

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

ESIG Spring Technical Workshop

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Energy+Environmental Economics

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E3's Integrated System Planning Experience

Utility Integrated Planning



**Hawaiian
Electric**

Integrated Grid Planning

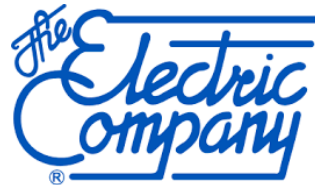


Integrated System Planning



**TENNESSEE
VALLEY
AUTHORITY**

Integrated G+T Planning



El Paso Electric

Integrated System Planning



Powering our future®

Integrated System Planning



SMUD®

Integrated Distribution (+ Resource) Planning

Regulator Strategy



Integrated G+T Planning + DER Valuation



Integrated Gas + Electric Planning

Thought Leadership



**Integrated System Planning:
A New Planning Paradigm**

ISP Webinar Series

**Integrated System Planning:
From Vision to Reality**

ISP Webinar Series



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



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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



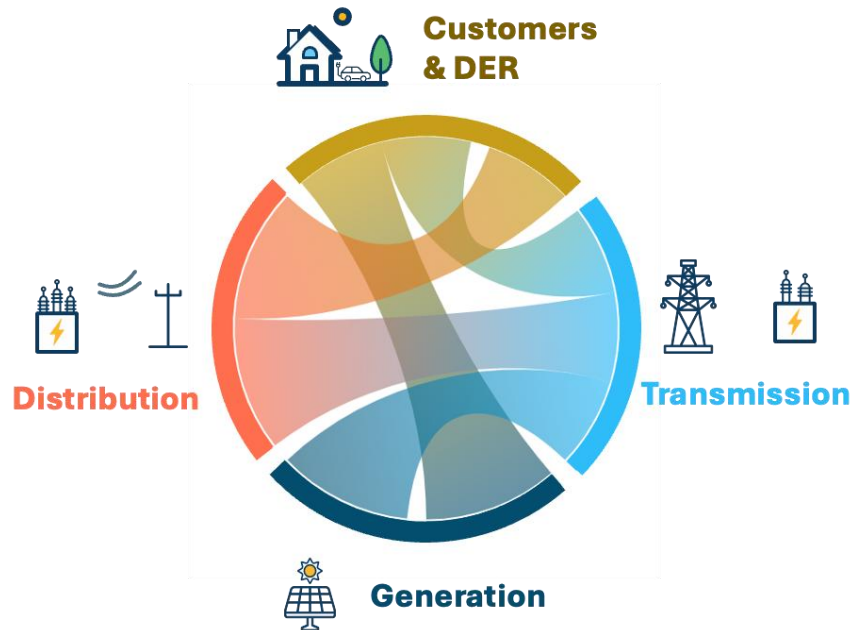
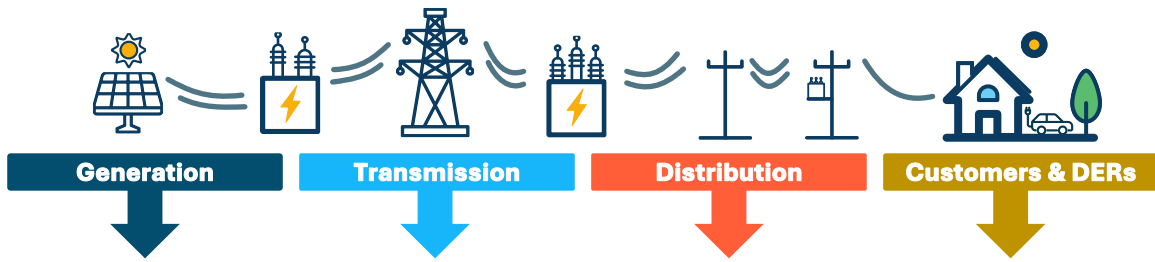
Clean



Need to ensure that planning identifies

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

What is integrated planning?



Traditional electricity planning 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



Integrated planning 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

3 Develop Action plans

Distribution

Transmission

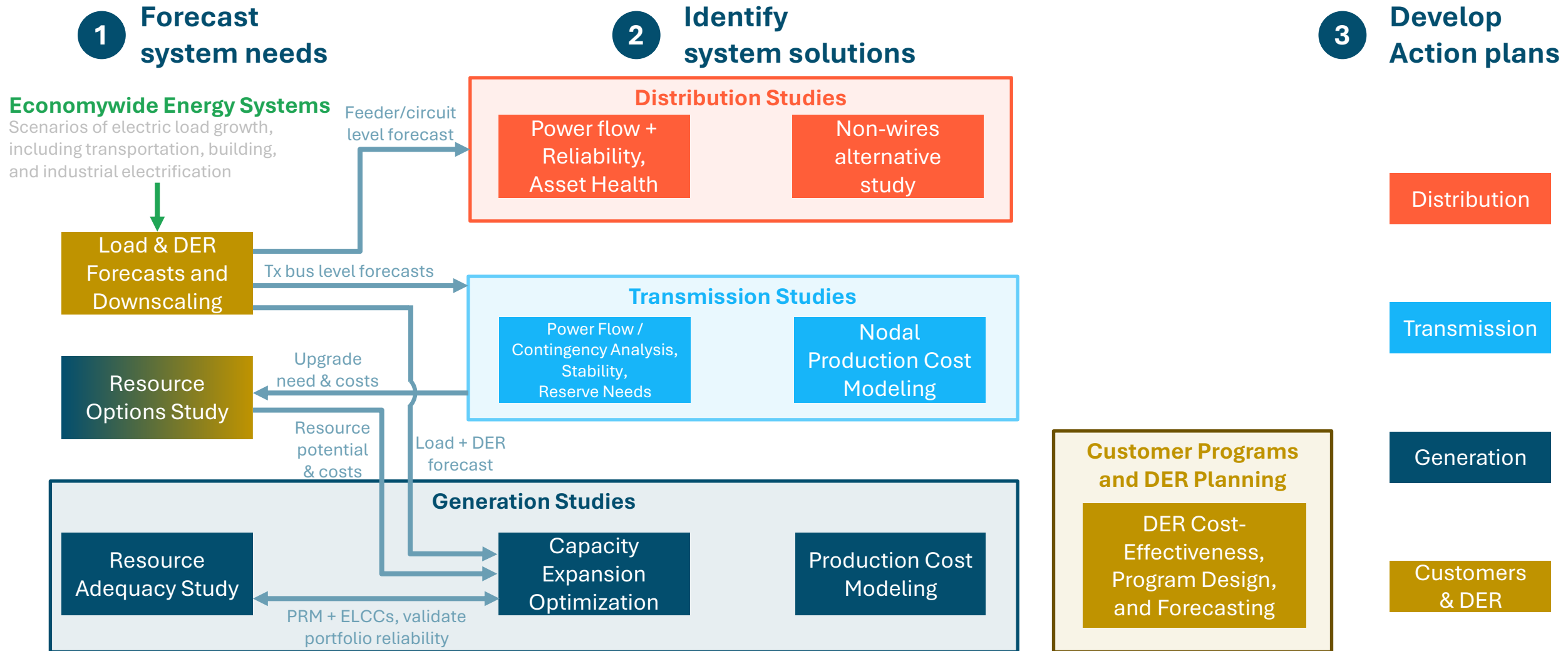
Generation

Customer Programs and DER Planning

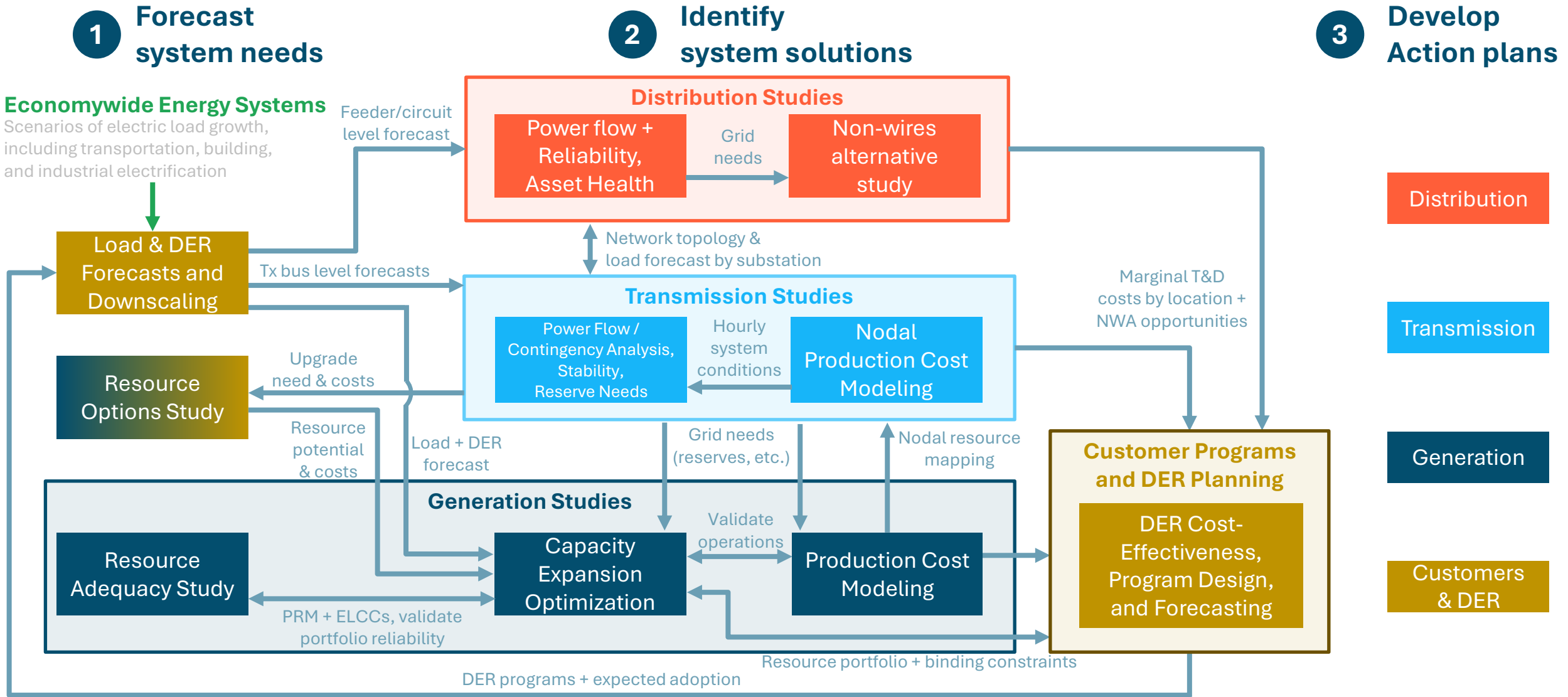
DER Cost-
Effectiveness,
Program Design,
and Forecasting

Customers
& DER

Electricity system planning integrations



Electricity system planning integrations

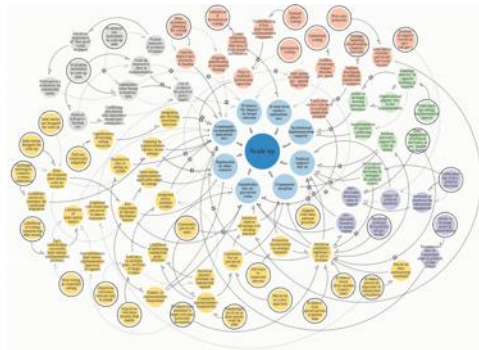


Integrated planning requires multiple modeling processes

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

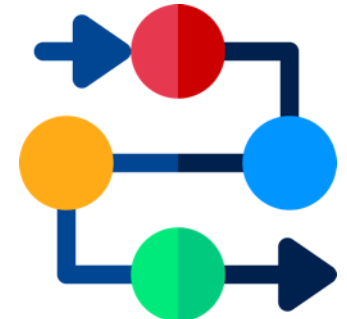
Single model that co-optimizes the full system

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



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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**

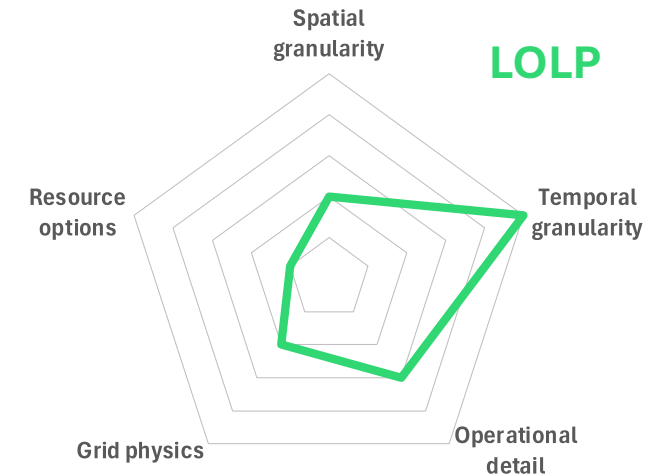
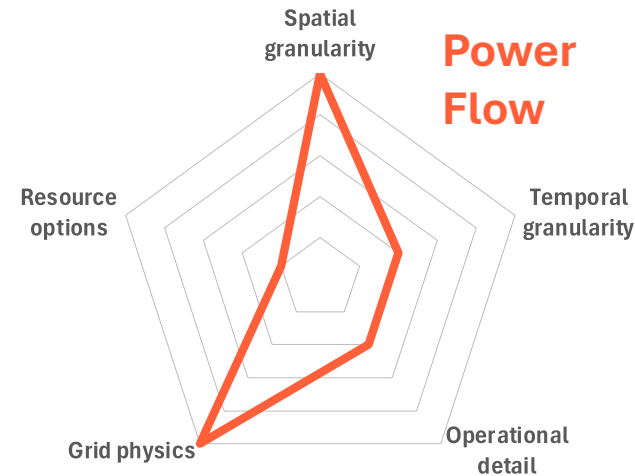
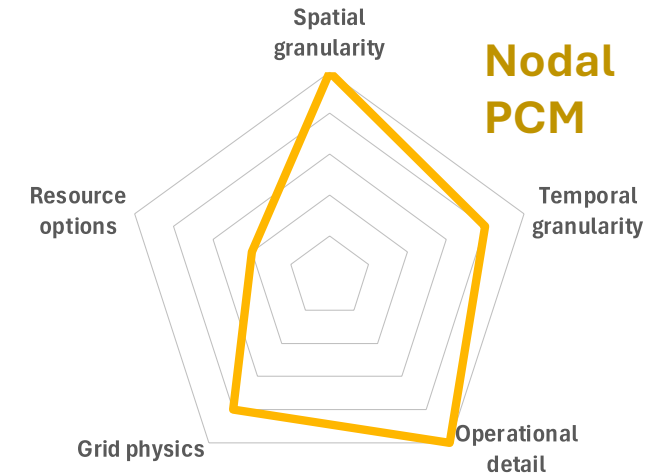
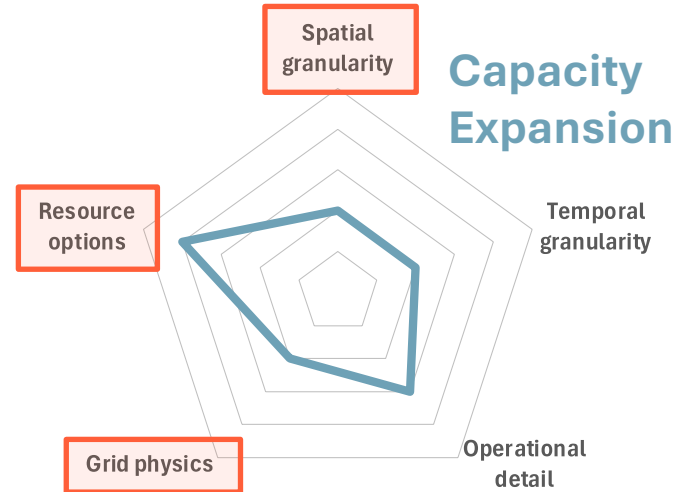
Challenges

- + 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:

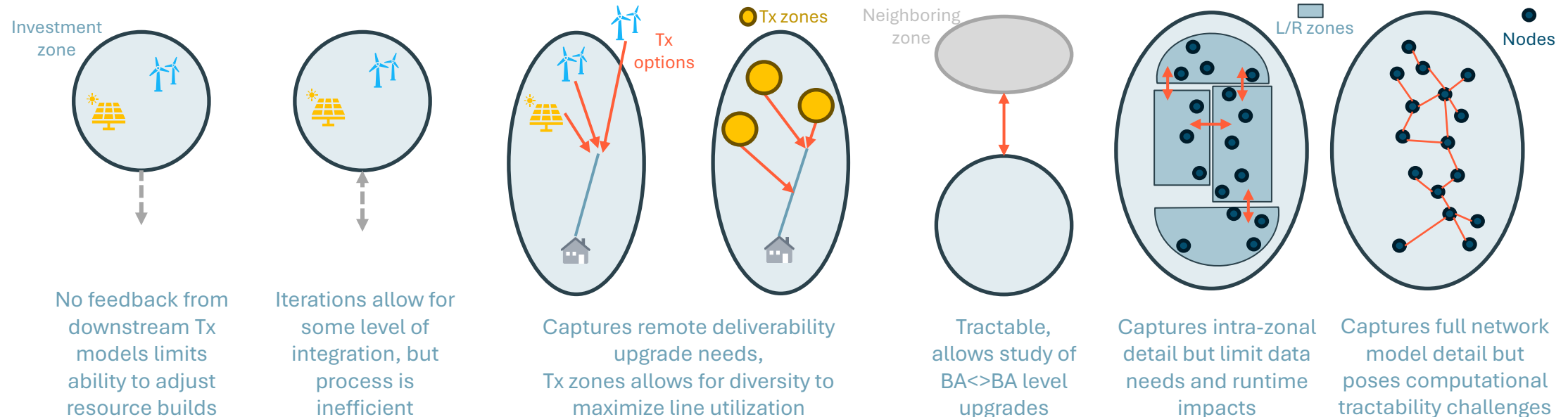
- **Spatial granularity:** typically zonal, nodal siting addressed in downstream models
- **Temporal granularity:** representative days or weeks from broader datasets
- **Operational detail:** approximations of economic dispatch
- **Grid physics:** limited detail, simple zone-to-zone transfers limits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



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

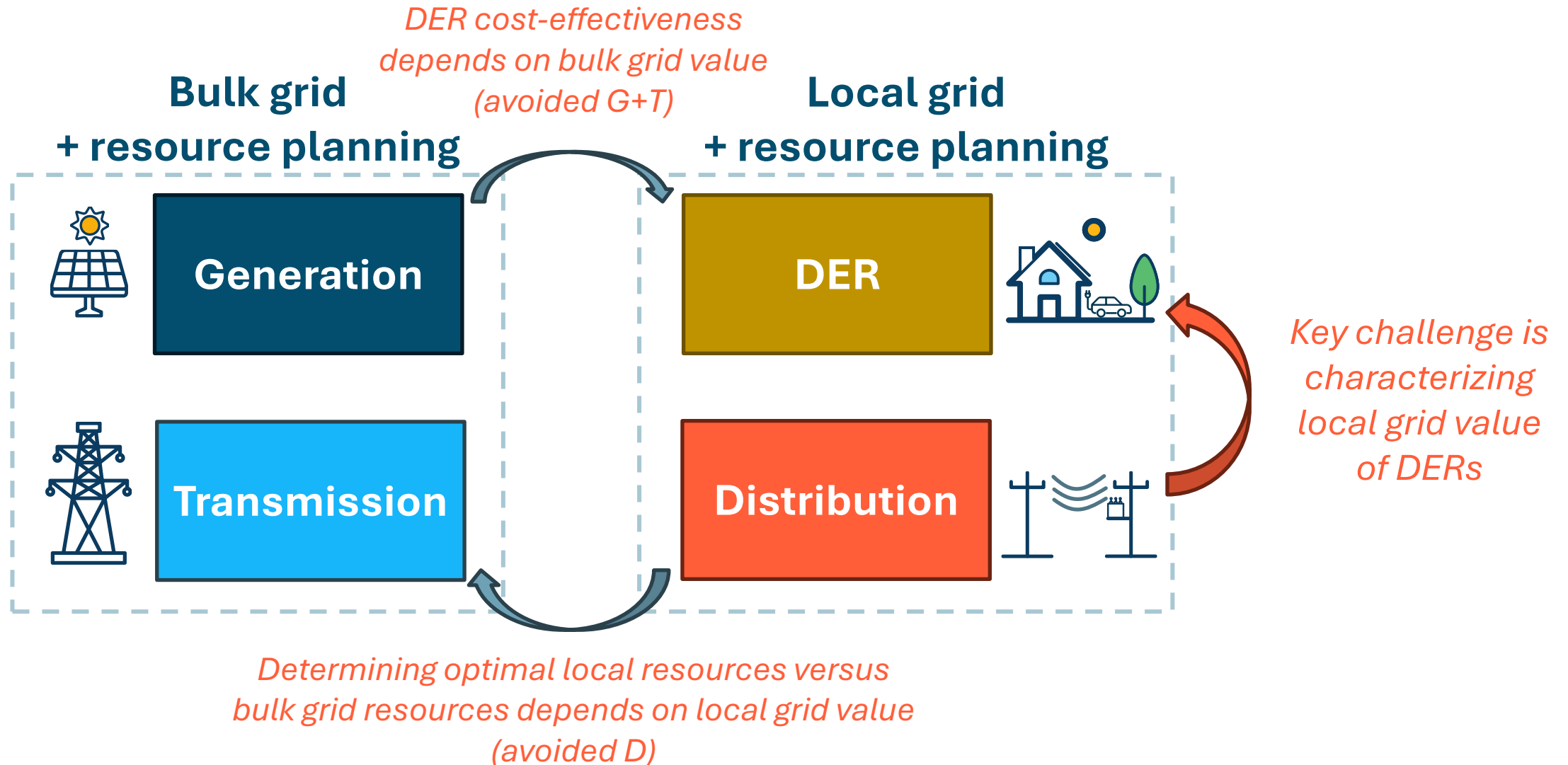


Limits of Economic Optimization for Transmission Planning

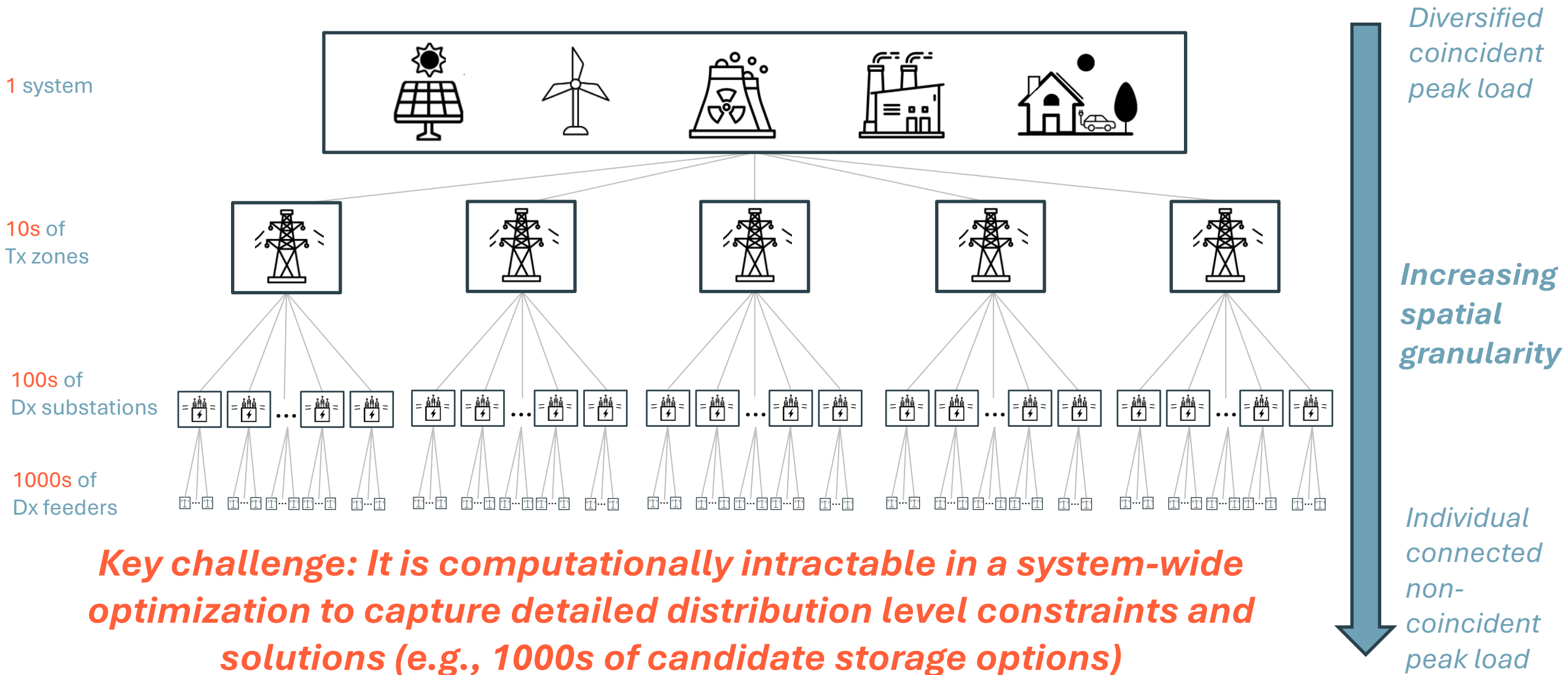
... and *why some iteration will still be needed*

- + 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.)

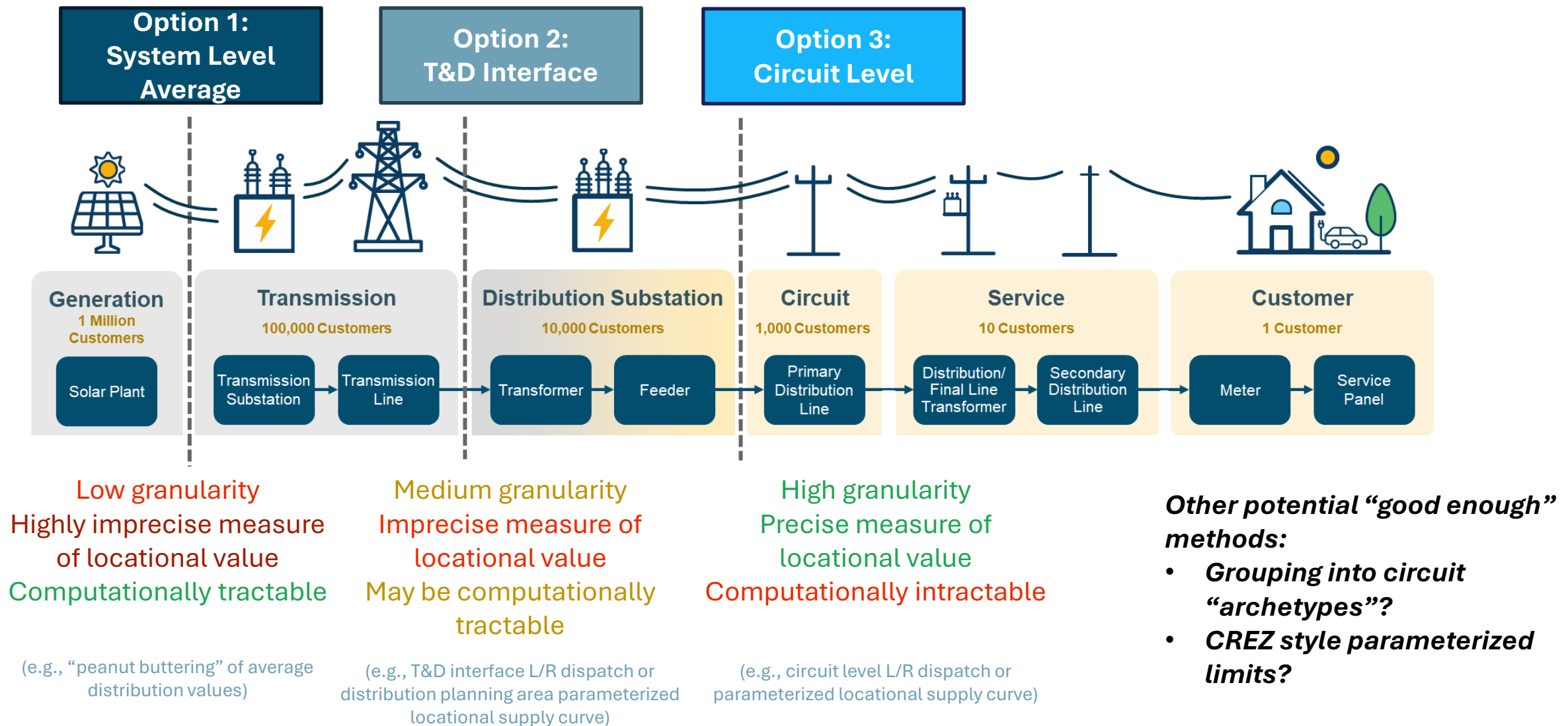
G+T+DER co-optimization is feasible, but incorporating precise distribution level local values has been a major challenge



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

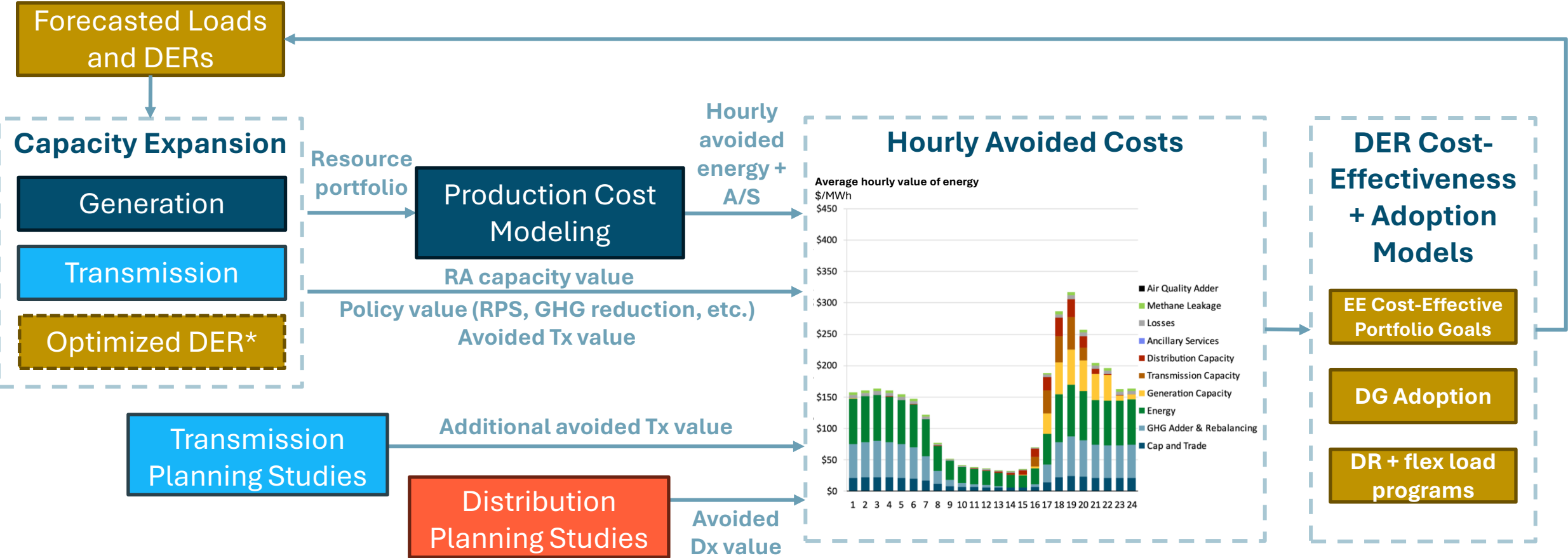


Locational Value: Spatial Granularity Tradeoffs



Avoided Cost Alternative Approach

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

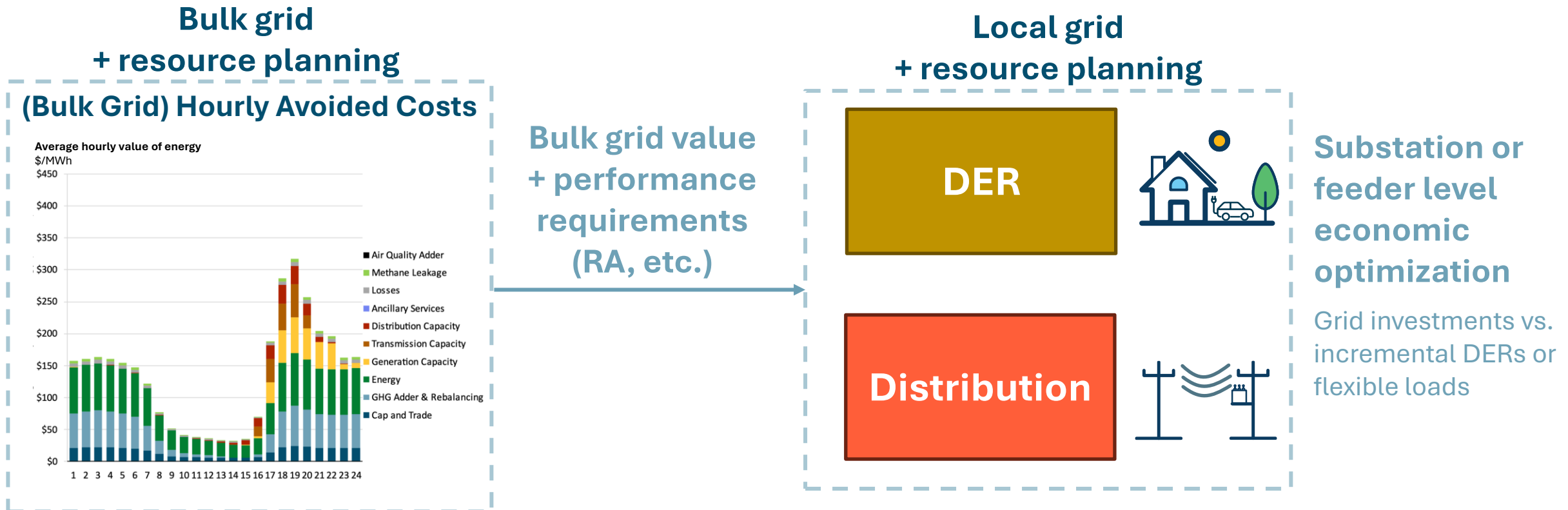


Note: this process allows for creation of granular locational avoided costs and/or targeted NWA opportunities. Multiple sourcing methods may be used to capture these values depending on the location and nature of the need (locational programs, solicitations, direct build, etc.). To the extent those values 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.

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



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