40C – Coordinated Expansion Planning

Overview and Relevance

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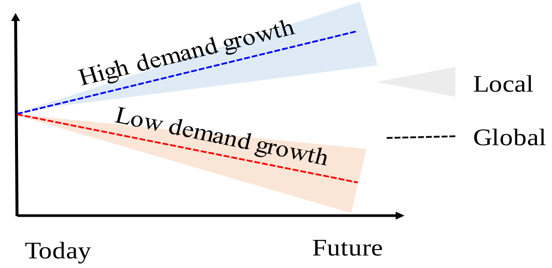
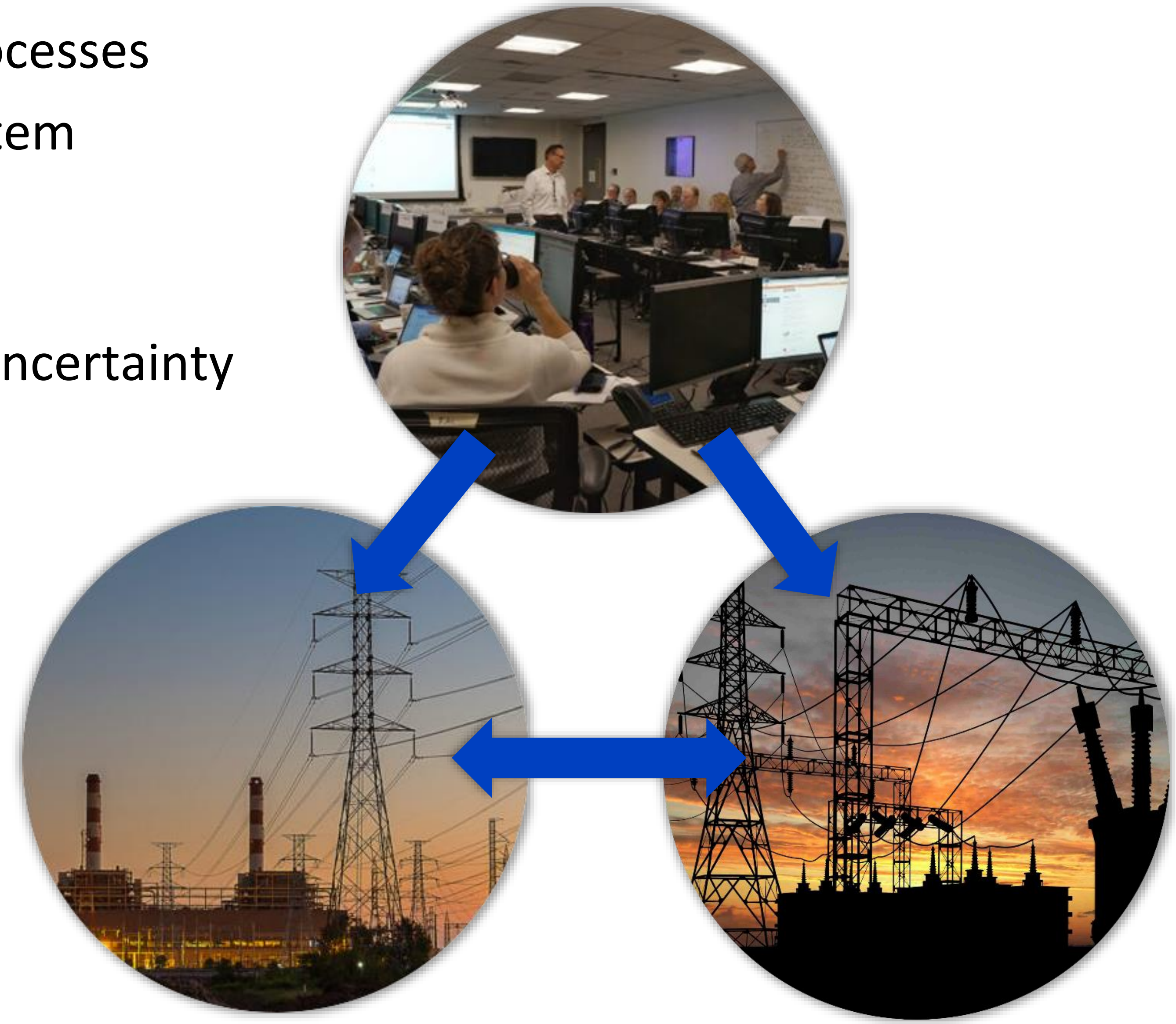
Coordinated Expansion Planning (CEP)

- Software tool to support planning processes
- Identifies optimal 5-40 years bulk system investment plans
- Large scale problem with significant uncertainty
  - Global
  - Local



- Flexible:
  - Supports G, D or T, D or G, T, D
  - Accounts for D-influence: EE, DR, DG, DS
  - Supports Utility, RTO, and IRP processes



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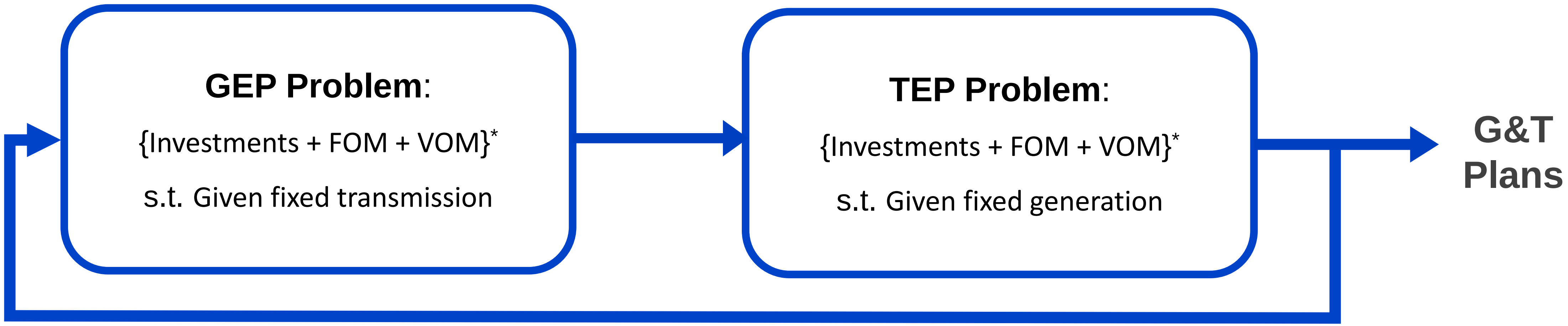
Reactive Planning & Coordinated Expansion Planning

- Conventional Approach:
  - Determine the best size, timing and type of **generating** units to build over a multi-decadal horizon to meet future load
  - Determine, in a multi-decadal basis, the **least-cost transmission additions** to meet net load from **set of generation facilities, subject to reliability constraints**



- CEP anticipates how generation expansion responds by co-optimizing transmission and generation → yield improved plan recommendations

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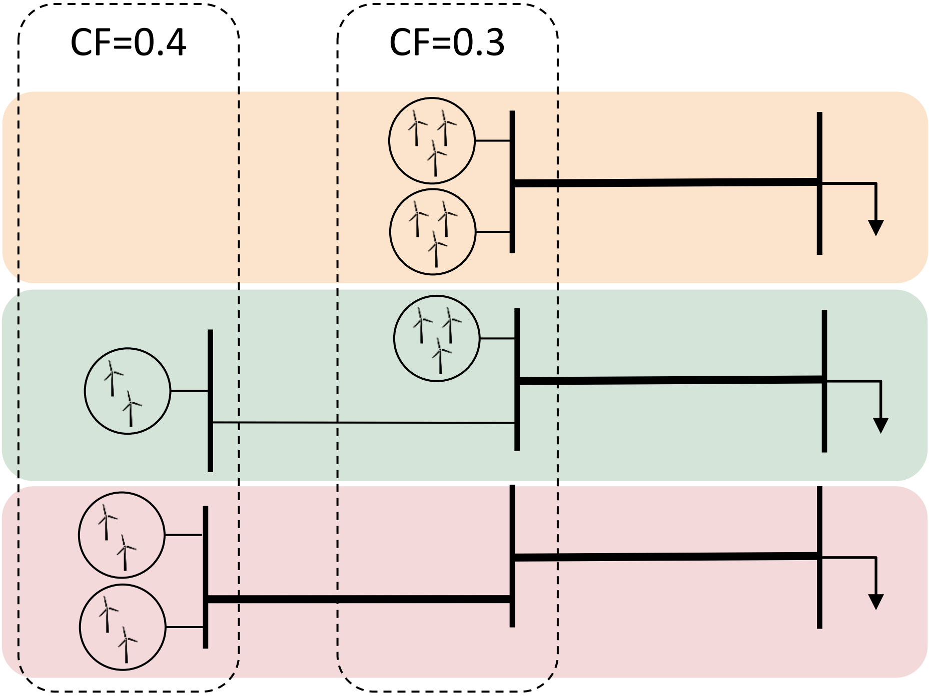
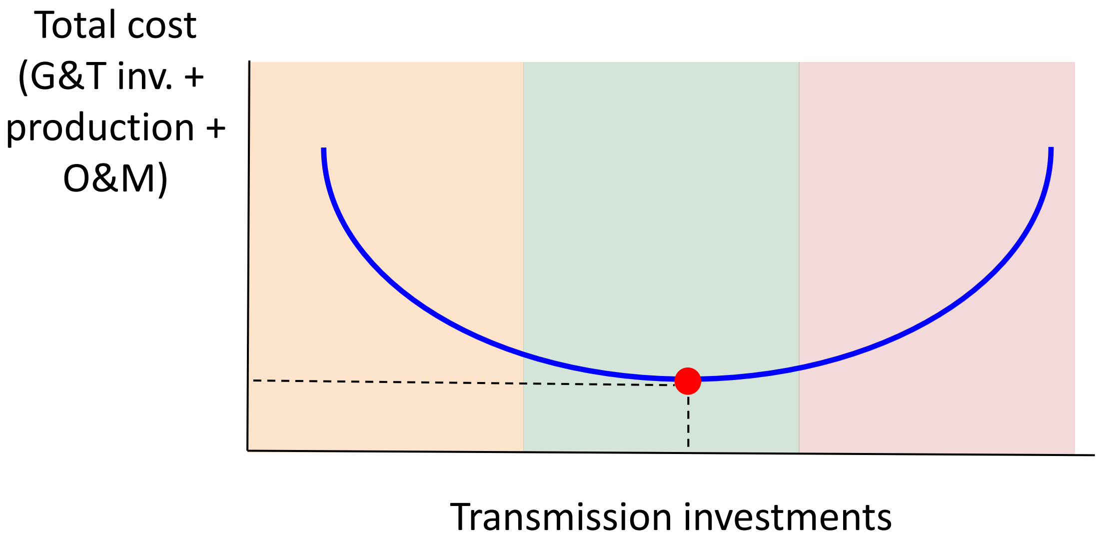
Value of Coordinated Expansion Planning

- Only by considering how all the alternatives interact within the context of the bulk power system can the benefits of particular investments be fully assessed:





J. McCalley

Allow for tradeoffs among alternatives to serve the same need

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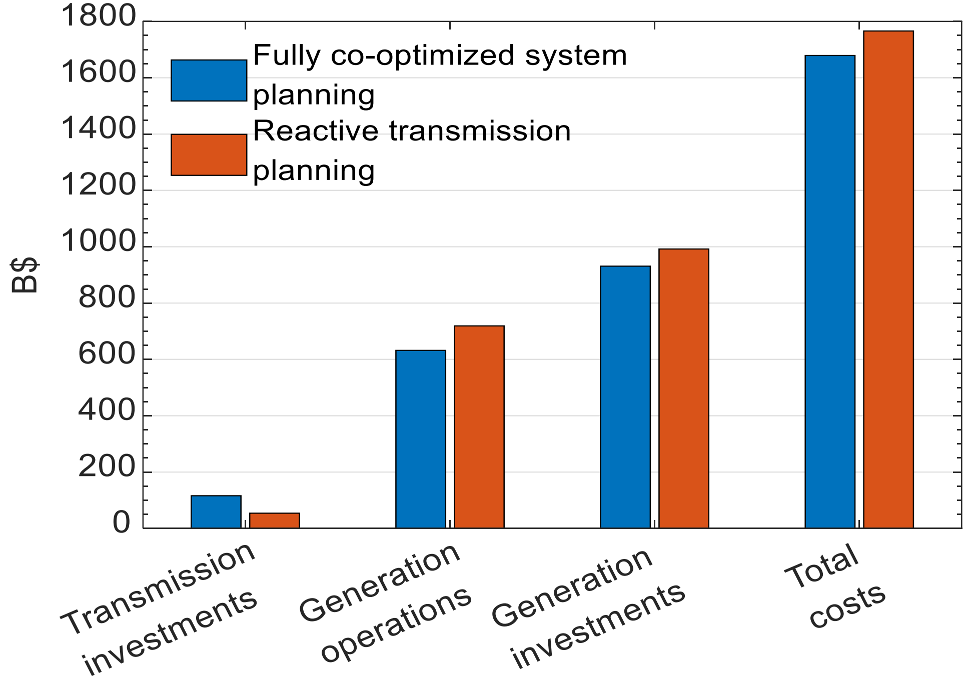
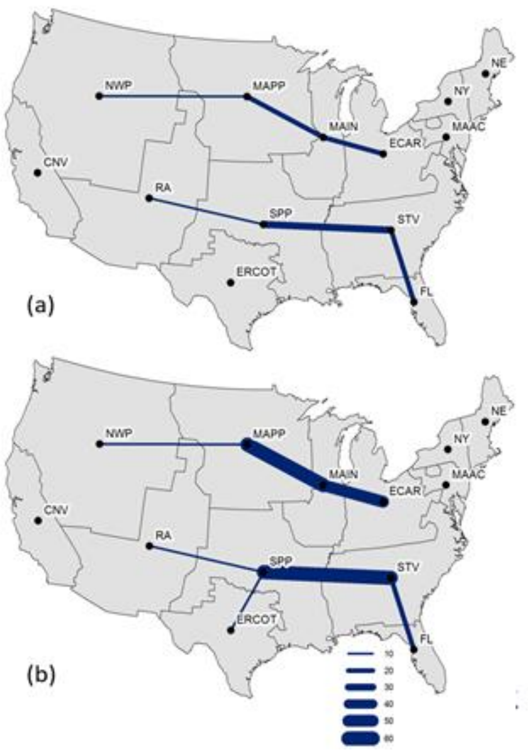
Example: Optimization of Interregional Transmission

- Eastern Interconnection model with 13 regions for the years 2020-2060:
  - Reactive expansion planning → G: 992B$ + O: 719B$ + T: 54 B$ = 1766B$
  - Coordinated expansion planning → G: 931B$ + O: 631B$ + T: 116 B$ = 1679B$





E. Spyrou, J. L. Ho, B. F. Hobbs, R. M. Johnson, and J. D. McCalley, "What are the Benefits of Co-Optimizing Transmission and Generation Investment? Eastern Interconnection Case Study," IEEE Transactions on Power Systems, vol. 32, no. 6, pp. 4265-4277, 2017.

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Relevance of CEP in Structured Markets

- Responsibility if transmission and generation planning are **assigned to different entities** (even different objectives)
- Transmission planners should **proactively anticipate how the mix and location of generation** will respond to grid reinforcements* → different lead times
  - Impact on LMPs, local prices for capacity in capacity markets → siting incentives
  - Transmission reinforcements **can increase the value of remote resource development**
  - **Inadequate transmission** would make sites within load pockets more attractive

Transmission planning and generation siting are **tightly** linked

*M. Awad et al., "The California ISO transmission economic assessment methodology (TEAM): principles and application to Path 26," in 2006 IEEE Power Engineering Society General Meeting, 2006, p. 8 pp.

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Relevance of CEP in Structured Markets

- From a modeling perspective:
  - A CEP that maximizes net economic benefits (consumer benefits – resources costs); which is equivalent to a planner (e.g., transmission) choosing investments to maximize net **benefits accounting for reactions of a perfectly completive market for all other investments**
- Efficient planning of a fully integrated utility is equivalent to anticipative/proactive transmission planning **in competitive markets**
- Accepted by regulators including the CPUC in their review of the CAISO Transmission Economic Assessment Method (TEAM)*

Equivalence: Utility & proactive planning in competitive markets

*M. Awad et al., "The California ISO transmission economic assessment methodology (TEAM): principles and application to Path 26," in 2006 IEEE Power Engineering Society General Meeting, 2006, p. 8 pp.

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Concerns with Reactive Planning in Unbundled Markets

- Transmission entities feeling obliged to implement generation first approach:
  - Despite transmission projects having a longer lead time than generation → justify transmission additions
  - Risky approach for both generation and transmission:
    - Transmission may be significantly **delayed or may not be large enough** to accommodate generation, e.g., West Texas prior construction of the Competitive Renewable Energy Zone lines, and China with large amounts of constrained-off wind
    - Transmission may be built based on generation that does not materialize resulting in **underutilized assets**
    - The **longer the lead times** for grid reinforcements & uncertainties on permits and siting **exacerbate these risks**

Reactive planning may lead to inefficiencies

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Concerns with Proactive Planning in Unbundled Markets

- Using CEP assumes that the model has an **accurate representation of other entities reaction**
  - Miscalculation of reaction of other entities
  - Reactions are plagued with uncertainty, which can be explicitly accounted for and thus reduce such risk
- **Market response to grid expansion can only be estimated**
  - More sophisticated models can anticipate market investments under **market failures** (incomplete markets, scale economies, market power, transmission tariffs not based on LMPS, policy interventions, and seams issues)
- **Different objectives by different entities**
  - Higher-level policy design (deeper penetration of VRES) which could conflict with zonal-level planning
  - Higher-level and local objectives would be imperfectly aligned ("second-best" solution)
  - In such cases the CEP could be framed as a multi-level optimization with different objectives

Realistic representation can be attained by modeling enhancements

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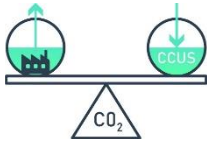
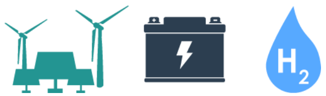
Relevance in the Paths for Decarbonization

- Decarbonization targets → **rapid transformation** of existing power grids

NET-ZERO	CARBON-FREE	100% RENEWABLES
Net carbon emissions equal zero. Any emissions produced from operations are balanced by an equivalent amount of carbon removal or offsets.	Electricity generation either does not use fossil fuels or does not emit carbon.	100% of electricity generated from renewable sources such as wind, solar, and hydro.





- Renewables are projected to play a major role in all scenarios
- Efficiency and electrification
- Low-carbon fuels (hydrogen and bioenergy)

“Power Decarbonizartion – Strategies for Net-Zero CO2 Emissions,” EPRI, Palo Alto, CA, Rep. No 3002020700, Feb. 2021.

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EPRI

Value for Macro Design Studies

- **Reliability**
- **Resilience**

- **Sustainable**

- Effective design of **clean energy futures** require a **massive development** of the bulk power system infrastructure
- Need to **harness resources across large (often electrically remote) regions** as well as **pooling resources** across geographical space and different time horizons

- **Affordable**

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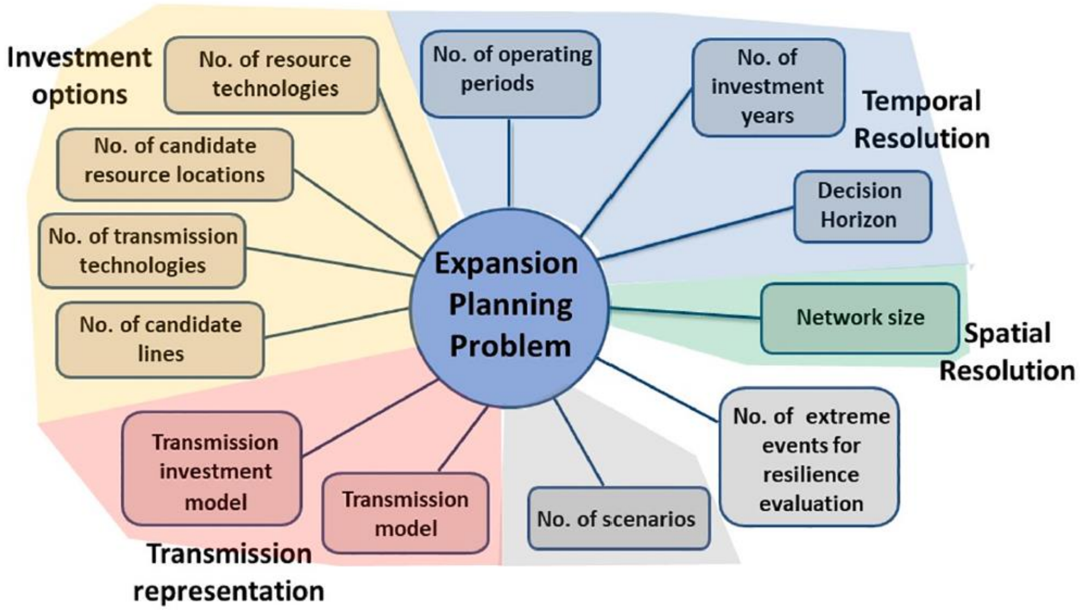
Features of the Next Generation of CEP Tools



Features affecting computing time and solution quality

- Conventional planning tools use simplifications (e.g., LDCs)
  - Worked well in the past (systems with low VRES)
  - Computationally tractable
  - Inadequate to capture the needs for agile generation and cycling

Enhance CEP tools to capture increased temporal granularity:

- As penetrations of variable renewable energy sources (VRES) deepen, the needs for flexibility increase
- Capture the flexibility needs, not only those of capacity
- Enables tradeoffs: hi-fidelity operational flexibility ↔ investments

P. Maloney, P. Chitkara, J. D. McCalley, B. F. Hobbs, C. T. M. Clack, M. A. Ortega-Vazquez, A. Tuohy, A. Gaikwad, J. Roark, "Research to Develop The Next Generation of Electric Power Capacity Expansion Tools: What Would Address the Needs of Planners?," Int. Journal of Electrical Power & Energy Syst., Vol. 121, Oct. 2020.

Program on Technology Innovation: "Coordinated Expansion Planning: Status and Research Challenges," EPRI, Palo Alto, CA, Rep. No. 3002016661. Dec. 2019.

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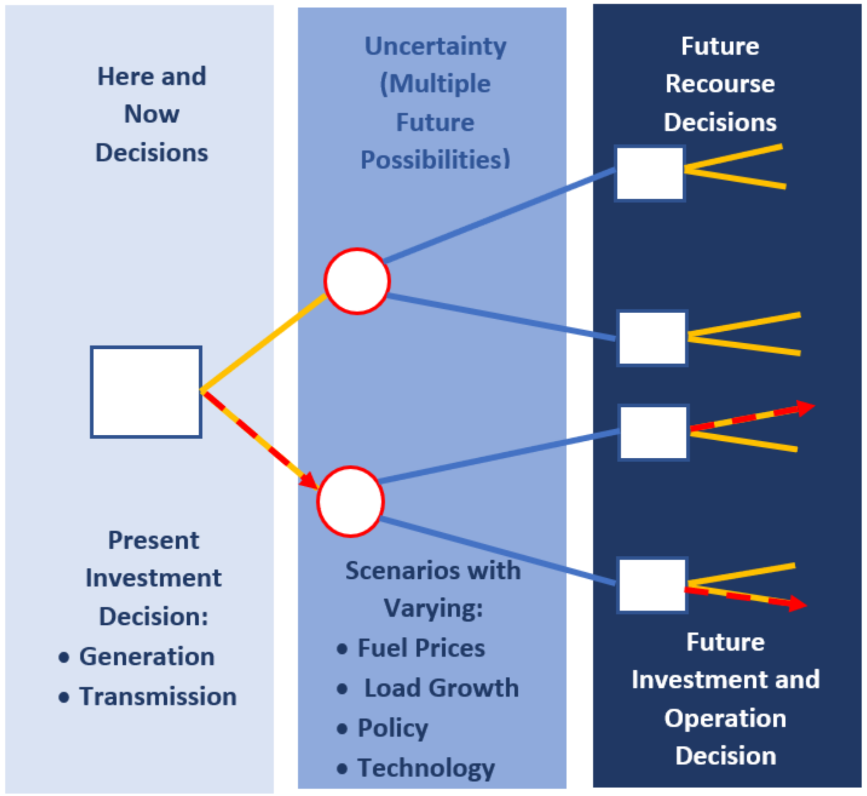
JHSMINE

- **J**ohns **H**opkins **S**tochastic **M**ulti-stage **I**ntegrated **N**etwork **E**xpansion (JHSMINE)
  - Prof. Benjamin Hobbs and team
- Based on stochastic programming
- Minimizes probability weighted investment and operation costs across multiple future scenarios to obtain:
  - A set of here-and-now decisions (present investment decisions)
  - Future recourse decisions (future investment and operation decisions)
  - Recourse decisions enable adaptability to various possible futures



$$\text{MIN} \quad C_1 X_1 + \Sigma_{\text{scenarios } S} P_S * C_2 X_{2,S}$$

$$A_{1,1} X_1 \leq B_1$$

$$\{A_{2,1,S} X_1 + A_{2,2,S} X_{2,S} \leq B_{2,S}\}, \forall S$$

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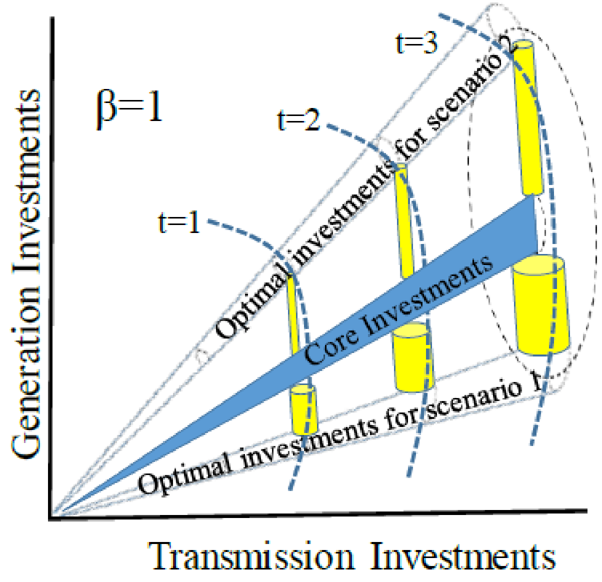
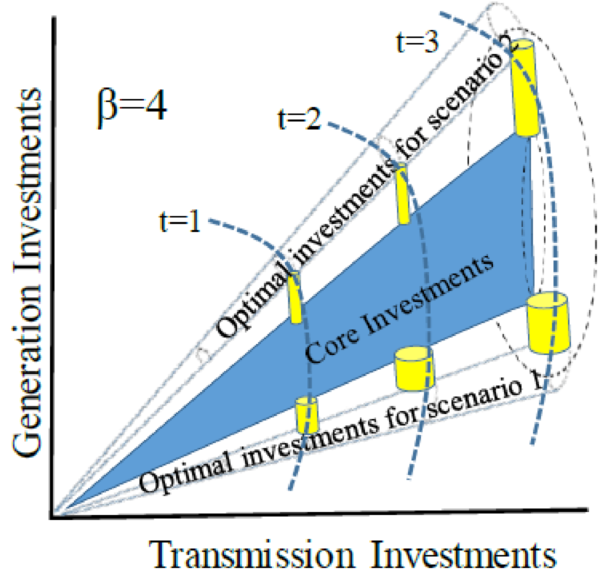
Adaptive Coordinated Expansion Planning - ACEP

- Adaptive Coordinated Expansion Planning
  - Prof. James McCalley and team
- Approach that adjusts to a desired investment robustness
- Minimizes the cost of the core investments, the expected cost of the adaptations and the expected operational cost
  - β : Robustness Parameter
  - Robustness parameter controls the tradeoffs between core costs and adaptation costs
  - For small β, core expansion plan less robust to future uncertainties
  - For large β, core expansion plan more robust to future uncertainties





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