Integrated System Planning: Opportunities and Challenges for Co-optimization Across Planning Domains

ESIG Spring Technical Workshop

March 18, 2025

Energy+Environmental Economics

Aaron Burdick, Director

E3’s Integrated System Planning Experience

Utility Integrated Planning

Hawaiian Electric
Integrated Grid Planning

SRP
Integrated System Planning

TVA TENNESSEE VALLEY AUTHORITY
Integrated G+T Planning

The Electric Company
El Paso Electric
Integrated System Planning

SaskPower
Powering our future®
Integrated System Planning

SMUD®
Integrated Distribution (+ Resource) Planning

Regulator Strategy

Public Utilities Commission State of California
Integrated G+T Planning + DER Valuation

British Columbia
Integrated Gas + Electric Planning

Thought Leadership

Whitepaper + Webinar Series

ESIG ENERGY SYSTEMS INTEGRATION GROUP
Integrated Planning Task Force

Forthcoming ESIG Integrated Planning Whitepapers

ESIG has organized an Integrated Planning task force, focused on drafting the following whitepapers by spring 2025:

1. **Foundations of Integrated Planning:** core components of a holistic planning framework

2. **Integrated Planning Guidebook:** practical recommendations for today's planners to increase integration across domains

3. **Optimization for Integrated Planning:** opportunities and limits to use optimization for integrated planning

Integrated planning background

Energy+Environmental Economics

Motivations for Integrated System Planning

Many forces are driving high investment needs over the coming decades…

- Decarbonization policies
- Industrial and data center load growth
- Electrification
- Aging infrastructure
- Wildfire risks
- Cybersecurity

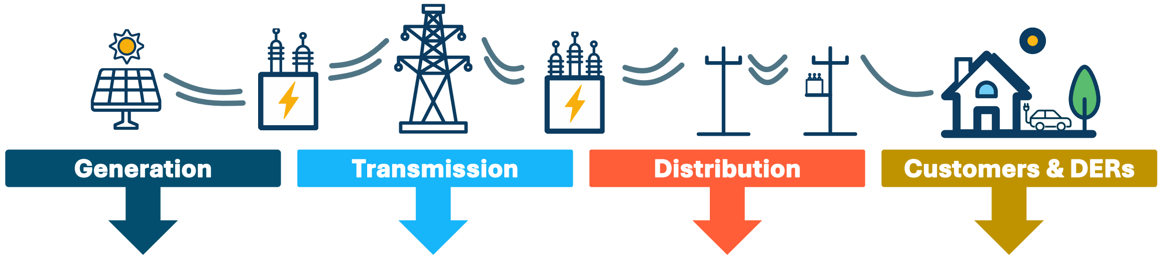
…this creates opportunities and challenges for meeting planning goals:

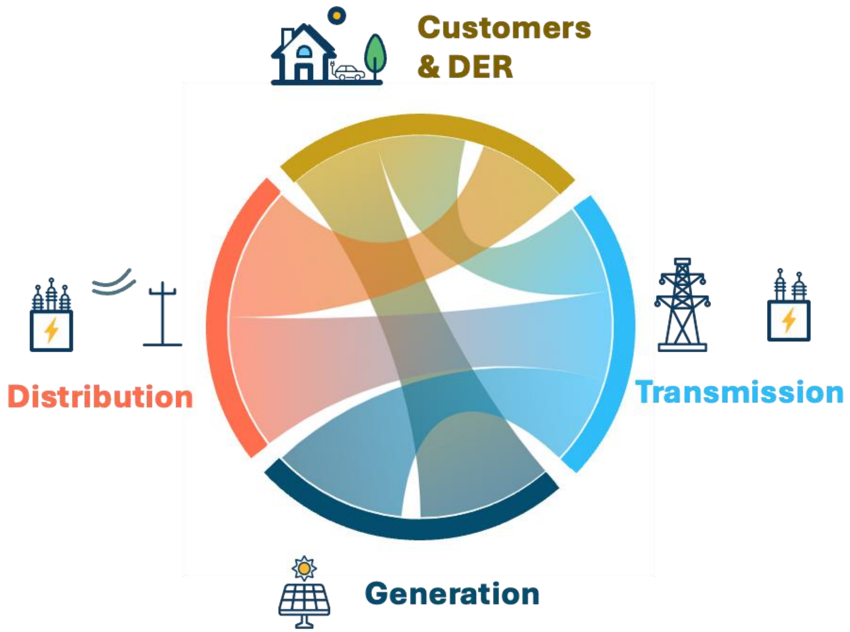
- Reliable
- Affordable
- Clean

Need to ensure that planning identifies

- the right investments…
- in the right locations…
- at the right times

What is integrated planning?





<u>Traditional electricity planning</u> has often been siloed

Siloed planning worked when investments in one planning domain had limited impact on other planning needs – this is no longer the case

<u>Integrated planning</u> is a holistic energy system planning approach that links traditionally siloed planning processes to develop affordable, reliable, and robust investment plans

Integration of Analytical Processes

- **There is no "one-size-fits-all" analytical approach for integrated planning**
  - E.g., small island grid vs. RTO wide study, a vertically integrated utility vs planning across organizations in deregulated markets, etc.

- **The key focus should be on implementing the necessary data linkages between planning models/decisions to ensure a holistic solution that meets all planning objectives**

Electricity system planning integrations

1 Forecast system needs

Economywide Energy Systems

Scenarios of electric load growth, including transportation, building, and industrial electrification

↓

Load & DER Forecasts and Downscaling

Resource Options Study

2 Identify system solutions

Distribution Studies

- Power flow + Reliability, Asset Health
- Non-wires alternative study

Transmission Studies

- Power Flow / Contingency Analysis, Stability, Reserve Needs
- Nodal Production Cost Modeling

Generation Studies

- Resource Adequacy Study
- Capacity Expansion Optimization
- Production Cost Modeling

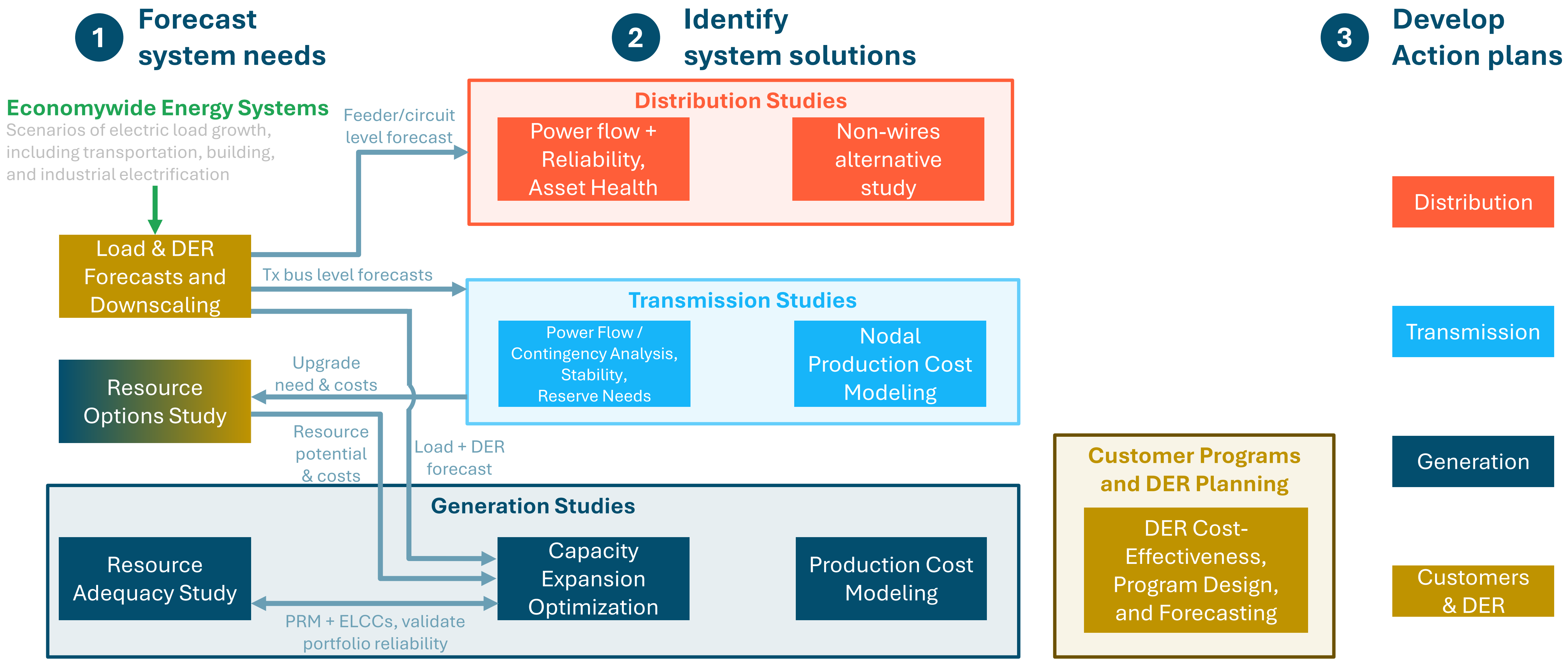
Customer Programs and DER Planning

- DER Cost-Effectiveness, Program Design, and Forecasting

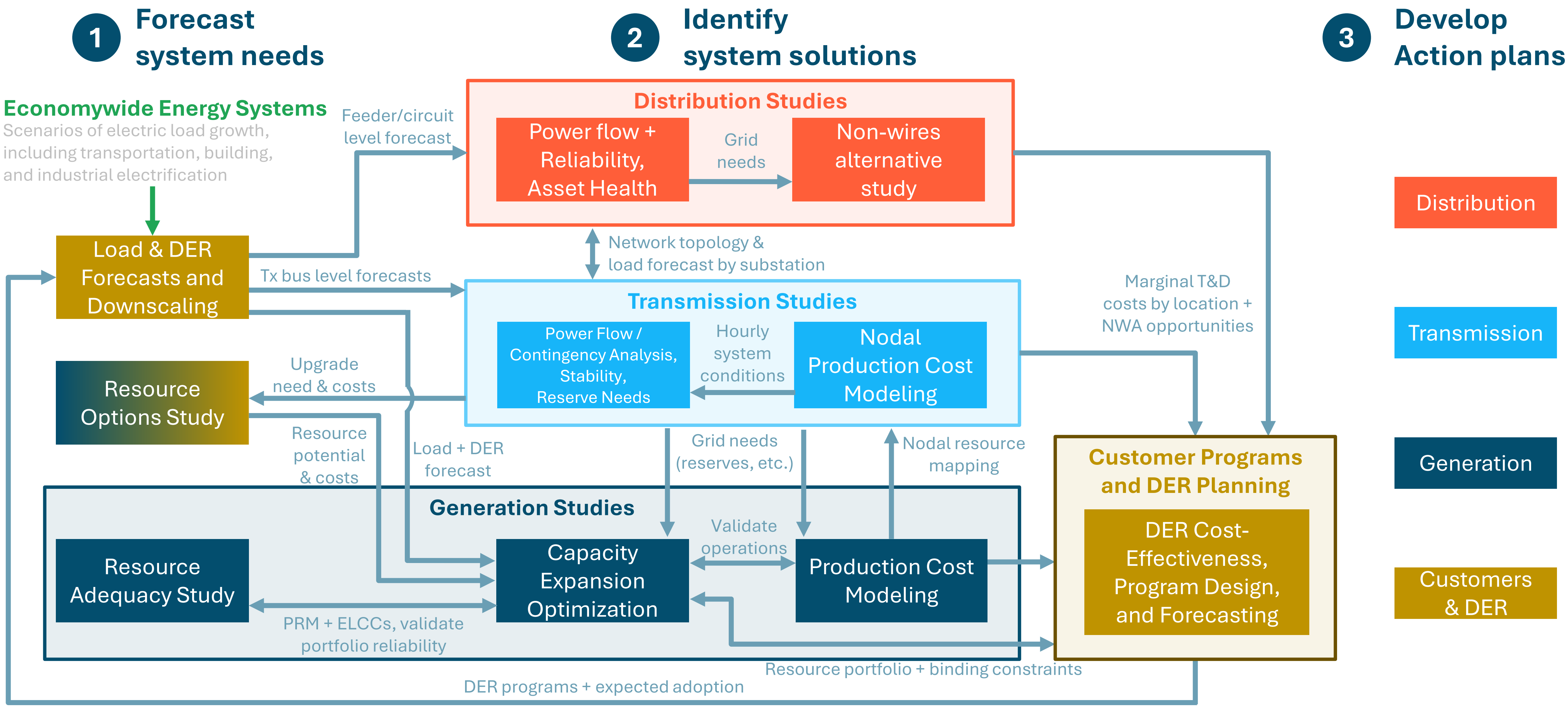
3 Develop Action plans

- Distribution
- Transmission
- Generation
- Customers & DER

Electricity system planning integrations



Electricity system planning integrations

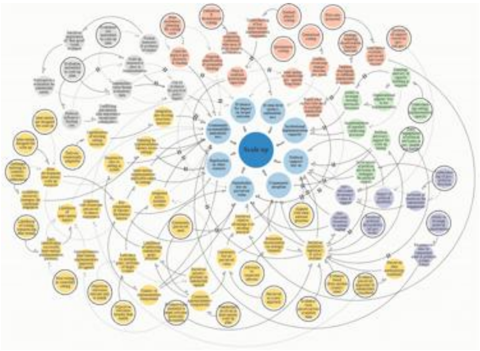


Integrated planning requires multiple modeling processes

How do we balance the complexity of interdependent parts of the system with the practical needs for modeling, decision making, and stakeholder engagement?

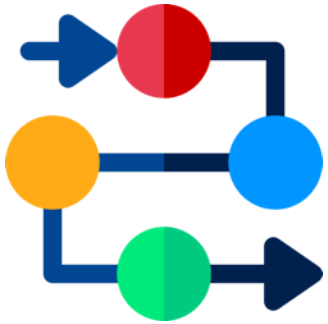
Single model that co-optimizes the full system

Such a model is not feasible for the foreseeable future due to data, modeling, and process constraints



Multiple, coordinated modeling processes

Multiple modeling processes, if coordinated appropriately, can capture the interdependent nature of full system planning



What planning components can be tractably combined into a co-optimization framework today?

Opportunities and challenges to use capacity expansion modeling for integrated planning

Energy+Environmental Economics

Benefits and challenges of co-optimization

Benefits

+ Endogenously identify integrated investment opportunities
  - Transmission impacts on optimal generation type/quantities
  - Storage siting
  - DERs vs. bulk grid investments
+ Lower total cost solution
+ Fewer iterations between planning models

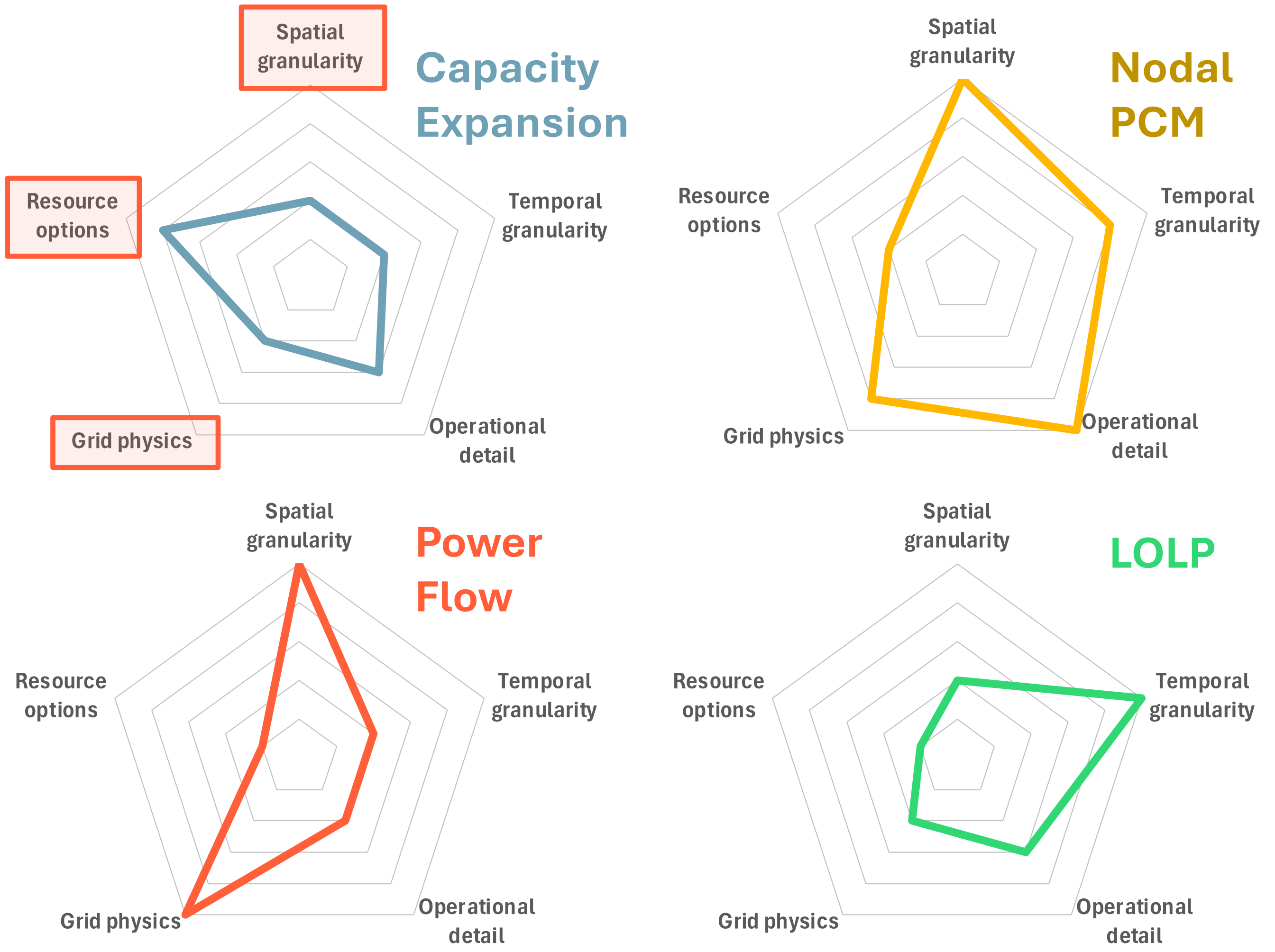
Challenges

+ New data development requirements
  - More granular locational load + resource data
+ Potential for false precision or over-optimization
+ Computational tractability
+ Cannot fully eliminate iterative processes

Economic optimization in capacity expansion already requires key tradeoffs for computational tractability

Existing tradeoffs in capacity expansion:

- **Spatial granularity**: typically zonal, nodal siting addressed in downstream models
- **Temporal granularity**: representative days or weeks from broader datasets
- **Operational detail**: approximations of economic dispatch
- **Grid physics**: limited detail, simple zone-to-zone transfers limits
- **Resource options**: multiple candidate resource technologies (some aggregation, often linear not integer variables)

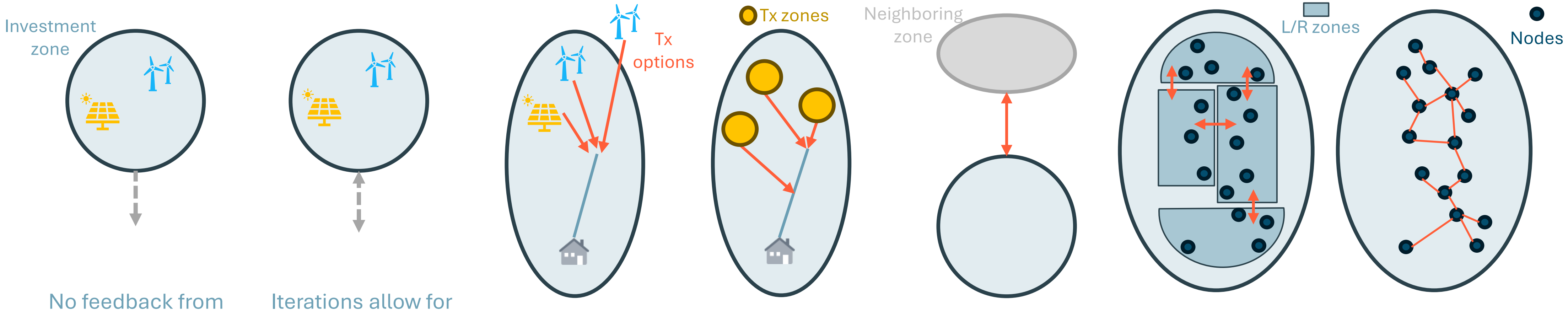


Integrated planning will require expanding detail in these areas

G+T: Integration Options for Co-optimized Investment

Note: methods are not mutually exclusive. They can be combined within the same capacity expansion problem.

	No integration	Iteration	Resource or Tx zone limits		Hourly flow constraints (pipe + bubble representation)		
	One-way flow	**G<>T Iterative Process**	**Resource specific constraints**	**Tx zones**	**Inter-zonal**	**Intra-zonal (aggregated nodes)**	**Nodal**
Cap. Ex. Model Dispatch	Zonal	Zonal	Zonal	Zonal	Inter-zonal	Intra-zonal (aggregation of full network nodes)	Nodal
Cap. Ex. Model Tx Limits	None	None	Resource-level	Tx zone level (across resources)	Inter-zonal flows	Intra-zonal flows	Nodal flows



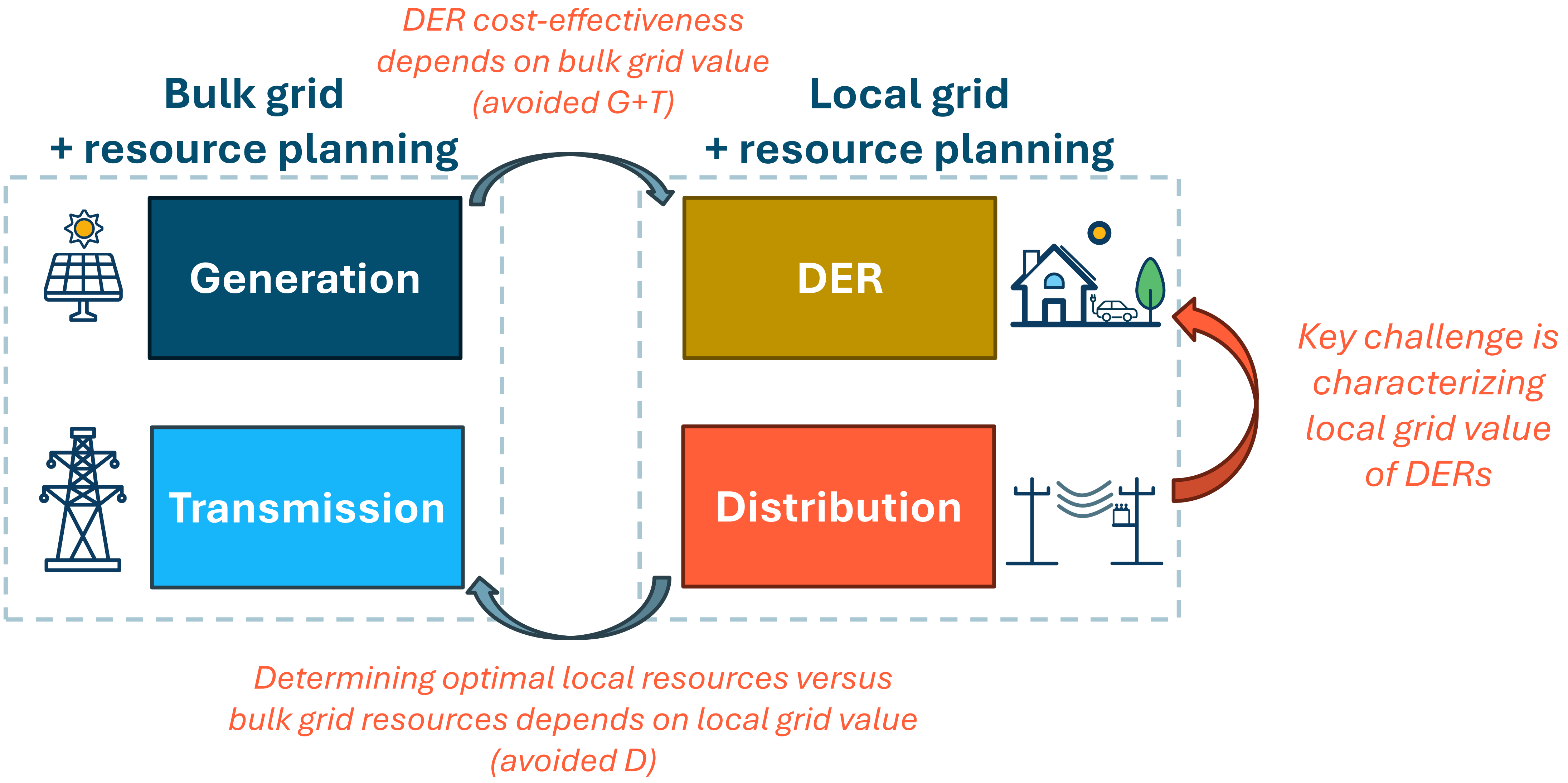
No feedback from downstream Tx models limits ability to adjust resource builds	Iterations allow for some level of integration, but process is inefficient	Captures remote deliverability upgrade needs, Tx zones allows for diversity to maximize line utilization	Tractable, allows study of BA<>BA level upgrades	Captures intra-zonal detail but limit data needs and runtime impacts	Captures full network model detail but poses computational tractability challenges

Limits of Economic Optimization for Transmission Planning

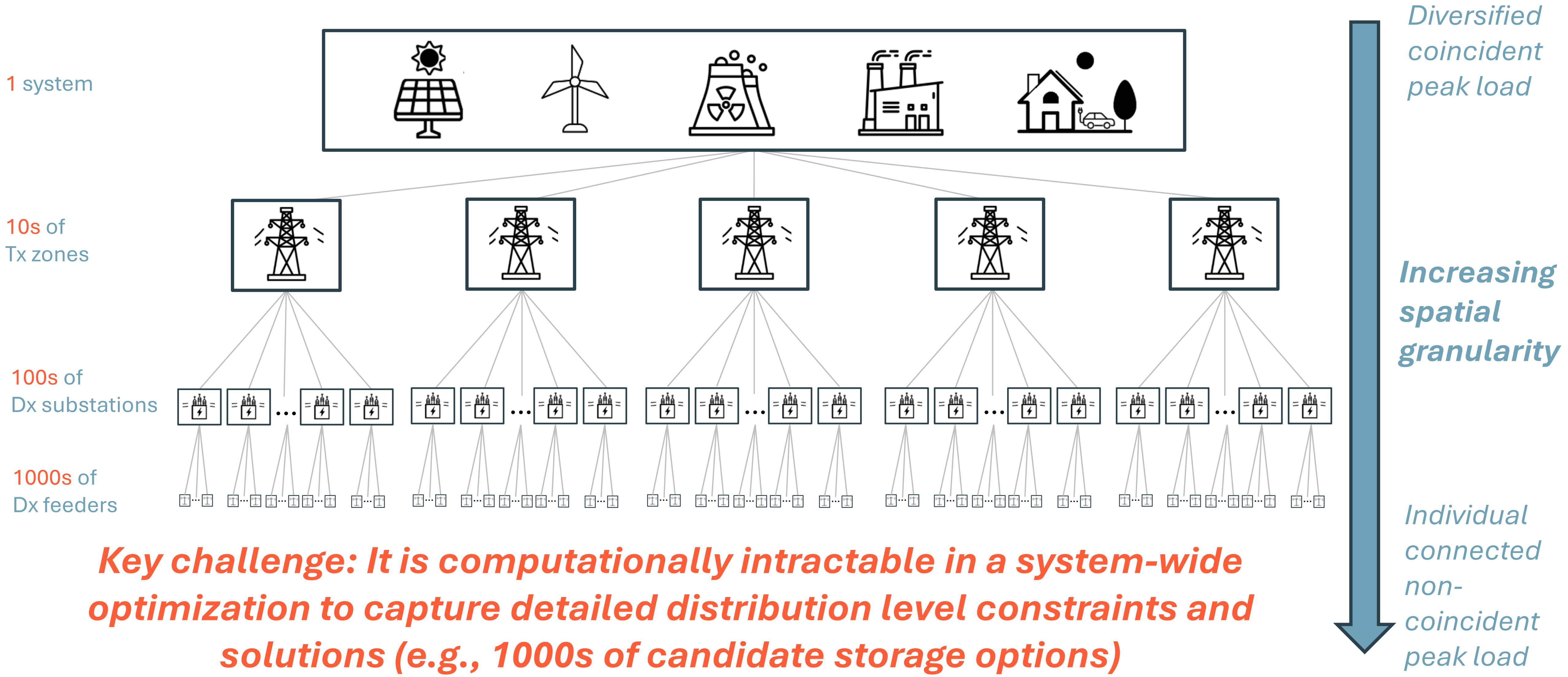
… and *why some iteration will still be needed*

- **Economic co-optimization of generation and transmission can identify new transmission lines for deliverability or congestion relief**
- **Outputs still require validation in "downstream" transmission models**
  - **Nodal PCM:** SCED and DC power flow surface economic upgrades for congestion
  - **AC power flow**: more robust power flow physics capture thermal overloading, voltage, etc.
  - **Contingency analysis**: captures grid needs during one or more outage events (N-1, N-2, etc.)
  - **Stability**: sub-second dynamic response during disturbance events
  - **Resource adequacy and resiliency**: RA or resilience value of transmission during extreme events
- **"Downstream" analyses identify additional investments**
  - Can also feedback back information to capacity expansion and/or production cost simulations (e.g., dispatch limits, inertia constraints, etc.)

G+T+DER co-optimization is feasible, but incorporating precise distribution level local values has been a major challenge

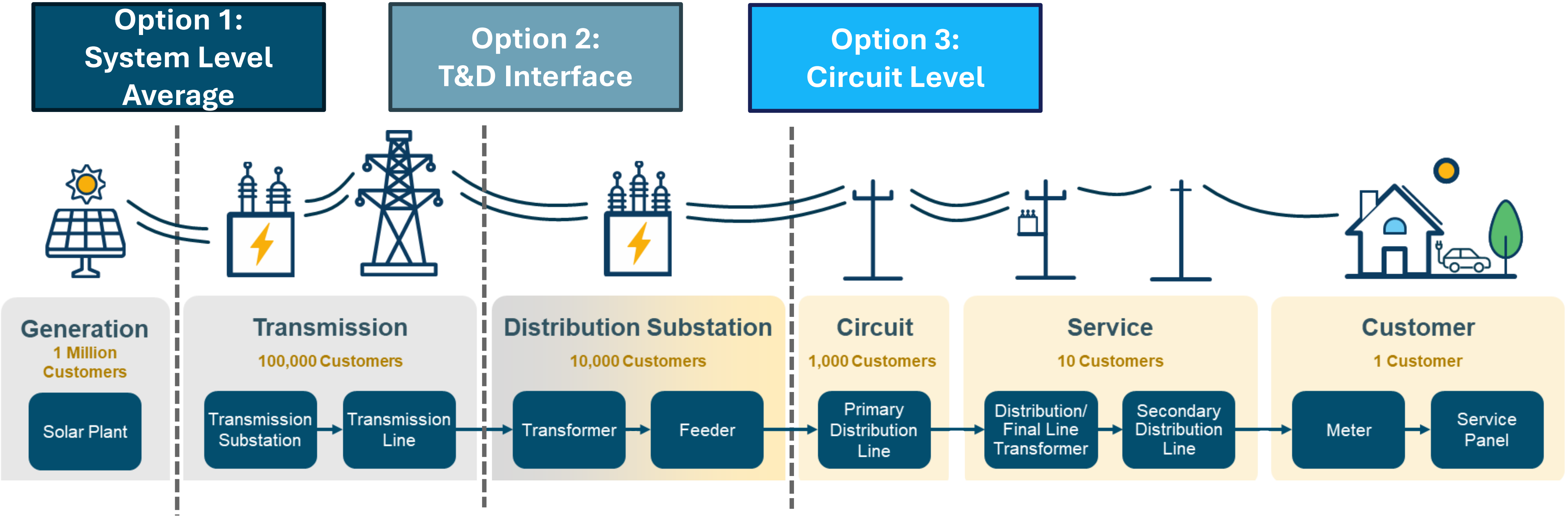


Incorporating local grid value is a challenge due to the scale of the distribution system



Key challenge: It is computationally intractable in a system-wide optimization to capture detailed distribution level constraints and solutions (e.g., 1000s of candidate storage options)

Locational Value: Spatial Granularity Tradeoffs



Low granularity
Highly imprecise measure of locational value
Computationally tractable

(e.g., "peanut buttering" of average distribution values)

Medium granularity
Imprecise measure of locational value
May be computationally tractable

(e.g., T&D interface L/R dispatch or distribution planning area parameterized locational supply curve)

High granularity
Precise measure of locational value
Computationally intractable

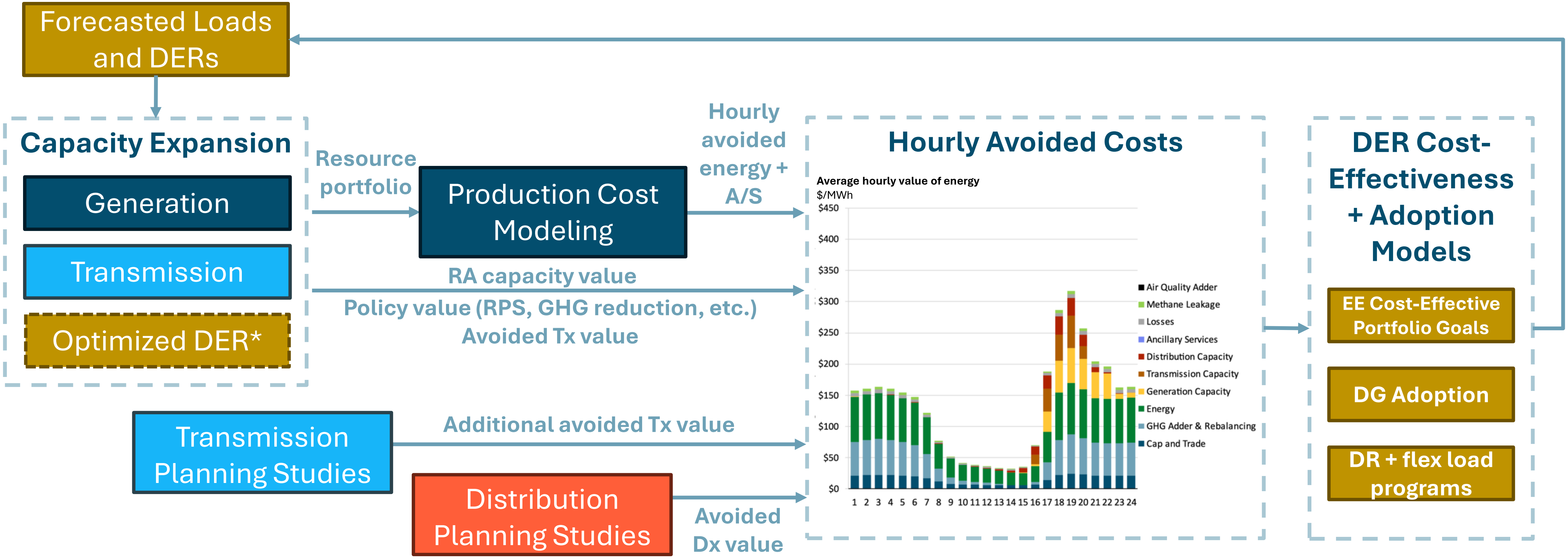
(e.g., circuit level L/R dispatch or parameterized locational supply curve)

Other potential "good enough" methods:

- ***Grouping into circuit "archetypes"?***
- ***CREZ style parameterized limits?***

Avoided Cost Alternative Approach

Marginal avoided costs for DER program cost-effectiveness, forecasting, and tariff design



Note: this process allows for creation of granular locational avoided costs and/or targeted NWA opportunities. Multiple sourcing methods may be used to capture these values depending on the location and nature of the need (locational programs, solicitations, direct build, etc.). To the extent those values will be sought out via sourcing of additional DERs, those additional resources can then be fed back into the forecast for G/T/D planning processes to assess residual needs.

* Incremental DERs can still be optimized above forecasted DERs if desired

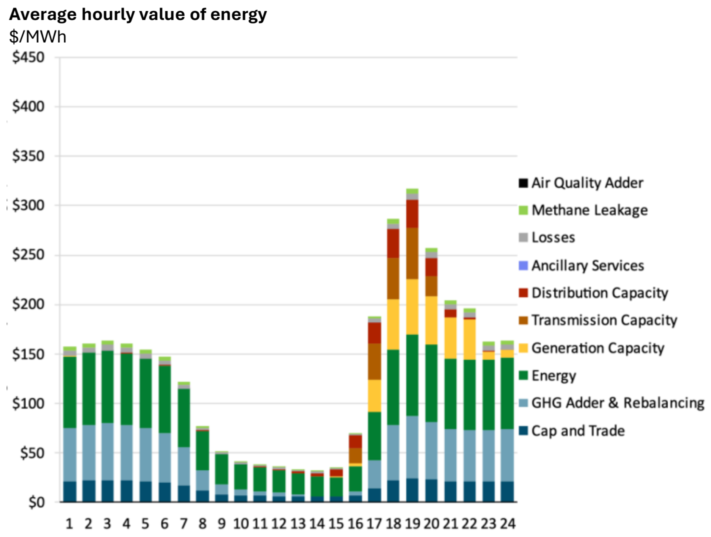
Avoided Cost Alternative Approach

Use economic optimization within integrated D+DER models, informed by bulk grid avoided costs

+ **Instead of local values informing a larger full system co-optimization, bulk grid values can inform targeted local integrated distribution system planning (IDSP) optimization models**
    - Optimize DER versus grid investments, with DER costs measured incremental to their bulk grid value

Bulk grid + resource planning

(Bulk Grid) Hourly Avoided Costs

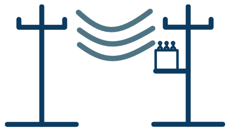


Bulk grid value + performance requirements (RA, etc.)

Local grid + resource planning

DER

Distribution



Substation or feeder level economic optimization

Grid investments vs. incremental DERs or flexible loads

Summary conclusions for incorporating T/D/C into generation capacity expansion optimization

- **Transmission can and generally should be integrated into generation planning capacity expansion**
  - Tradeoffs regarding spatial granularity and model runtime
  - Continued need for downstream studies
- **Distribution investment decisions are not necessary (nor feasible) to integrate with capacity expansion**
  - Intractable spatial granularity for 1000's of individual circuits
  - Distribution studies can identify local costs and benefits for DERs… but no existing methods to parameterize this (with precise granularity) into system-level studies
- **Customer-DERs and flexible loads can be integrated into capacity expansion, but require key considerations in doing so**
  - What DERs to forecast vs. optimize, how to measure cost-effectiveness, and how much local value can tractably be included
  - Using avoided costs for DER cost-effectiveness offers a tractable alternative method to co-optimization