ESIG
ENERGY SYSTEMS INTEGRATION GROUP

ESIG REPORT

Optimization for Integrated Electricity System Planning: Opportunities for Integrated Planning in Capacity Expansion Models

EXECUTIVE SUMMARY

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A confluence of factors is now driving electricity system planners to consider the need for deeper integration across traditionally siloed planning processes, models, and—in some jurisdictions—organizations. These factors include rapidly accelerating load growth, technological evolution, growth in inverter-based resources, and power sector decarbonization goals. Integrated planning methods hold the promise of meeting generation, transmission, distribution, and customer/distributed energy resource (DER) system needs at lower costs through a comprehensive planning approach. Historically siloed planning processes are no longer sufficient for today's power system, where investments such as energy storage and flexible loads can serve multiple functions for resource and grid needs across planning domains. Initial integrated planning efforts have broadly focused on increasing links between existing planning siloes and facilitating a two-way flow of information between models and planning domains. Additionally, some co-optimization of generation, transmission, storage, and/or DERs has been performed. This report focuses on the technical opportunities and challenges for a theoretical expanded full-system capacity expansion optimization, as well as practical recommendations for moving planning processes toward more optimal solutions.

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Initial efforts at integrated planning may start by assessing process gaps and aligning key inputs and scenarios into siloed processes, progressing toward more

All three integrated planning reports can be found at https://www.esig.energy/integrated-planning/.

advanced approaches to integrated analytical methods. At a minimum, comprehensive planning involves iterative feedback loops between existing siloed processes, where even adding a single iterative loop can improve results. Taken further, co-optimization methods hold the promise of applying a least-cost optimization framework across a broader set of planning needs and potential solutions. Increasing the scope of the widely used generation (G) capacity expansion optimization provides a potential starting point for co-optimization of transmission (T), distribution (D), and customer/DER (C) investments alongside the optimal generation plan. Such an approach could support the identification of capacity investments in each planning domain, though additional models would still likely be needed to fully co-optimize the system due to limits in computation and mathematical formulations. These include the need for deeper modeling of resource adequacy, operational flexibility, power flow, system stability, protection schemes, and other detailed complementary analyses, which may require additional process iterations.

To explore the key steps and options involved in moving toward a more integrated, comprehensive planning paradigm, the Energy Systems Integration Group convened

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a task force of experts from utilities, system operators, research organizations, national laboratories, consultants, and other planning practitioners. Three reports were produced which contribute to the nascent knowledge base of integrated planning practices.[1] The first report, *Foundations of Integrated Planning,* defines integrated planning and why it is needed, followed by a broadly applicable framework for comprehensive planning. The second report, the *Integrated Planning Guidebook*, provides practical recommendations for today's electricity system planners to advance toward increasing levels of integration through a walk/jog/run approach. This is the third report, *Optimization for Integrated Electricity*

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Planning, focusing on the opportunities and current challenges in using economic optimization–based capacity expansion modeling to consider a broader set of integrated planning constraints and investment opportunities. Key points made in this report are the following.

The benefits of a full-system capacity expansion optimization include the potential for endogenous identification of integrated planning solutions, lower-cost integrated system plans, and fewer iterations between planning models.

For example, co-optimization can support the identification of where to build out the transmission grid for new bulk-grid investments, where to optimally site energy storage resources, and the value of DER versus bulk-grid resource investments. However, there are also major challenges to a full-system capacity expansion optimization. It requires significantly more granular resource, load, and grid constraint data, which leads to computational tractability challenges at scale. It also may lead to unrealistic outcomes or false precision, where value-stacked integrated solutions are maximized further than their real-world feasibility. Current decision-making venues and processes may not be ready to implement a fully optimized plan across multiple planning domains.

Bulk-grid generation and transmission co-optimization methods are rapidly evolving, with multiple tractable methods for co-optimization.

These broadly include using either (a) aggregated zonal topology for dispatch with detailed transmission deliverability limits and upgrade costs for new resources, or (b) various levels of more detailed dispatch topology—such as multiple sub-zones or a full nodal representation—with transmission upgrades represented as flow constraints between zones or nodes. The former is adept at capturing deliverability upgrade requirements and the latter at capturing the impacts of congestion. They may be used individually or in tandem to co-optimize G and T investments.

Optimizing local grid investments faces higher hurdles, as it is not tractable to model load and resource balance down to the distribution system level, let alone down to the customer.

Recognizing the limits of capturing granular distribution system values, DERs and flexible loads can be directly optimized against G+T investments or indirectly optimized through process iterations, subject to a few key considerations. Methods that can align the valuation for supply-side and demand-side resources can enable the identification of the least-cost resource mix needed to meet generation and grid needs. Optimizing DERs necessitates significant data development and bundling to create tractable DER supply curves. DER and flexible load performance must be measured relative to a clear baseline so that their incremental value to the system can be properly assessed. Planners need to consider whether existing DER sourcing mechanisms—such as utility programs, tariffs, or solicitations—are sufficient for sourcing the optimized system and/or local needs modeled, or whether additional real-world validation is needed. Additionally, least-cost optimization has important limitations when compared to the broader cost-effectiveness frameworks often used in customer DER planning and rate design, which consider multiple stakeholder perspectives. In general, planning frameworks for DERs will need to match the decision frameworks used by utilities and regulators to determine DER investments and incentives.

Alternative approaches exist to a single full-system optimization that can tractably capture key interactions across planning domains.

Three alternative approaches to a single full-system optimization are presented in this report (Table ES-1, p. 4). First, hourly avoided costs from bulk-grid G+T planning and distribution system planning can be used

TABLE ES-1

Three Alternative Approaches to a Single Full-System Optimization

Option 1: Hourly avoided costs	Option 2: Many local system optimizations	Option 3: Bulk grid and DER optimization
Develop hourly avoided costs for all distributed energy resource value streams based on an optimized bulk-grid generation and transmission solution, supplemented by additional detailed transmission and distribution studies to inform locational values	Optimize a single bulk-grid generation and transmission solution that informs the bulk-grid value for distributed energy resources studied in many local integrated distribution system optimizations against distribution upgrade needs	Use a parameterization of marginal distribution system costs to inform a generation, transmission, and distributed energy resource co-optimization

Source: Energy Systems Integration Group.

to align DER valuation with system and local displaceable investments. Second, distribution system planning optimization models can be used to assess grid versus DER investments, incorporating bulk avoided costs from a G+T co-optimization to evaluate the net value of new DERs in local grids. Third, marginal distribution system costs can be created and parameterized in reduced form as inputs into a G+T+C capacity expansion model, and this process can be iterated to converge on the appropriate mix of resource versus wires investments.

In the *run* stage, planners will use expanded capacity expansion optimization models and/or tightly coupled iterative processes to coordinate investments across generation, transmission, distribution, and customer loads and DERs. This may include either varying degrees of fully combined optimization using appropriately parameterized datasets or carefully designed iterative loops between planning processes.

A walk/jog/run framework supports a phased approach for continual improvement that provides a tractable pace of change management.

Recognizing both technical and practical challenges for being able to model and implement a "theoretically optimal" planning solution, this report shares specific recommendations for planners to make incremental progress toward the fully integrated analytical models presented. The format for the suggested steps in the conclusion is a walk/jog/run framework, which supports a phased approach for continual improvement that provides a tractable pace of change management (Table ES-2).

TABLE ES-2

Incremental Stages of Progress Toward Fully Integrated Analytical Models

Incremental Stage of Progress Toward Fully Integrated Analytical Models	Planners' Tasks
Walk	Planners align objectives, assess key gaps, and harmonize inputs and scenarios. These low-hanging fruit can enable initial integration stages with minimal new data or model development and set the stage for later phases.
Jog	Planners address the gaps assessed in the *walk* phase. This involves creating new data needed for integrated planning, building new modeling capabilities, and creating an integrated planning process through which these new data can be incorporated into expanded modeling and decision-making processes.
Run	Planners use expanded capacity expansion optimization models and/or tightly coupled iterative processes to coordinate investments across generation, transmission, distribution, and customer programs and DERs.

Source: Energy Systems Integration Group.

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In the *walk* stage, planners focus on aligning objectives, assessing key gaps, and harmonizing inputs and scenarios. These are key low-hanging fruit that can enable initial integration stages with minimal new data or model development and set the stage for later phases. In the *jog* phase, the gaps assessed in the prior phase are addressed. This involves creating new data needed for integrated planning, building new modeling capabilities, and creating an integrated planning process through which these new data can be incorporated into expanded models and decision-making processes. In this phase, spatially and temporally granular data are generated for loads, grid constraints, grid upgrades, and supply- and demand-side resource options, and combined generation, transmission, and energy storage capacity expansion is possible.

As planners approach the final phase of integrated planning, they will have new data available and new modeling capabilities to support advanced and/or novel analyses. In the *run* stage, planners will use expanded capacity expansion optimization models and/or tightly coupled iterative processes to coordinate investments across generation, transmission, distribution, and customer loads and DERs. As outlined in this report, this may include either varying degrees of fully combined optimization using appropriately parameterized datasets or carefully designed iterative loops between planning processes such as the use of marginal avoided costs; either approach can be sufficient.

The practical methods outlined in this report provide a framework for planners to increase integration of their analytical processes. The methods support efficiently identifying comprehensive planning solutions that facilitate informed decision-making, lower-cost outcomes, and continuous improvement. These methods are broadly accessible today through careful coordination and data exchange between modeling tools. As computational capabilities and new methods evolve, tighter integration, more seamless data interaction, and increased automation may become feasible.

Optimization for Integrated Electricity System Planning: Opportunities for Integrated Planning in Capacity Expansion Models, by the Energy Systems Integration Group's Integrated Planning Task Force, is available at https://www.esig.energy/integrated-planning/.

To learn more about the topics discussed here, please send an email to info@esig.energy.

The Energy Systems Integration Group is a nonprofit organization that marshals the expertise of the electricity industry's technical community to support grid transformation and energy systems integration and operation. https://www.esig.energy.