



Grid Research, Innovation, and Transformation

Integrated Reliability and Economic Analysis Tool

March 2026

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Cite: ERCOT. “Integrated Reliability and Economic Analysis Tool.” ERCOT, March 2026.

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Executive Summary

System planning involves a tightly coupled set of core studies, including Capacity Expansion Planning (CEP), Production Cost Modeling (PCM), and Reliability Analysis (RA) that ensures the reliability and economic efficiency of the system across multiple planning horizons. CEP involves projecting the development of new resources over a 15-year horizon, including the timing and locations of these additions. PCM focuses on the next two-to-five years, evaluating the impact on the transmission system by simulating how resources are dispatched on an hourly basis, considering fuel prices, reserve needs, and market dynamics. Similarly, reliability analysis ensures the network can reliably serve the demand by meeting the North American Electric Reliability Corporation (NERC) Reliability Standards and the ERCOT Protocols and Planning Guide requirements.

Although these studies are often conducted by different teams, they are highly interdependent such that the output of one study serves as the input for another. For instance, resource buildouts from CEP inform the production cost modeling. Network topology from the RA serves as an input to PCM, and PCM's results are validated in RA. This creates a dependency chain where scenario-specific long-term resource decisions provide guidance in aligning near- to mid-term transmission improvements with long-term needs of the grid within the planning horizon. These interdependencies among CEP, PCM, and RA make the overall planning process inherently iterative. Moreover, the reliance on manual handoffs of data, models, and assumptions across these studies requires repeated case updates, data exchanges, and model adjustments, making the process labor-intensive, error-prone, and time-consuming. While this approach has been manageable under a limited set of worst-case operating conditions, the current process does not scale effectively as the number of grid conditions that must be studied increases, with each condition requiring iterative process and re-execution across the interdependent studies.

RA have traditionally focused on representative worst-case scenarios but identifying representative worst-case operating conditions is increasingly complex due to rising uncertainty from renewables, storage, and shifting demand. Conditions like net load, steep ramps, or weather-driven conditions can be as critical as peak load. As a result, planners must now conduct a broader set of snapshot analyses across diverse sets of operating conditions, potentially extending to an 8760-hour horizon. This expansion increases the scale of analysis required, as the number of snapshot studies

and the iterations across CEP, PCM, and RA increase within each snapshot. The current planning workflow, characterized by manual data translation and sequential execution does not scale efficiently to this expanded scope. Even for a single operating snapshot, completing an end-to-end planning cycle can take multiple months. Expanding the number of snapshots magnifies computational burdens and increases the risk of data inconsistency across these studies.

This whitepaper proposes an integrated reliability and economic analysis tool that automates and streamlines data, information, and assumptions among studies (CEP, PCM, and RA) under a single integrated planning workflow. The integrated tool will not replace existing tools; instead, it acts as a front-end orchestration that automates data exchanges, manages model conversion, and coordinates study execution. This approach preserves each tool's strengths while eliminating the manual, error-prone handoffs.

By streamlining how studies are executed and iterated, the integrated tool is intended to enable planning processes that scale to increased analytical scope, including 8760-hour assessments. This whitepaper defines a set of core functional requirements, including interoperability across studies, unified scenario management, automated workflow orchestration, embedded consistency validation, and scalable execution, to enable the following outcomes:

- **Critical Hour Identification:** Enable identification and characterization of critical system conditions based on the user-defined criteria to determine which hours require detailed RA
- **Snapshot Generation:** A streamlined process to generate hourly AC power flow snapshots from planning seed case
- **Full AC Reliability Analysis:** Enable execution of detailed AC power flow and contingency analysis across an expanded set of hours (up to 8760-hour studies) using a complete contingency set
- **Study Time Reduction:** Reduce end-to-end planning cycle timelines across CEP, PCM, and reliability analysis from months to weeks

1. Overview of System Planning Studies

System planners conduct a range of economic and RA to ensure grid reliability and efficiency. These activities span different time horizons and employ specialized analytical tools to maintain secure power delivery under varying conditions. This section provides an overview of the key studies and processes involved in system planning, including Capacity Expansion Planning (CEP), Production Cost Modeling (PCM), and Reliability Analysis (RA).

1.1 Capacity Expansion Planning

CEP is used to estimate the types and amounts of new generation resources to be added, and the existing generation resources expected to be retired. The key input assumptions for capacity expansion analysis are capital cost, new technology types, incentives, wind and solar locations, and profiles. Additionally, load profiles are considered to ensure that the analysis accurately reflects the demand patterns over time. The long-term capacity expansion and retirement concept is depicted in Figure 1.

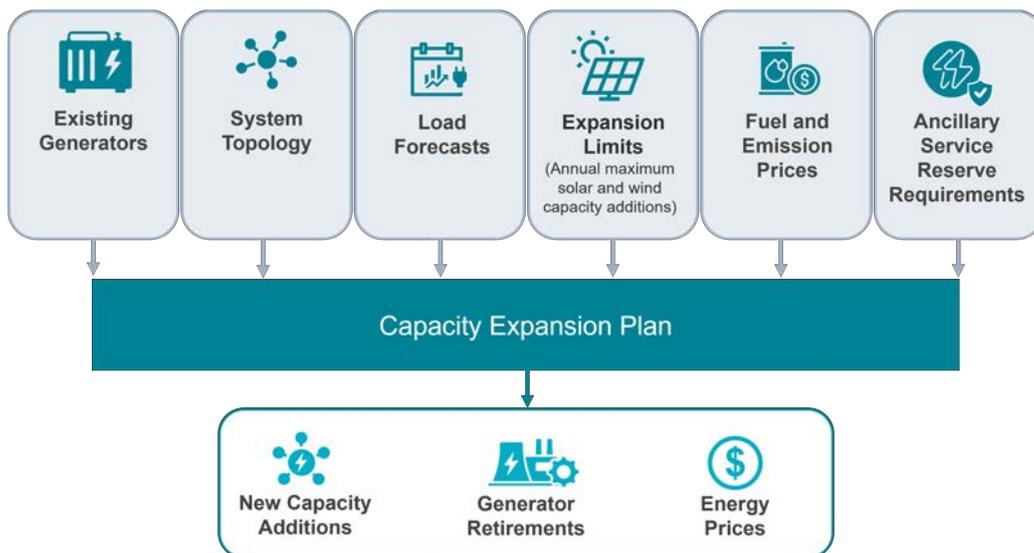


Figure 1. Overview of Long-Term Capacity Expansion and Retirement

A long-term generation capacity expansion study involves the planning and analysis of future generation needs to ensure that adequate capacity is available to meet demand over an extended period. This study typically employs a set of predefined assumptions and fixed parameters to simulate various scenarios and predict the economically optimal mix of generation technologies required. Key considerations include projected demand growth, fuel availability, renewable generation forecasts, technological advancements, regulatory constraints, and environmental impacts. By analyzing these factors, the study aims to provide a strategic roadmap for investments in new generation assets, ensuring reliability, cost-effectiveness, and sustainability of the power supply system for future generations.

1.2 Production Cost Model

PCM captures the operating costs and dispatch behavior of a fleet of generators over a defined study horizon. It is implemented as an hourly, security-constrained unit commitment and economic dispatch simulation, which determines how resources are committed and dispatched to meet forecasted demand while accounting for fuel prices, reserve requirements, and transmission constraints. The model aims to minimize total operating costs (objective function) under a set of operating constraints and produces hourly production costs and locational marginal prices (LMPs). PCM has the following key objectives:

- Simulate all the hours in the study timeframe (typically one year) and not just the peak load hour as in power flow models
- Look at economic benefits provided by transmission projects through LMPs (and their components) and production cost
- Identify hours with unserved energy

At a high level, here are the general steps that a PCM implements to perform production cost analysis.

1. Security-Constrained Unit Commitment (SCUC):
 - a. This step determines which generators are available to meet the forecasted demand at a given hour. The process considers must-run units and units committed/not committed during the previous

hour.

- b. It calculates the commitment cost for each unit using the forecasted load for the look-ahead period.
- c. It aims to minimize commitment costs (startup and operating costs) to balance supply and demand in the system while considering transmission constraints.

2. Security-Constrained Economic Dispatch (SCED):

- a. With committed units determined in the SCUC process, the tool performs SCED. The objective of this step is to dispatch all committed units to meet the load at each bus with optimal power flow while minimizing overall system costs.
- b. The dispatch is subject to transmission constraints such as pre-contingency limits (Rate A) and post-contingency limits (Rate B).

The model produces hourly prices, including generation production costs, shadow prices, line and interface flows, and energy revenue, among others.

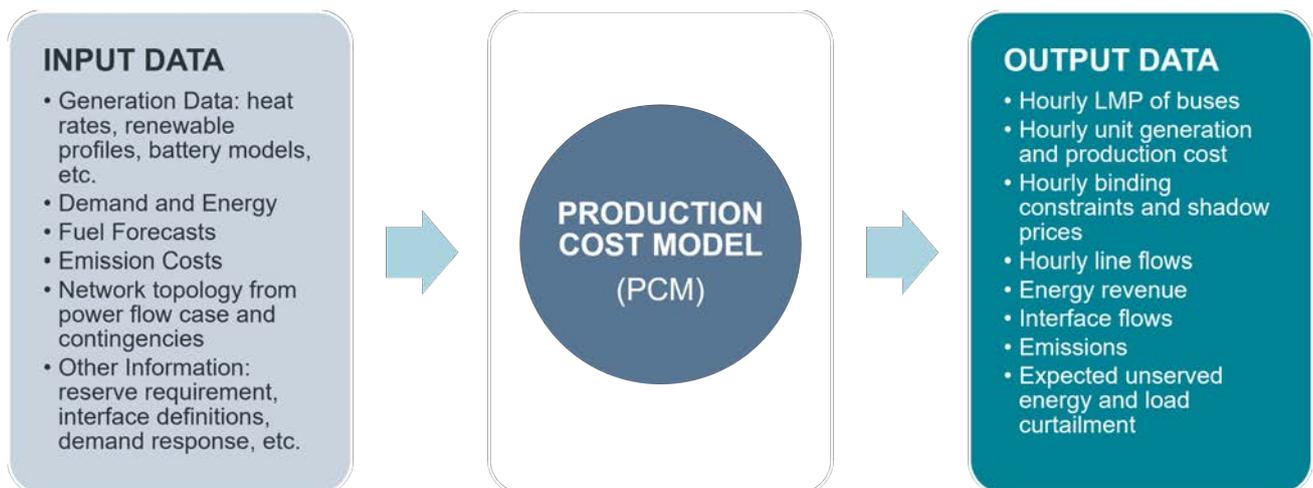


Figure 2: Conceptual Overview of PCM and Key Inputs and Outputs

PCM is currently performed using linear programming with a built-in DC Optimal Power Flow (OPF) formulation to support both SCUC and SCED.

1.3 Reliability Analysis

RA is a combination of several different analyses used to identify potential violations of reliability criteria and future system improvements that would be needed to address them.

- Security-Constrained Optimal Power Flow (SCOPF):
 - Determines optimal generation dispatch minimizing thermal violations while maintaining reliability of the system
- Contingency Analysis (CA):
 - Simulates the potential effects of loss of one or more system elements
- Multiple Element Contingency Analysis:
 - During this analysis, loss of elements due to the first contingency is followed by acceptable system adjustments, before testing the effect of the second contingency event. Other contingency scenarios, including extreme planning conditions involving extreme events and the simultaneous loss of multiple elements, are also analyzed. Extreme events associated with the disruption to supporting infrastructure, such as natural gas pipeline outages, are also included.
- Cascading Analysis:
 - Tests all planning and extreme events where equipment may be loaded above its relay loadability rating, resulting in immediate loss before any mitigation measures can be taken, which could lead to the rapid spread, or cascade, of relay violations and equipment loss

These various analyses are performed in sequence using a nodal system model, which is a full representation of the ERCOT network. As violations are identified at each stage, the nodal system model is updated with the changes necessary to resolve them. The result is a nodal system model for a future condition that is secure and free from reliability violations.

2. Relationships Among Planning Studies

Under the current planning approach, CEP, PCM, and RA are executed as distinct planning studies, each designed to address a specific planning objective and time horizon. CEP focuses on long-term resource development using aggregated representations, PCM evaluates near- to mid-term system operations through chronological dispatch simulations, and RA assess transmission system performance using detailed AC network models. These studies differ in modeling granularity, inputs, outputs, and execution frequency, reflecting their individual planning roles. Table 1 summarizes the key characteristics of CEP, PCM, and RA studies, including their objectives, study horizons, modeling detail, primary inputs and outputs, and typical execution timelines.

Table-1: Summary of Key Characteristics of CEP, PCM, and RA

Planning Activities	CEP	PCM	RA
Goals	Identify least-cost resource buildout, including generation, storage, and retirements	Simulate chronological system operations to access hourly dispatch, market dynamics, and production costs	Assess grid reliability under contingencies to comply with NERC Reliability Standards and ERCOT Protocols and Planning Guide
Study Horizon	Long-term (~15 years)	Near-to mid-term (2-5 years)	Near-to mid-term (2-6 years)
Modeling Granularity	Zonal or regional representation	Nodal, chronological (hourly) representation	Nodal, full AC network representation
Inputs	Load forecasts, technology costs, fuel prices, policy assumptions, reserve margin targets	Generation fleet characteristics, transmission topology, fuel and O&M costs, unit constraints, hourly load/gen profiles, and list of contingencies	Network topology, contingency lists, future year snapshot case developed by Steady State Working Group (SSWG)
Key Outputs	Generation mix, capacity additions and retirements, resource	Energy prices (LMPs), production costs, congestion patterns,	Transmission line and transformer flows, bus voltages, transfer

Planning Activities	CEP	PCM	RA
	adequacy outlook	emissions	capabilities, reliability violations
Study Frequency	Performed biennially.	Performed annually.	Performed annually.
Study Time	Takes about one week to simulate a single capacity expansion scenario over a 15 years horizon; multiple expansion scenarios are typically evaluated.	Takes about 2.5 - 3 hours per test case to simulate one year (8760 dispatch hours); Multiple test cases are evaluated.	Takes 15-20 minutes per snapshot for the full AC analysis; multiple studies are conducted to meet NERC and ERCOT Planning Guide requirements.

In practice, these studies are executed in a sequential planning workflow, where outputs produced in one stage are subsequently used to inform downstream analyses. Information such as resource buildouts, operating snapshots, network topology, and contingency definitions is exchanged across studies at defined points in the planning cycle. Figure 3 illustrates this traditional system planning framework. These elements describe the existing end-to-end planning process used to evaluate long-term resource needs, operational performance, and transmission system reliability. The coordination among these studies typically involves manual handoffs and model conversions.

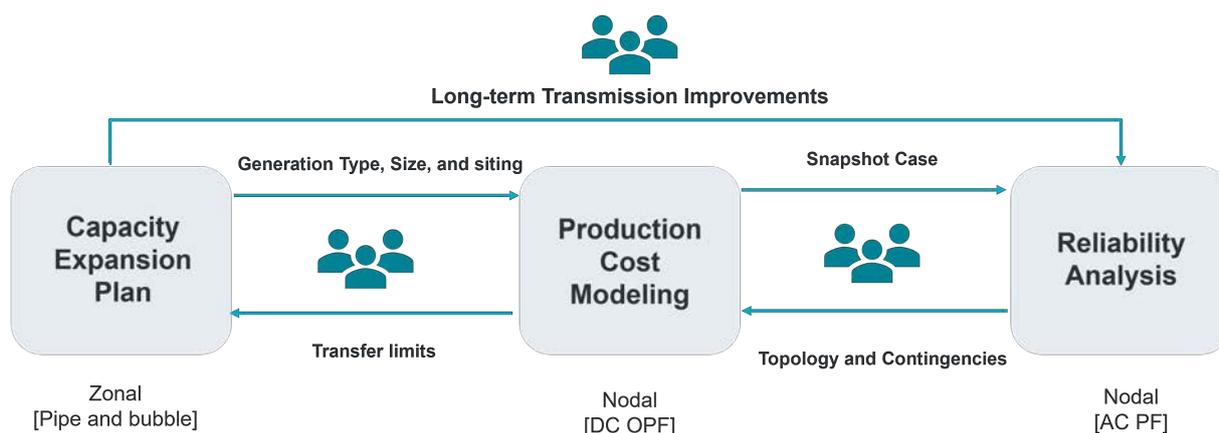


Figure 3 Schematic Diagram of Traditional Reliability and Economic Analysis

Table 2 summarizes the key information exchanged among different planning studies and the mechanisms used to transfer that information. It

also highlights the iterative nature of these interactions, illustrating how outputs from one study are repeatedly refined and incorporated into subsequent analyses across the planning process.

Table-2: Summary of Information Exchanges Among CEP, PCM, and RA

From <-> To	Shared information	How information is shared	Remarks
CEP -> PCM	Resource mix by type, retirements and additions at the zonal level	CSV, Excel	PCM disaggregates zonal information to nodal level for 8760-hour dispatch study. Two iterations between PCM-CEP are performed.
PCM -> CEP	Zonal transfer limits	CSV, Excel	Helps CEP adjust long-term resource placement. Two iterations between PCM-CEP are performed
PCM -> RA	Worst case snapshots	Base case power flow files, CSV (list of contingencies)	RA runs detailed AC analysis for the snapshots from PCM, including N-1 contingencies for feasibility and to identify and address any criteria violations
RA -> PCM	Updated topology and list of contingencies	Updated power flow files case files	Updated topology and list of contingencies are sent back after running detailed AC analysis with new transmission projects
CEP -> RA	Long-term transmission improvement projects	CSV, Excel	Transmission analysis is performed using generation buildouts from the capacity expansion plan to identify long-term transmission improvement projects, which are then provided as inputs to RA

3. Challenges in the Existing Planning Process

The existing planning process was largely developed under the assumption that a limited set of representative worst-case operating snapshots, typically peak load conditions, is sufficient to assess system risk and ensure reliability. As system conditions evolve, system risk increasingly arises not only during peak load periods but also under net-load extremes, ramping conditions, and weather-driven operating patterns. Addressing this expanded risk space requires evaluating system conditions across a broader range of operating hours and scenarios, exposing limitations in how planning studies are currently executed, iterated, and coordinated. The following subsections describe the key challenges that increasingly constrain the scalability, consistency, and efficiency of the existing planning approach.

3.1 Planning Studies Scalability

Even though each planning study (e.g., CEP, PCM, and RA) is performed as a stand-alone analysis, the overall planning process is highly interdependent, with outputs from one study serving as inputs to others. Because these studies are currently executed independently, changes in one study often require re-validation of assumptions and re-execution of related analyses to maintain consistency across the planning process. As the number of scenarios and operating conditions increases, this coordination burden grows significantly, making it increasingly difficult to efficiently perform planning studies.

3.2 Data Consistency and Model Translation

As information moves across planning studies, data integrity and consistency become significant technical challenges. Each study relies on different tools, data structures, and modeling assumptions. Transforming outputs from individual models into formats that can be used consistently across tools often requires manual model conversion and reconciliation. These translation steps are complex and error-prone, particularly as studies

iterate and assumptions evolve. Misalignment in resource assumptions, network topology, operating limits, or contingency definitions can propagate across studies, increasing the risk of inconsistent results and rework.

3.3 Expanded Risk Scenarios

Another key challenge in the existing planning approach is identifying representative worst-case operating scenarios for reliability analysis. Historically, RA focused on a limited set of peak load scenarios. However, increasing renewable penetration, battery charging behavior, and evolving demand patterns have expanded the range of conditions that can drive system risk. Net-load extremes, steep ramps, and weather-driven operating conditions can now be as critical as traditional peak load scenarios. As a result, planning studies must evaluate a broader set of scenarios (e.g., winter peak, high-renewable/low-load, steep ramps, and low-solar output conditions) to adequately assess system reliability.

Planning studies now need to incorporate more scenarios, such as winter peak, high-renewable/low-load, and no solar output conditions, to ensure reliability. A similar approach is being adopted for PCM analysis, where different representative weather years are considered, increasing the number of scenarios and iterations required to determine economic projects.

3.4 Planning Workflow Complexity

The planning workflow itself presents a major limitation to scalability. Feeding data from one tool to another often requires substantial manual effort, including the development of equivalent or simplified system models. The process often involves extracting outputs, transforming data, and reconditioning models and case to align with the requirements of the downstream study. Differences in modelling granularity and tool-specific representations further complicate this translation.

These workflows are time-consuming, difficult to repeat consistently, and prone to error—especially when multiple scenarios are evaluated.

Moreover, because planning studies are iterative, changes introduced in one stage frequently require re-execution of upstream and downstream analyses. As a result, repeated data exchanges, model adjustments, and re-validation across studies become a key driver of the overall study timelines. The most critical workflow limitation is the absence of a standardized, interoperable representation of the grid models that can be used consistently across CEP, PCM, and RA. As scenario counts and snapshot requirements grow, these circular and manual workflows increasingly constrain planning agility and extend study timelines.

4. Integrated Reliability and Economic Analysis Tool

Addressing the limitations of the existing planning approach described in Section 3 requires an integrated reliability and economic planning capability. The integrated tool is intended to support expanded analysis across a broader range of operating conditions and scenarios while maintaining consistency and efficiency across CEP, PCM, and RA as described in Section 2. Rather than replacing existing planning tools, the integrated capability functions as an orchestration layer that coordinates data flow, manages model conversion, and automates iterative study execution. Figure 4 illustrates the conceptual framework for coordinating CEP, PCM, and RA studies through an integrated planning tool.

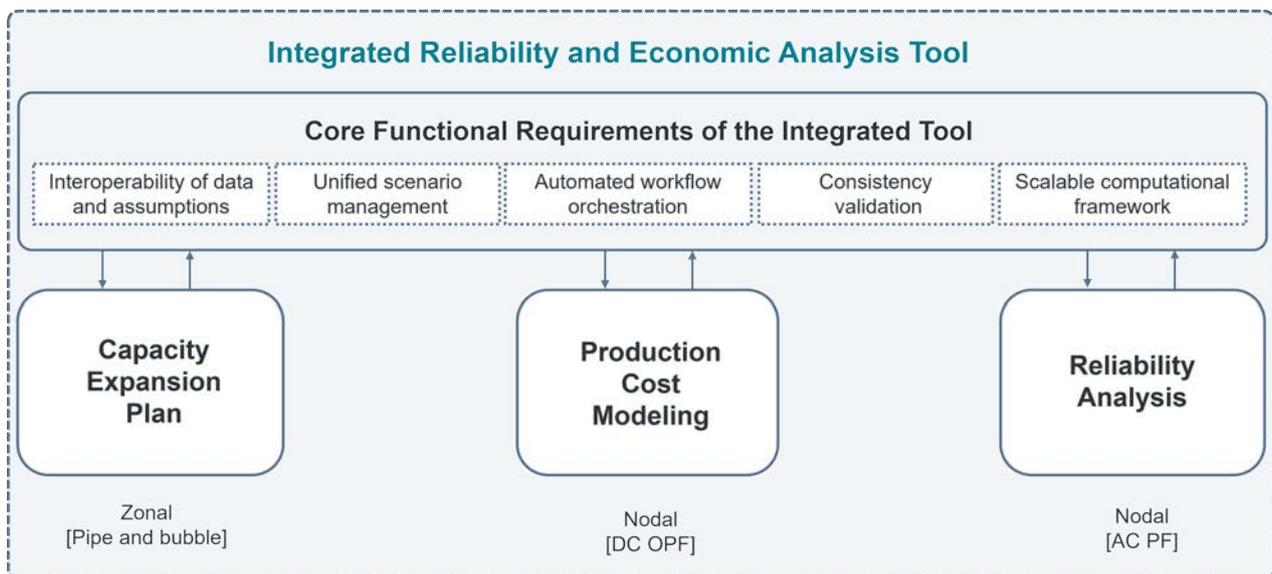


Figure 4 Conceptual Overview of the Integrated Reliability and Economic Planning Tool

4.1 Overview of the Integrated Capability

The integrated planning capability is designed to bridge the analytical gaps between long-term resource planning, near-term operational analysis, and detailed reliability analysis. By providing a coordinated framework across CEP, PCM, and RA, the integrated tool enables consistent application of assumptions, scalable execution of studies, and efficient iteration as

planning scenarios evolve. This capability supports planning needs that extend beyond traditional worst-case snapshots, including evaluation of diverse operating conditions and expanded scenario sets.

4.2 Core Functional Requirements

As shown in Figure 4, the integrated planning capability is defined by a set of core functional requirements that are intended to enable consistency, scalability, and efficiency across planning studies.

Interoperability Across Studies

Interoperability ensures consistent and seamless exchange of inputs and outputs across CEP, PCM, and RA. The integrated tool must maintain alignment of resource assumptions, network topology, and contingency definitions so that outputs from one study can be reliably used as inputs to subsequent studies without manual reformatting. This capability preserves data integrity and traceability across planning horizons while reducing translation errors and rework.

Unified Scenario Management

Unified scenario management enables planners to define scenarios once and apply them consistently across all planning studies. Key assumptions, such as load growth, renewable penetration, fuel prices, and candidate transmission projects, must remain synchronized to ensure each study reflects the same future conditions. This capability reduces inconsistencies across study stages and supports repeatable, transparent planning workflows.

Automated Workflow Orchestration

Automated workflow orchestration coordinates the sequential and iterative execution of CEP, PCM, and RA studies within a single planning process. By managing data flow and iterative dependencies across studies, this capability reduces manual handoffs, accelerates iteration cycles, and supports scalable evaluation of multiple scenarios. It enables planners to efficiently manage circular dependencies as results from downstream analyses inform upstream assumptions.

Embedded Consistency Validation

Embedded consistency validation provides automated checks to ensure that data, assumptions, and model translations remain aligned across planning studies. By detecting discrepancies early, such as mismatches in system totals, network mappings, or operational parameters, this capability prevents errors from propagating through the planning workflow. Early validation improves confidence in study results and reduces rework.

Scalable Computational Framework

A scalable computational framework enables efficient execution of large numbers of scenarios and system snapshots across CEP, PCM, and RA. While individual model runtimes (e.g., single PCM run) may be relatively short, the overall study time increases significantly due to the need to evaluate multiple test case runs and iteration across interdependent studies (CEP, PCM, and RA). This capability supports expanded analyses, including hundreds of snapshot hours or full 8760-hour studies, while maintaining consistent inputs and manageable runtimes. Without improvements to the current workflow, this expansion leads to substantial increases in study timelines due to repeated coordination, iterative rework, and the need to perform detailed reliability validation across expanded grid conditions. Scalability ensures planners can evaluate uncertainty and system stress conditions without extending planning cycle timelines.

4.3 Expected Outcomes Enabled by the Integrated Tool

These functional requirements enable an integrated planning capability that materially improves how reliability and economic planning studies are performed. The integrated tool leads to the following specific outcomes:

- Identification of critical operating hours that warrant detailed reliability and security analysis, moving beyond reliance on a limited set of worst-case snapshots
- Efficient generation of AC system snapshots from the DC economic dispatch studies that are fully aligned with the underlying planning assumptions

- Scalable execution of full AC reliability analysis, including expanded 8760-hours studies, under a complete contingency set
- Significant reduction in end-to-end planning cycle study timelines, enabling studies that currently take months to be completed in weeks, while maintaining analytical rigor

5. Conclusion

As planning studies expand beyond traditional worst-case snapshots to evaluate a broader range of operating conditions, existing planning processes, largely fragmented and manually coordinated, are increasingly unable to scale effectively. What was sufficient when analyses focused on a limited set of scenarios now faces growing challenges in managing complexity, iteration, and consistency. An integrated reliability and economic planning tool offers a clear opportunity to improve the efficiency, consistency, and scalability of the planning process not only by coordinating study execution, but also by enabling consistent scenario definition, scalable generation of system snapshots, and robust linkage between economic dispatch outcomes and full AC reliability analysis.

This whitepaper defines the functional requirements for an integrated reliability and economic analysis tool that enables systematic identification of critical system conditions, efficient generation and evaluation of reliability snapshots, feasible execution of expanded AC analyses, and material reductions in end-to-end planning cycle timelines. Building on this foundation, the next phase will focus on evaluating practical implementation approaches and engaging with solution providers to assess how these capabilities can be realized in support of ERCOT's evolving planning needs.



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