean resources, new uncertainties are emerging. For example, how will emerging resources perform, given limited operational experience? How will weather impacts on generation and load vary year to year, which may also be influenced by evolving weather patterns? How rapidly and flexibly will load grow, with the adoption of transportation and building electrification technologies, and data center related load growth? How will capital costs evolve, given changes in global supply chains and other factors? How will cost, availability, and performance develop for emerging technologies that are early in terms of learning curves? How will new constraints, such as emissions reduction targets or power plant operation limitations, impact generation? How will emerging modeling techniques and data availability influence our view of future trajectories and risk? Increasingly, planners face a diversity of options which can hinge critically on these questions.

A planner's selection of clean energy options should consider that there are a range of potential cost outcomes when considering that parameters of fuel and technology costs are also subject to uncertainty. For example, a capacity expansion model built around a view of low future fuel costs (gas, coal, even hydrogen) may set planners down a path in which a utility and its customers face a high degree of exposure to shifts in fuel prices and availability—pursuing a least-cost portfolio based on 'blue sky conditions' but failing to prepare for a future in which these fundamentals are altered, as we observed during the geopolitical tumult of 2022. Similarly, the choice of how weather information is incorporated into the analysis steps can have significant impacts. Using a single weather year in the portfolio design step, which is common practice, can impact how much renewable generation, storage or fossil generation is built. Assessing operations and performance in production cost and resource adequacy modeling for a limited number of weather years may fail to design a portfolio that is robust against rare weather conditions, which are the important conditions to assess the portfolio against.

While increasingly central, the way in which these uncertainties are accounted for remain buried deep in the technical appendices of most planning proceedings. To the extent they are explicitly represented, it is often in the form of probabilistic modeling, direct representation of uncertainty within each portfolio, or as scenarios, represented across portfolios. Many other uncertainties lurk under the surface of the black box—distilled from qualitative uncertainty into a single deterministic vector or point estimate.

FIGURE 3. An illustrative example of various uncertainty assessment, including probabilistic, scenario-based, and deterministic methodologies.



While utilities have long been able to evaluate various “pathways” that account for uncertainty (e.g., through scenario analysis or probabilistic LOLE modeling), the range and number of uncertain factors makes it difficult to appropriately evaluate all risks. Unfortunately, our conventional planning tools and the processes by which we apply them make it difficult to appropriately evaluate these risks on a common footing.

CAPACITY EXPANSION OUTPUTS MUST EVOLVE AS PLANNING OBJECTIVES AND PRIORITIES CHANGE

At the same time, our planners are dealing with new policy objectives that impact portfolio design and system operations, and add complexity to the analytical process. Emissions constraints, demand-side technology, environmental justice considerations, load growth uncertainty are just a few of the new policy topics that must be integrated into resource planning processes, further complicating our preexisting methods of system planning.

Against emerging multiple policy objectives, other complexities and uncertainties, it is less meaningful to have a narrow focus exclusively on a single least cost portfolio. Yet, current planning practices narrowly focus on the least cost outcome of the capacity expansion model. This approach will lead planners to ignore portfolios that may have similar costs, even if those scenarios offer other advantages in terms of policy or other objectives. Without visibility into the range of outcomes under alternative scenarios, we run the risk of wholly ignoring planning pathways that could lead to more optimal outcomes. A sole focus on least cost under a single future scenario ignores the increasing complexity of our policy landscape.

INTRODUCING NEW METHODS TO DEAL WITH UNCERTAINTY AND COMPLEXITY IN RESOURCE PLANNING

It is increasingly resource intensive to consider all of these complexities. Our objective is to introduce and explore new methodologies that enable planners to evaluate multiple uncertainties, while at the same time reducing computational run-time, simplifying portfolio results for further analysis, and improving decision making. Such techniques, historically explored mainly in academia, could help planners more quickly prototype and evaluate resource portfolios that meet reliability and other criteria. As the grid gets more complex, our planning tools and methodologies must continuously iterate and evolve to keep up with increased complexity, uncertainty, and risk.

We highlight some of these efforts in this series. Article 2 of the series, “Rethinking the role of capacity expansion modeling: An alternative approach for reliable and economic portfolio design under uncertainty”, introduces work by Telos Energy that aims to better integrate risk and uncertainty into portfolio design, recognizing the limitations of capacity expansion modeling. The work demonstrates how policy makers can use this approach to rapidly evaluate a suite of portfolios for reliability, cost, and other considerations, while minimizing computational intensity and the resources required to review and analyze thousands of scenarios. This method can help stakeholders fully recognize the range of outcomes under any given portfolio and better weigh risks and benefits, particularly where multiple portfolios have an overlapping range of expected performance depending on future circumstances.

Article 3 of the series, “Iterative portfolio optimization: an essential tool for reliable and clean electricity planning”, addresses the challenges of incorporating complex planning considerations, including resource adequacy and policy requirements in capacity expansion models. In the article, Sylvan Energy Analytics describes a systematic, flexible, and mathematically robust approach to developing optimized portfolios that account for complex planning considerations with the same level of accuracy provided by more complete and granular models. The paper demonstrates how the technique produces superior portfolios to current methods and shows how it can be used to support multi-objective planning exercises and to identify and investigate near-optimal portfolios.

We are envisioning this series to be an ongoing one where experts continue to explore innovative analysis approaches—beyond the themes raised in Articles 1 through 3. In 2025, we will take this initiative in a different direction and will collaborate with Energy Futures Group to evaluate the role of energy efficiency in providing resource adequacy. It is anecdotally appreciated that energy efficiency measures, especially related to heating and cooling services (e.g., efficient heating and cooling equipment, and efficient building envelopes) will lower the amount of energy requirements during extreme weather conditions. However, resource adequacy modeling tends to ignore this phenomena and we hope to bring an analytical lens towards this issue.



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