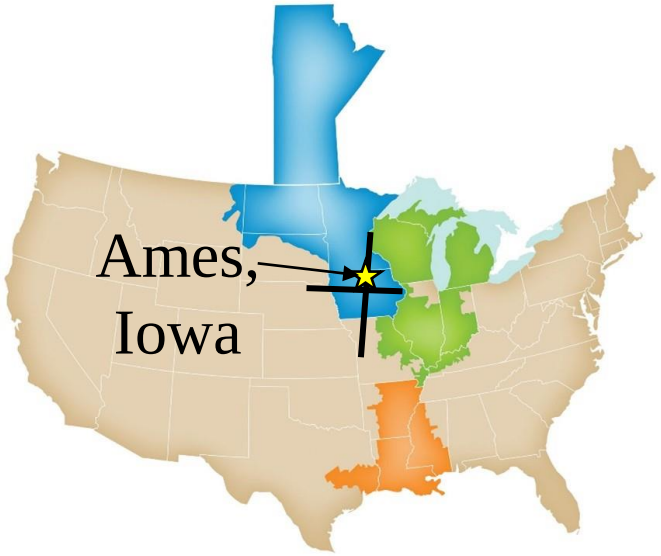
Adaptive Cooptimized Expansion Planning (ACEP): An approach well-suited for RTO planning

James McCalley, Iowa State University

Session on Emerging Methods for Probabilistic Long-Term Planning
MISO Probabilistic Planning Symposium, Nov. 19-20, 2024, Carmel, Indiana



Overview

1. Planning tool summary
2. RTO planning processes
3. ACEP – what it is (and what it is not)
4. Uncertainty representation & futures reduction
5. ACEP results
6. ACEP with resource adequacy
7. Conclusions

1. Planning tool summary

MODEL REDUCTION; minimize EP tool compute time, maximize model fidelity.

1. PREPROCESS
a. Trim & map
b. Identify study sys
c. Reduce ext system

2. DIVIDE
a. Key branch ID using rolling sim
b. Zones

3. RETAIN
Identify buses to keep.

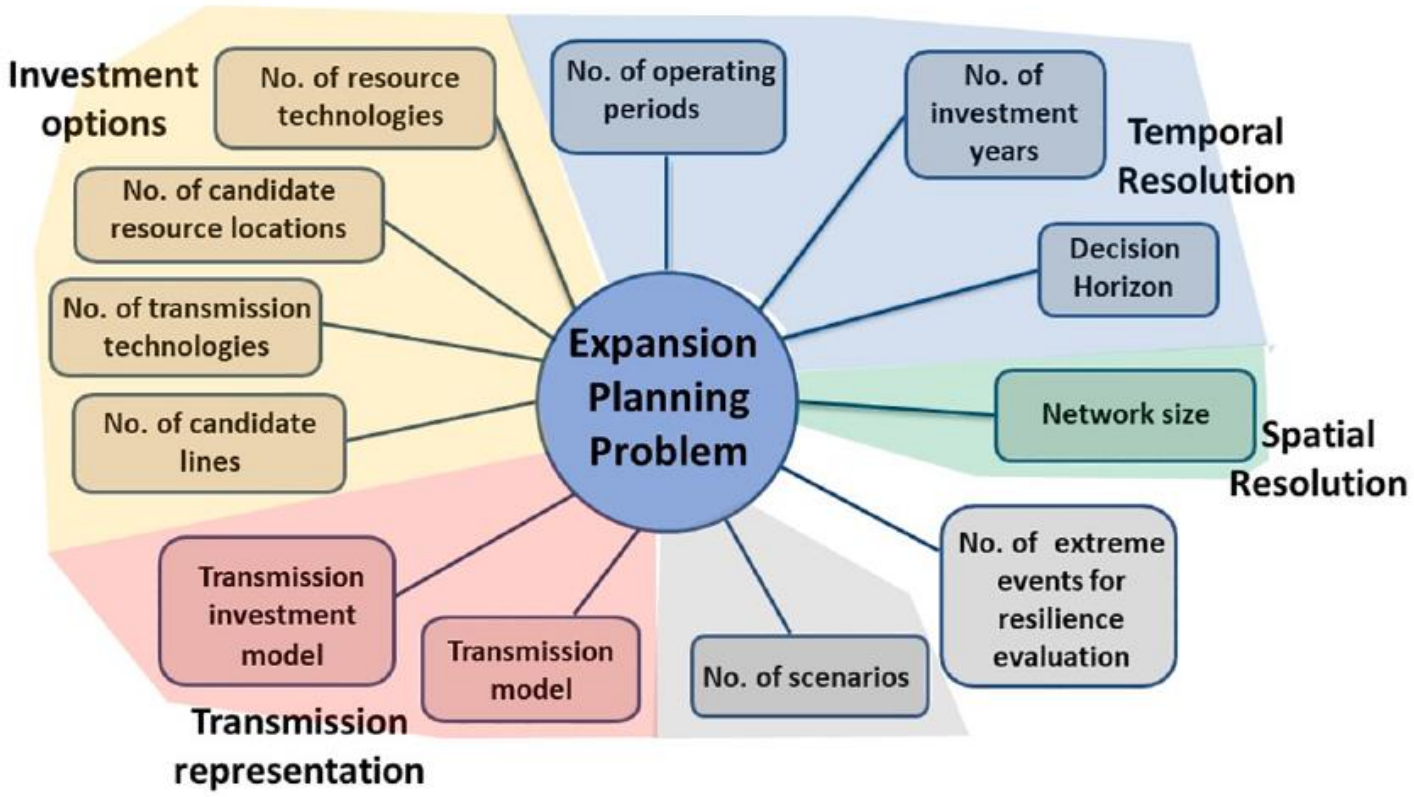
4. ELIMINATE
Apply Ward to each zone.

5. AGGREGATE
a. Topology-based
b. QG

6. ESTIMATE
a. Capacities
b. Exp cost

7. EXPANSION

8. TRANSLATION



EXPANSION PLANNING TOOLS

Step 2 (full model) Rolling simulation

Step 7: Reduced model

- **Adaptive-CEP (ACEP)**
- **Resilience-CEP (RCEP)**
- **Folding horizon simulation (FHS)**

Step 8: Translation (reduced to full)

2. RTO planning processes

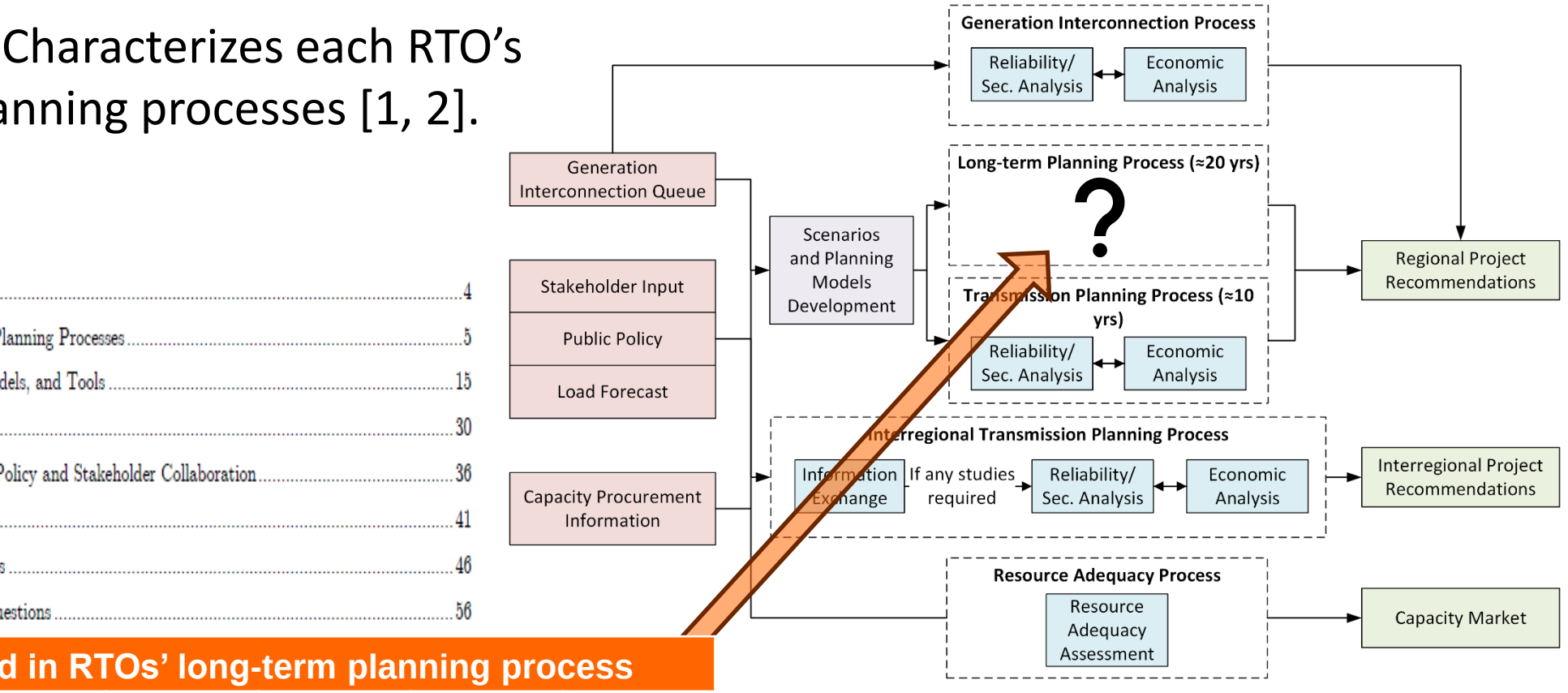
ISO/RTO Long-term Planning Processes

➔Characterizes each RTO's planning processes [1, 2].

A Report for Project M-43,
"Integrating RTO and Utility Processes in Planning and Cost Allocation," funded by the Power Systems Engineering Research Center (PSERC)

November 2023

1. Introduction 4
2. Overview of ISO/RTO Planning Processes 5
3. Analysis Procedures, Models, and Tools 15
4. Integration of Processes 30
5. Incorporation of Public Policy and Stakeholder Collaboration 36
6. Cost Allocation 41
7. Findings and Conclusions 46
Appendix A - Summary of Questions 56



Analyses procedures used in RTOs' long-term planning process

CAISO	ERCOT	ISO-NE	MISO	NYISO	PJM	RTE	SPP
SA	**GEP, TEP**	**EA, RA, AS**	**GEP, SA, EA**	**EA**	**SA, EA**	**SA, EA**	**GEP, SA, EA**

Generation Expansion Planning (GEP), Transmission Expansion Planning (TEP) Security Assessment (SA), Economic Analysis (EA), Resource Adequacy (RA), Ancillary Services (AS)

TAKEAWAYS on long-term planning:

1. **Some diversity in approach**
2. **but common feature: futures!**

[1] G. Cuello-Polo and J. McCalley, "Enhancing grid development through integration of ISO/RTO planning functions," IEEE PES GM, 2024.

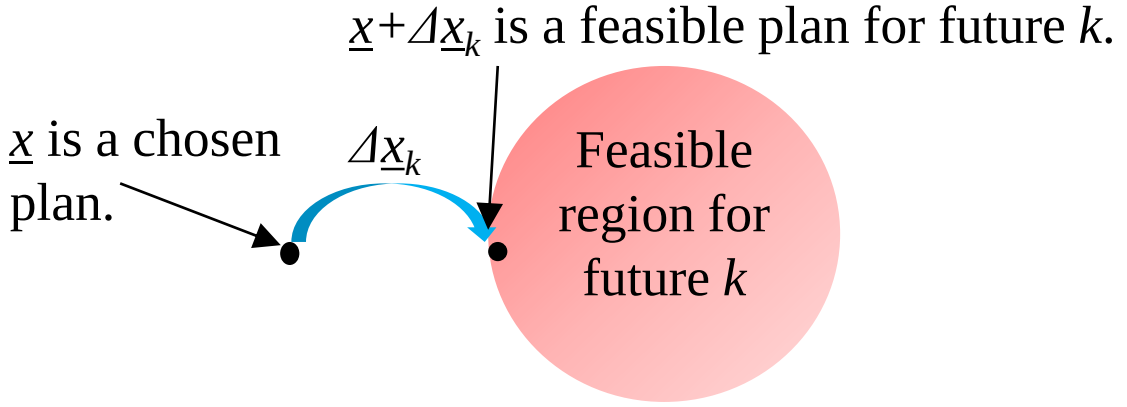
[2] https://home.engineering.iastate.edu/~jdm/psercm43.pdf

3. What is Adaptive Coordinated Expansion Planning (ACEP)?

Adaptation, $\Delta \underline{x}_k$, is the additional *investment* necessary for plan $\underline{x}$ to acceptably perform under future *k*:

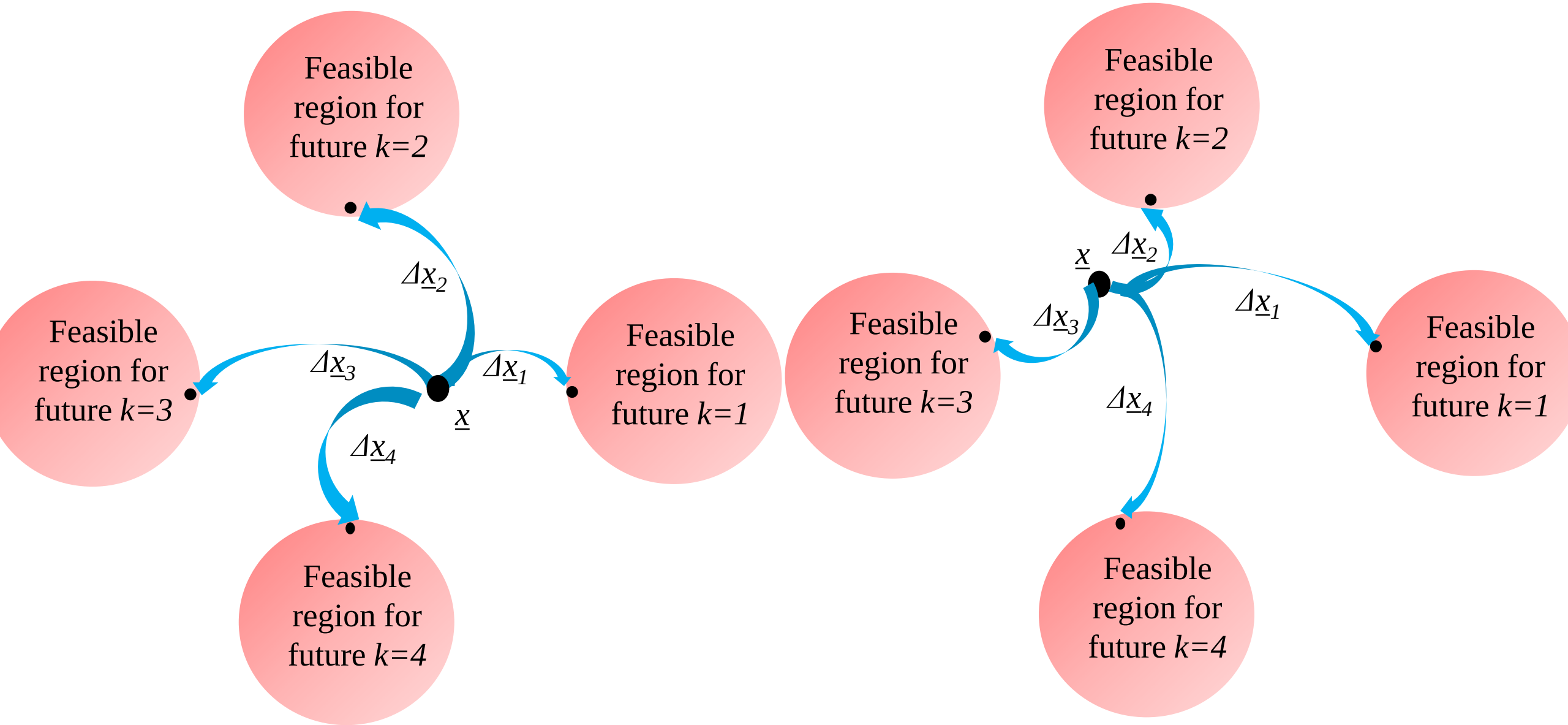
- **the adaptation cost of additional investment is *AdaptationCost*($\Delta \underline{x}_k$)**
- **$\Delta \underline{x}_k = 0$ if plan $\underline{x}$ is designed under future *k***

The adaptation cost of $\underline{x}$ to future *k* is the minimum cost to move $\underline{x}$ to a feasible design in future *k*.
It measures the additional cost of plan $\underline{x}$ if future *k* happens.



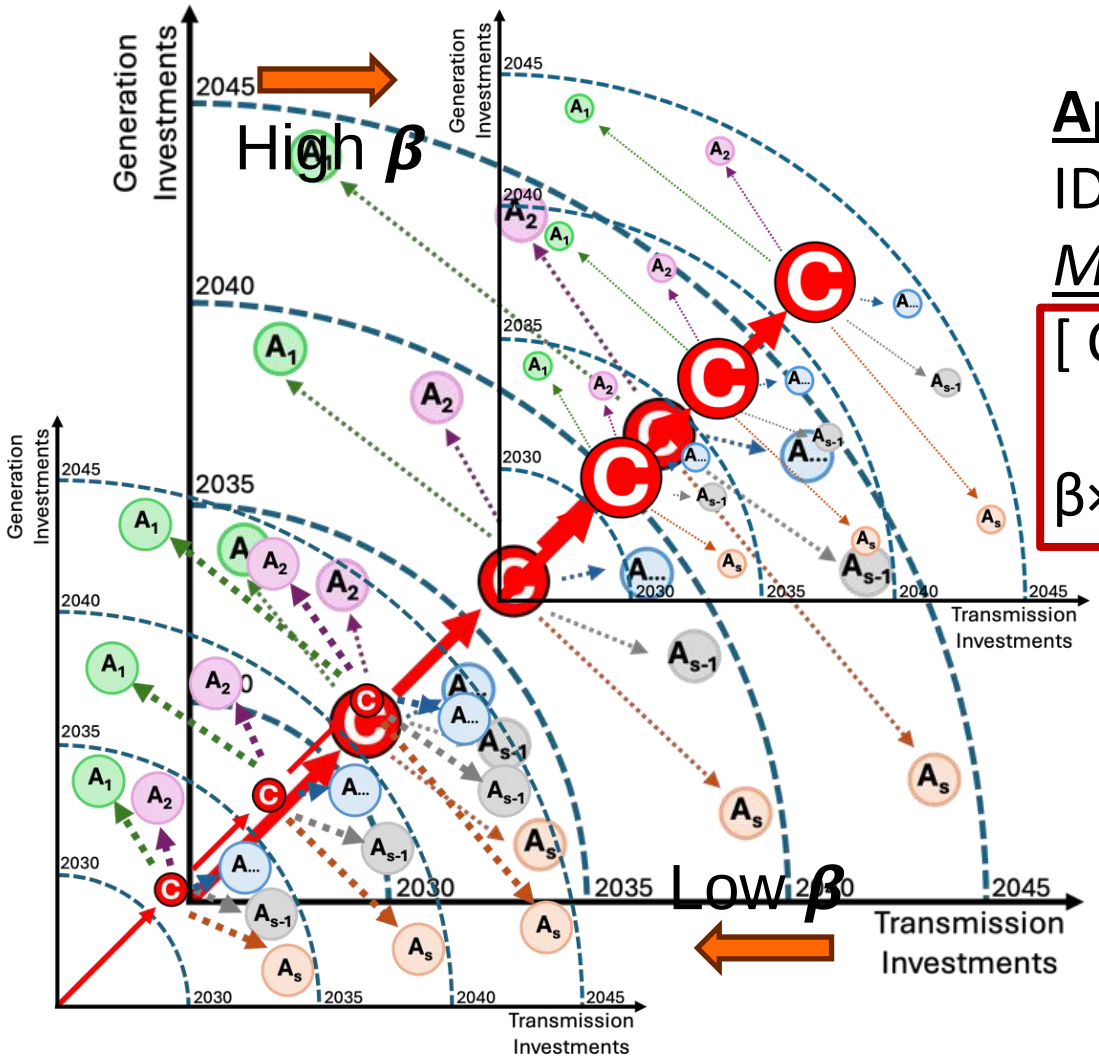
1. P. Maloney, P. Liu, Q. Xu, J. McCalley, B. Hobbs, S. Daugenberger, A. Johnson, S. Williams, *A. Jahanbani-Ardakani, A. Ramos, S. Lumbreras, "Treatment of uncertainty in long-term planning: adaptive vs traditional stochastic programming," under review by IEEE Transactions on Power Systems.
2. D. Mejia-Giraldo and J. McCalley, "Maximizing future flexibility in electric generation portfolios," IEEE Transactions on Power Systems, Vol. 29, Issue 1, 2014, pp. 279-288.

3. What is Adaptive Cooptimized Expansion Planning (ACEP)?



3. What is Adaptive Cooptimized Expansion Planning (ACEP)?

Applications:
- BPA, 2019
- MISO (now)
- Iowa (now)
- SPP (next 3 years)



Approach:

IDENTIFY G&T EXPANSIONS TO:

Minimize:

[Cost of Core (red)]

+

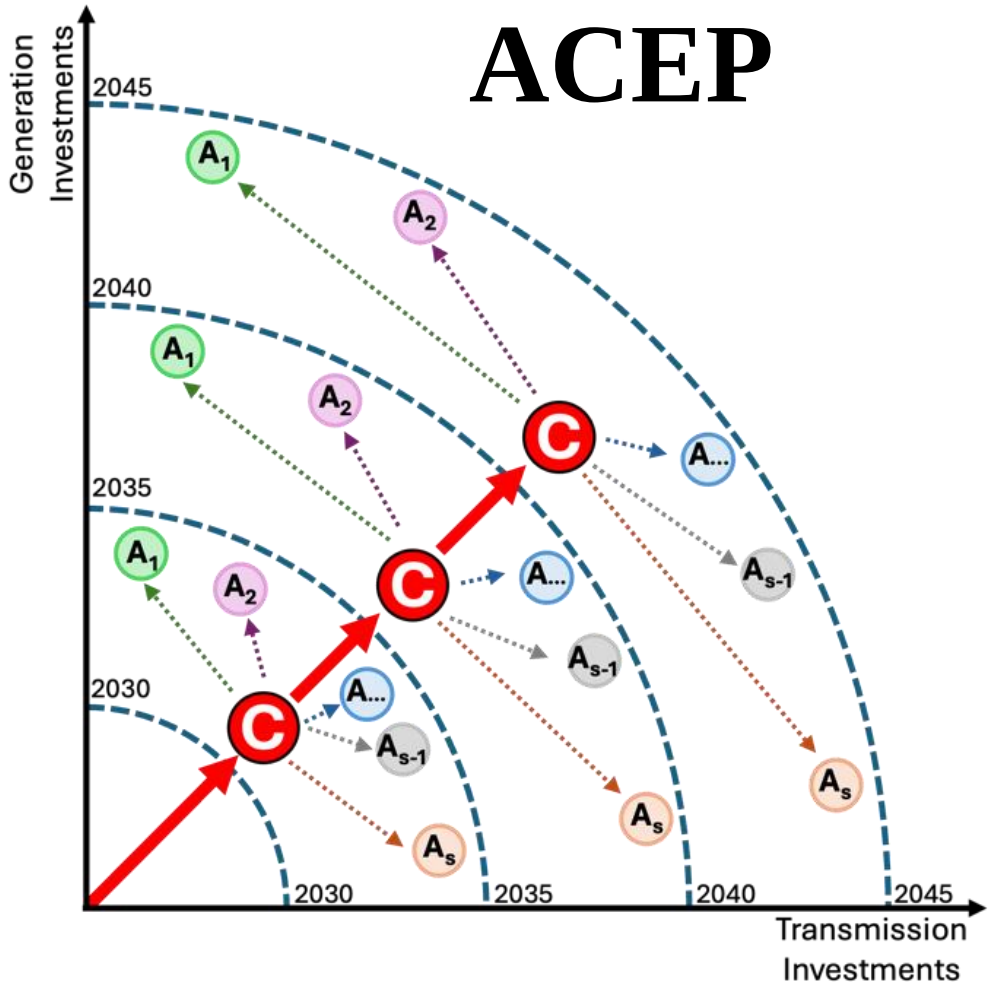
β×[Prob{Future}×Cost of Adapting core to each future].

Subject to, for each future:

- network flow laws, flow limits, gen limits
- reserve requirements
- environmental targets or constraints
- investment targets or constraints
- resource adequacy constraints

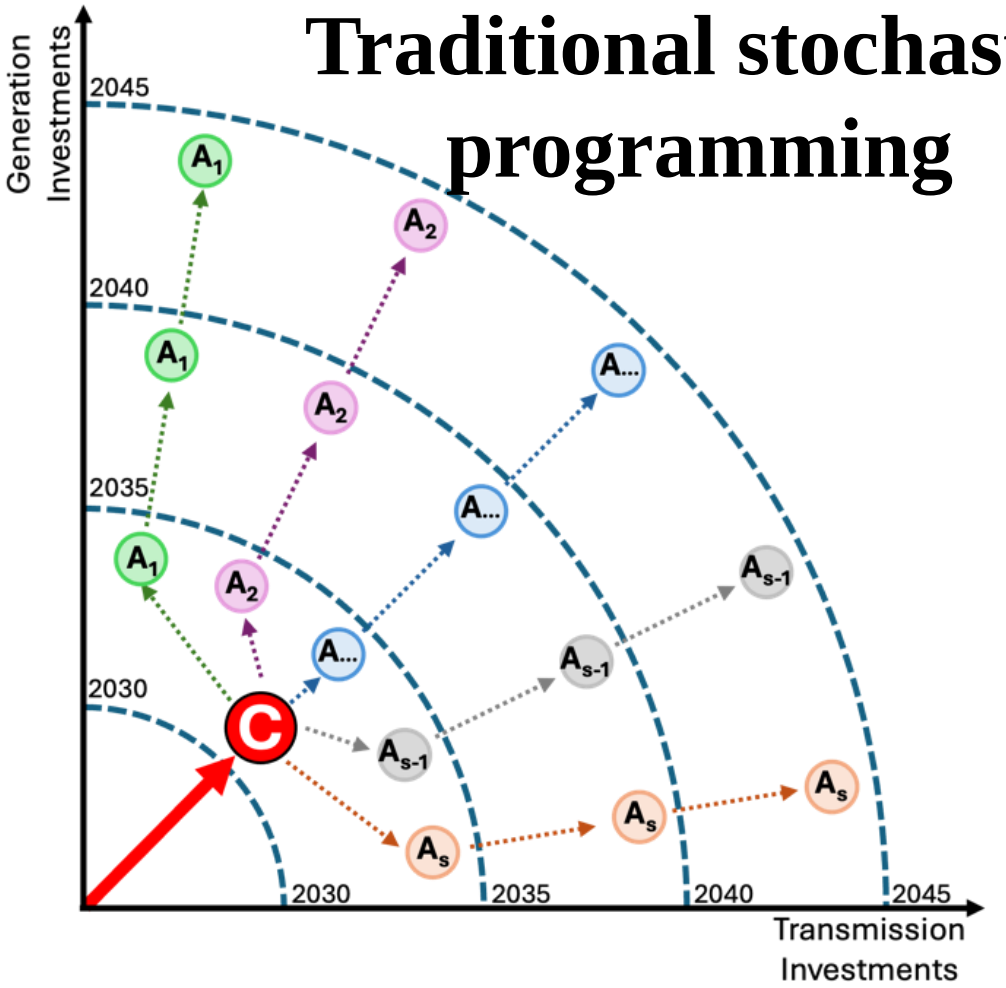
3. And what it is not…

ACEP



Provides single investment trajectory through time (red);
➔Good for long-term planning.

Traditional stochastic programming

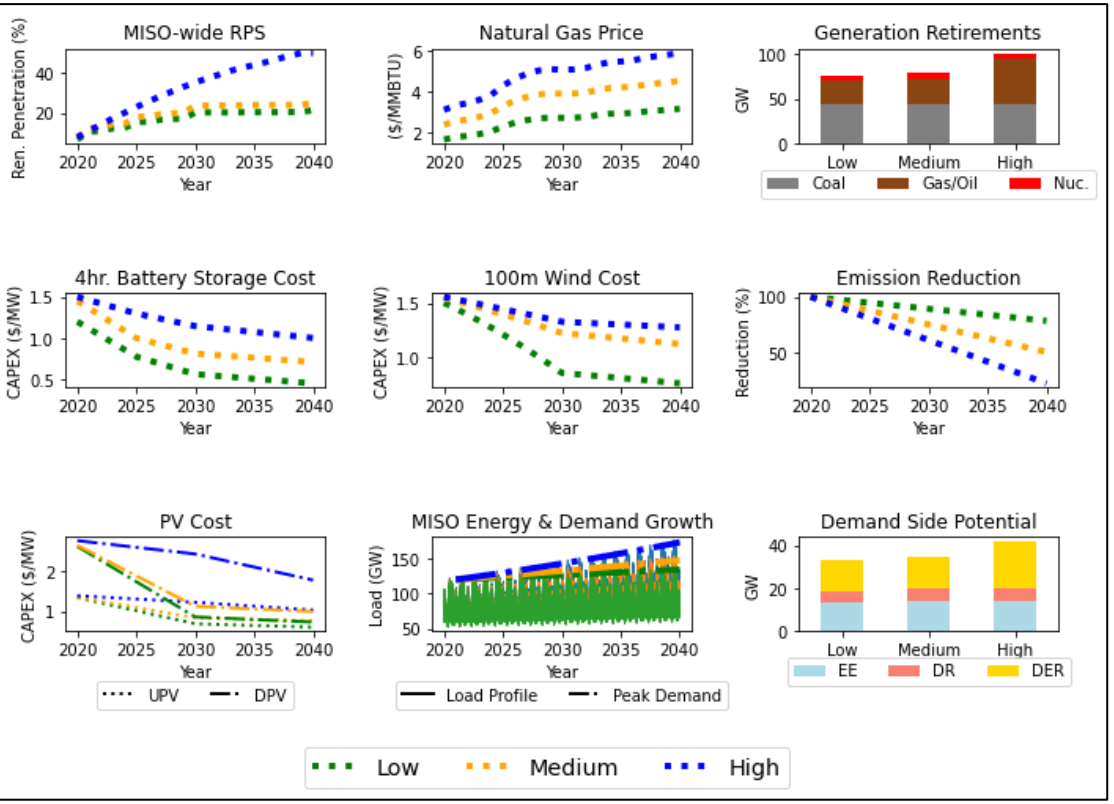


Requires single t=1 investment plan; can model more stages with time but exponential growth in problem size.
➔Good for decision (in early time periods).

4. Uncertainty representation and “futures reduction”

Uncertainty Characterization

- Adapted from MTEP19 and MTEP21 studies [1],[2]
- MISO’s bookending was used to develop low/medium/high values [3]



References:

[1] Midcontinent Independent Systems Operator, “MTEP18: MISO Trans-mission Enhancement Plan,” 2018. [Online]. Available: https://www.misoenergy.org/planning/planning/.

[2] Midcontinent Independent Systems Operator, “Appendix E: MTEP19EGEAS Assumptions Document,” 2019. [Online]. Available: https ://www.misoenergy.org/planning/planning/

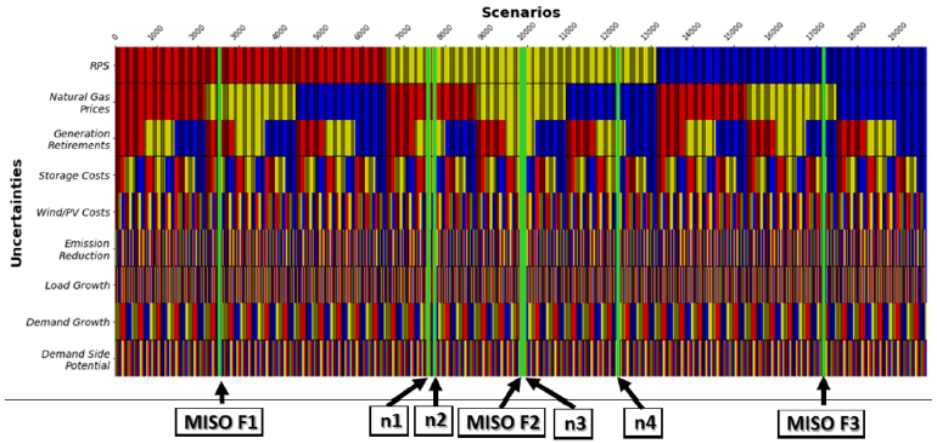
[3] National Renewable Energy Laboratory, “2020 Annual Technology Baseline (ATB),” Jul. 2020. [Online]. Available: atb.nrel.gov

[4] GAMS, Gams scenred2, 2021. [Online]. Available: https://www.gams.com/latest/docs/T_SCENRED2.html..

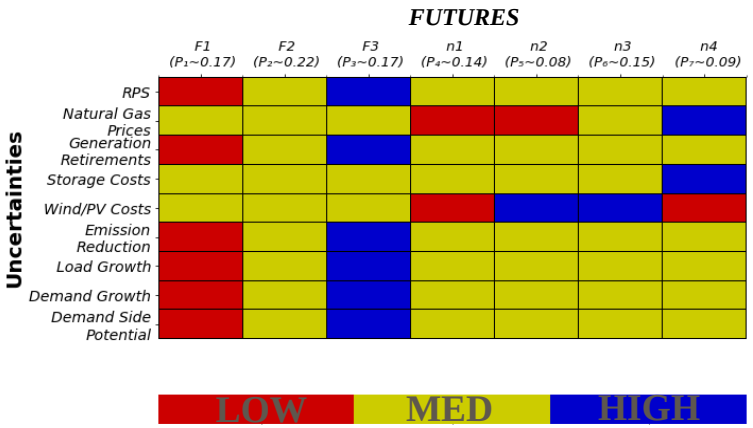
→ Futures reduction

Entire Uncertainty Space:

- 3^9 =19683 Futures
- GAMS ScenRed2 function – input-based methods [4]



These seven future are chosen to maximize probability space and minimize distance between unselected and selected futures.



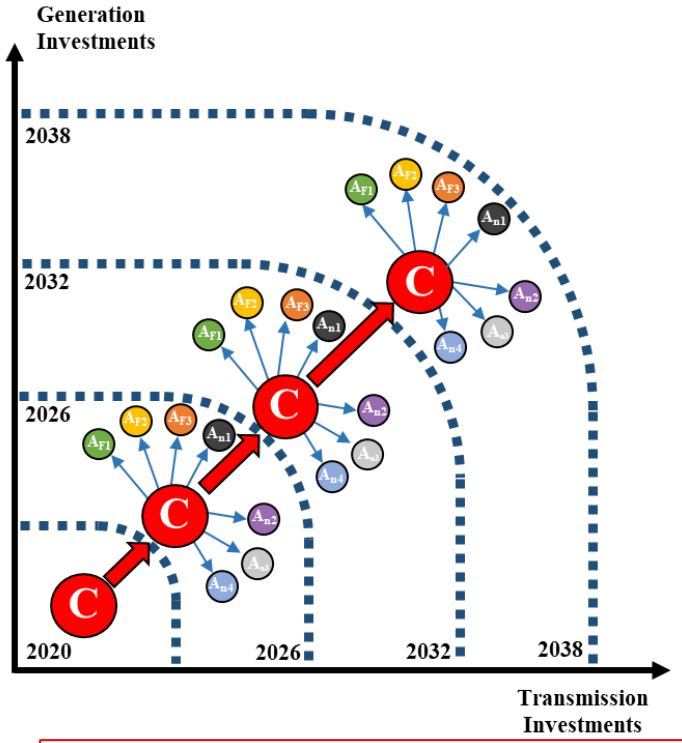
Reduced Future Set:

F1: Low carbon reduction, RPS, demand, medium costs
F2: Medium everything
F3: High carbon reduction, RPS, demand, medium costs
n1: Low gas & renewable cost
n2: Low gas cost, high renewable cost
n3: High renewable cost
n4: High gas & storage cost, low renewable cost

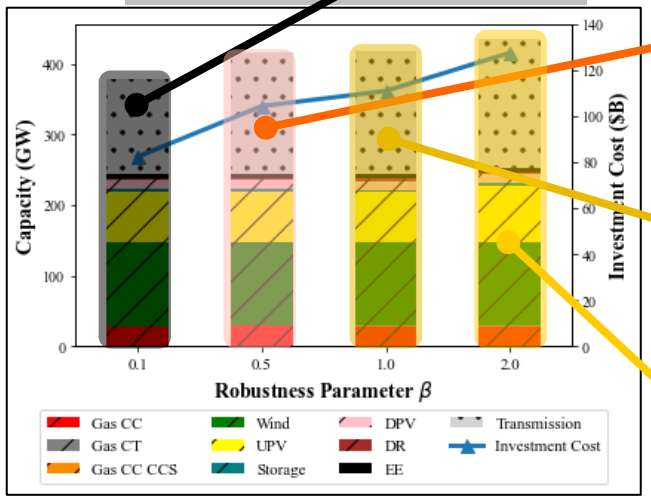
5. ACEP Results – β comparison

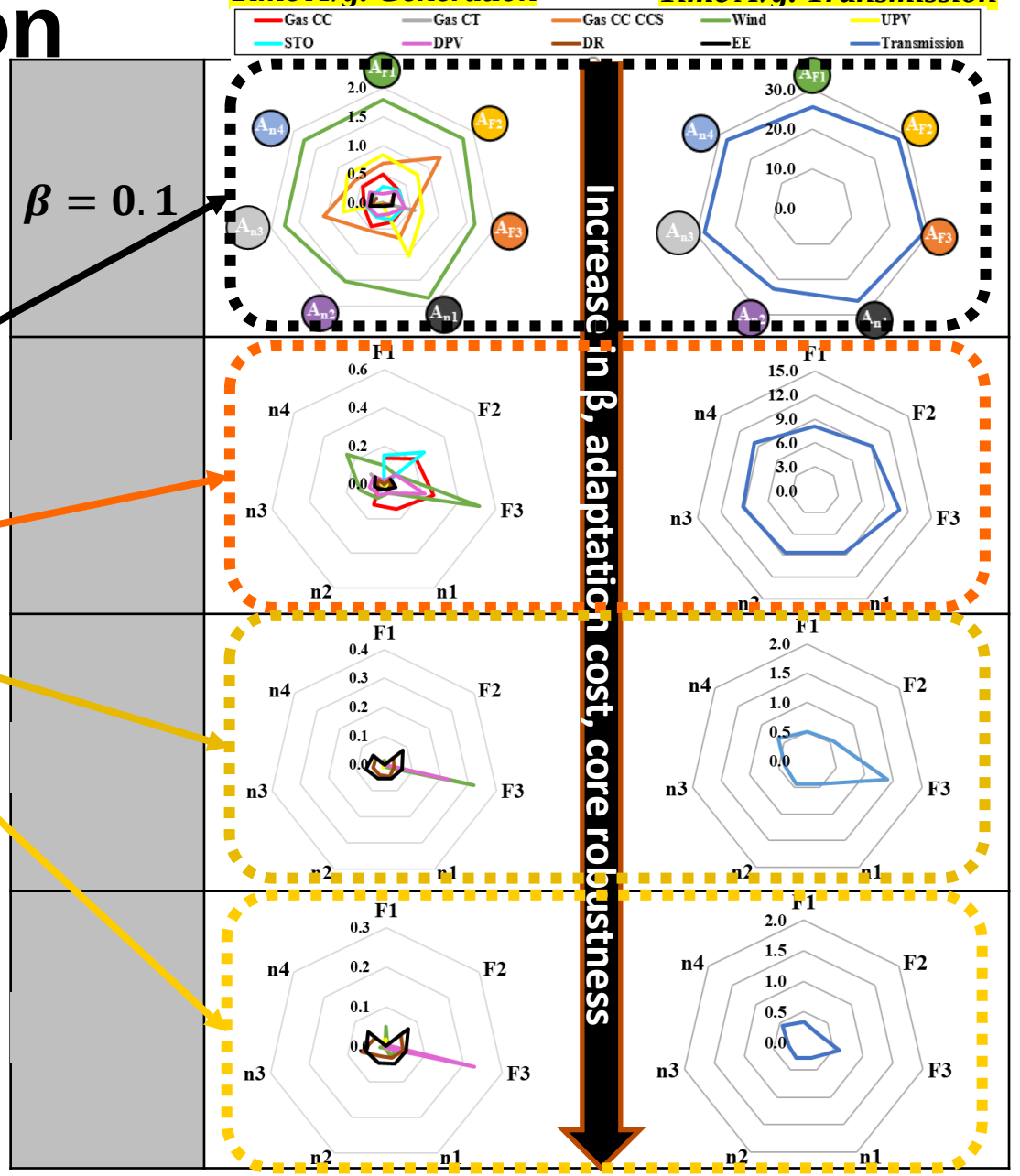
Adaptation Investments

- Adaptation investments provide insight into future-specific investments – indicates to planner which investment options are ***more risky compared to core investments***



Core Investments

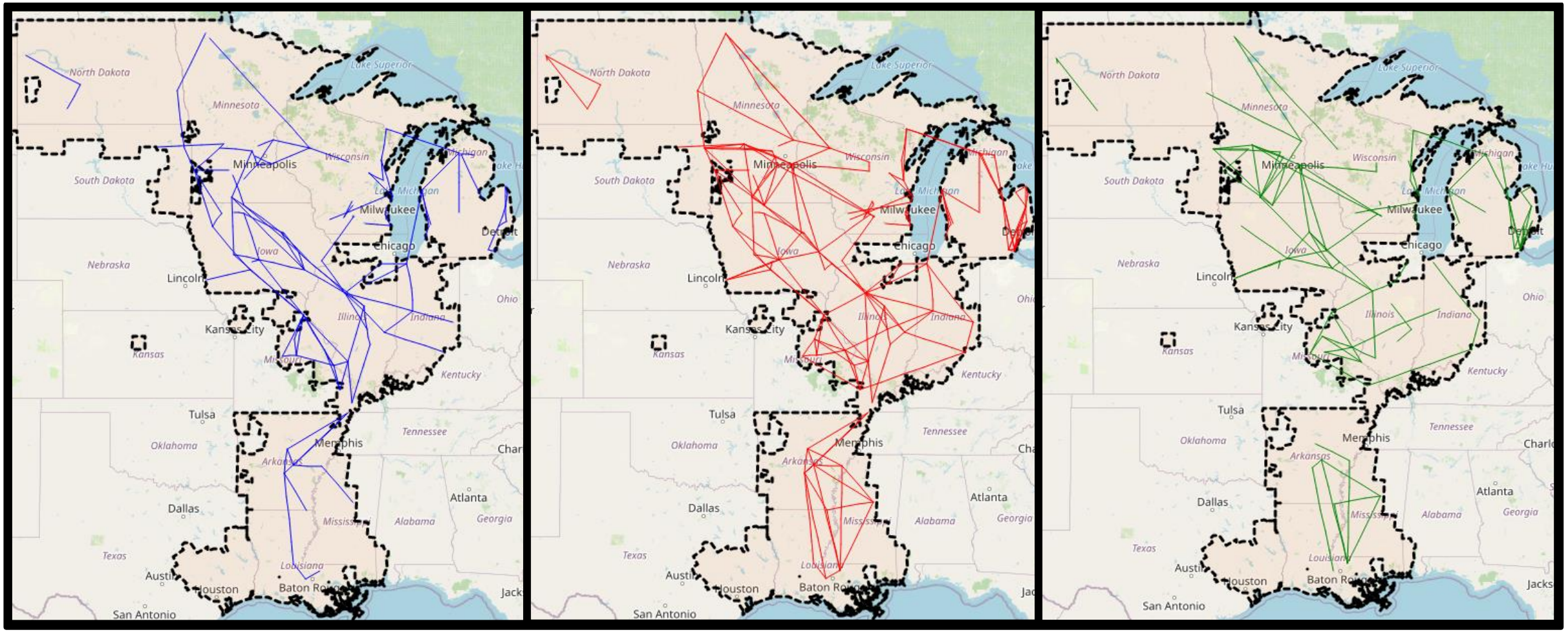




*Each core investment portfolio can be adapted to each future scenario via the adaptive investments – **flexible investment plan**!!*

5. ACEP Results – identifying uniquely flexible investments

"… a transmission investment might perform well in many scenarios because it gives the system flexibility... But that investment might never be the very best choice in any single scenario of renewable development. However, when considered stochastically, that line would provide a hedge against uncertainty and could be optimal overall." B. Hobbs, et al., "Adaptive transmission planning," IEEE Power & Energy Magazine, July/Aug., 2016.

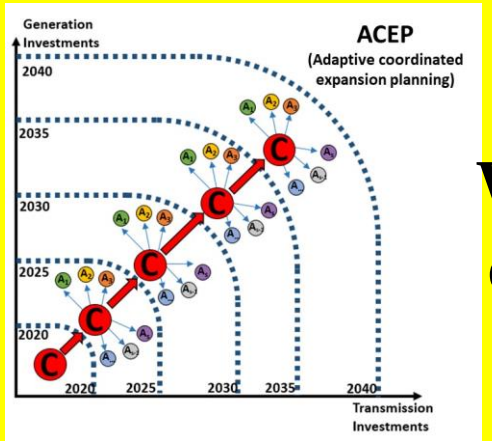


CEP: Transmission investments ***common*** to all scenarios from the CEP simulations.

ACEP: Transmission investments in ***core*** for $\boldsymbol{\beta = 1}$. → ***Unique*** investments identified by the ACEP and not by the deterministic solutions.

6. ACEP with resource adequacy

Adaptive Cooptimized Expansion Planning (ACEP)



With PRM constraint

GE-MARS

GE MARS is a full sequential Monte Carlo simulation

Chronological system simulation performed by combining:

- Randomly generated operating histories of units through time
- Hourly chronological load cycles
- Transmission links

Years are simulated until a convergence criterion is met, or for a set number of samples

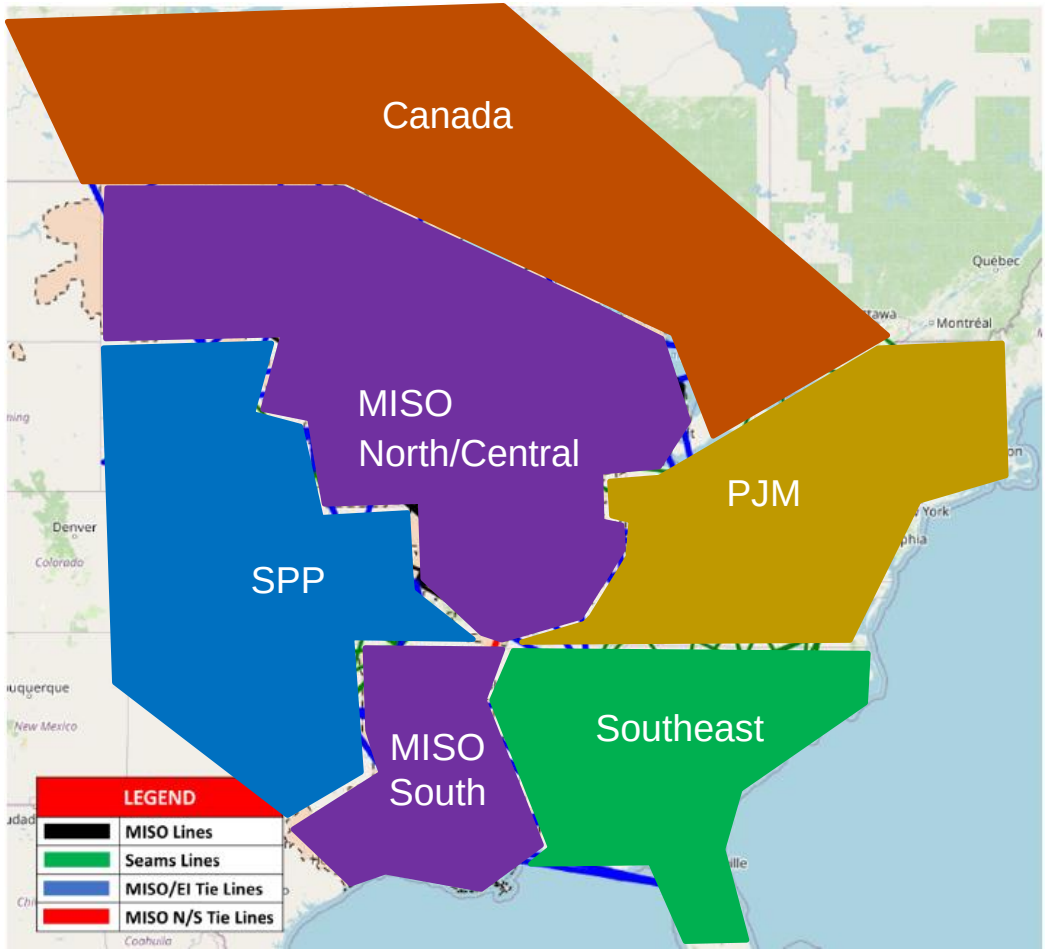
Applied by season & by MISO LRZ.

LOLE≈ 0.1 days/yr ?

YES → **DONE**

NO → **ADJUST PLANNING RESERVE MARGIN**

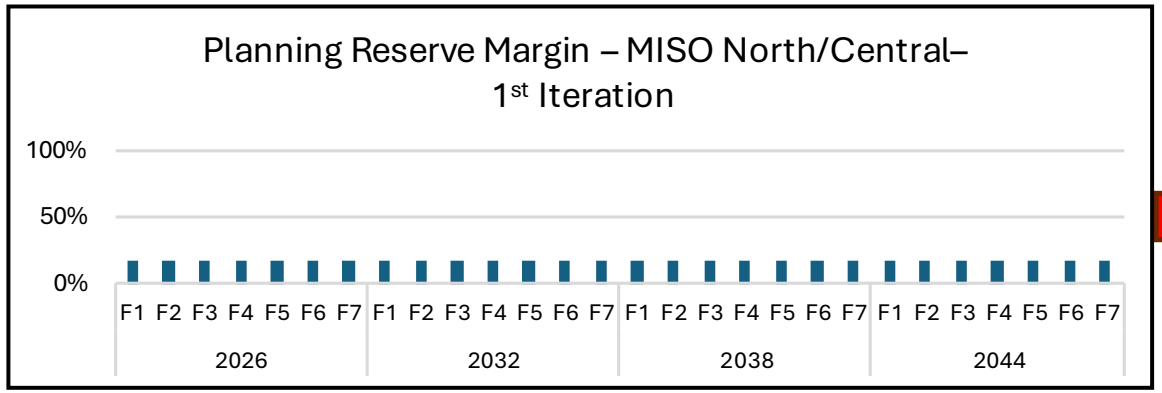
6. ACEP with resource adequacy



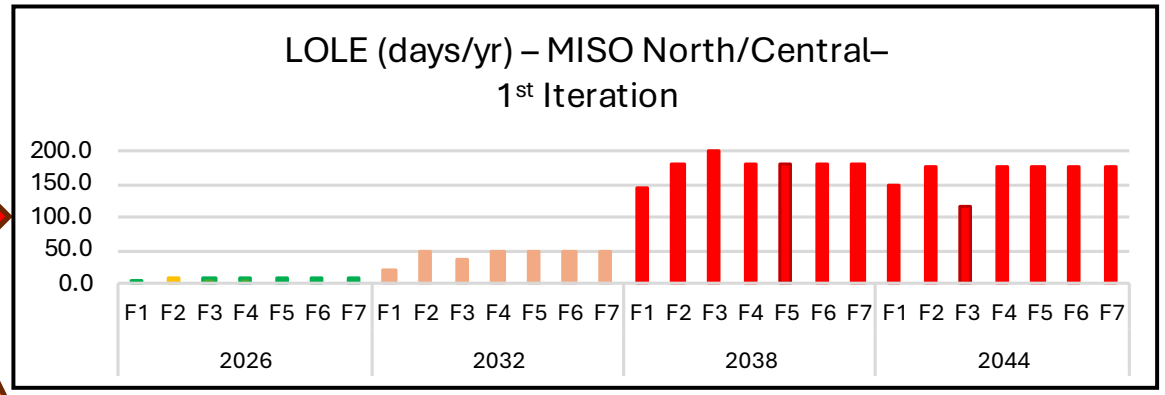
Results were obtained by testing our approach using a reduced model of the Eastern Interconnection.

- Two cases were simulated: β = 1 and β = 0.1.
- ACEP Topology: Same reduced model as previously used. Nodal model with buses distributed across states and regions.
- GE-MARS Topology, 6 areas:
  - MISO North/Central,
  - MISO South,
  - Canada,
  - Southeast, and
  - PJM.
  - SPP

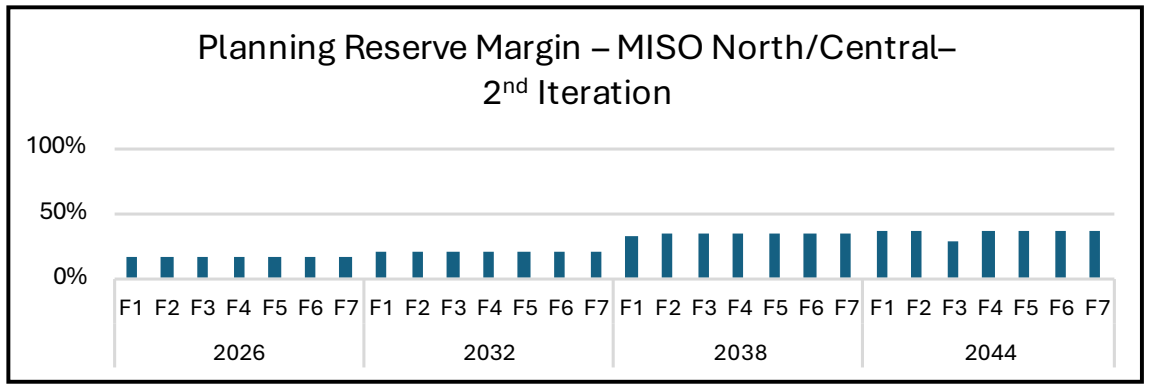
6. ACEP with resource adequacy



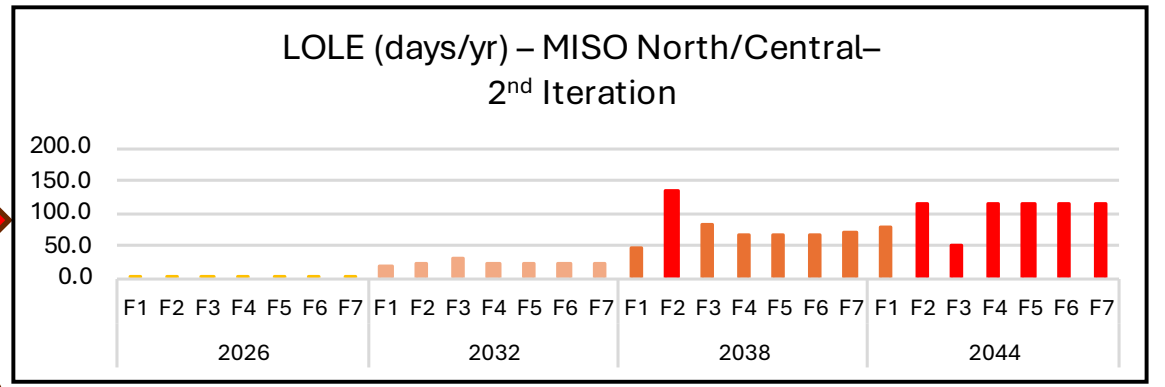




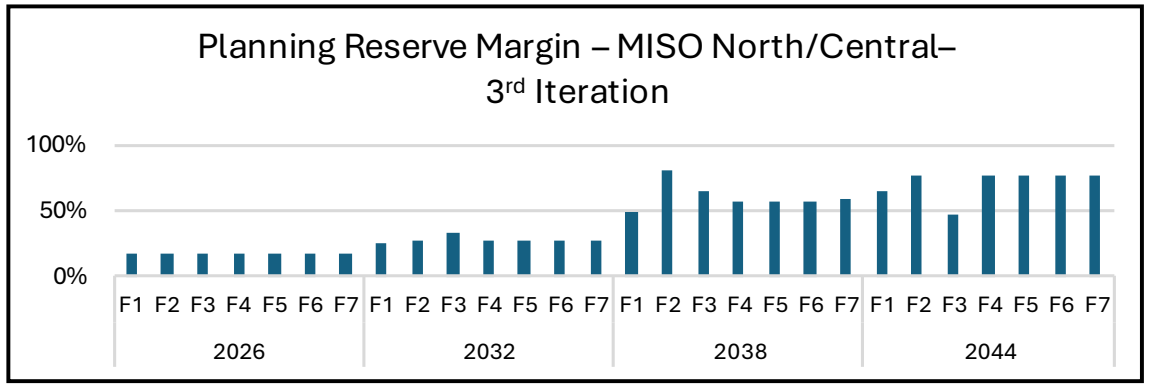




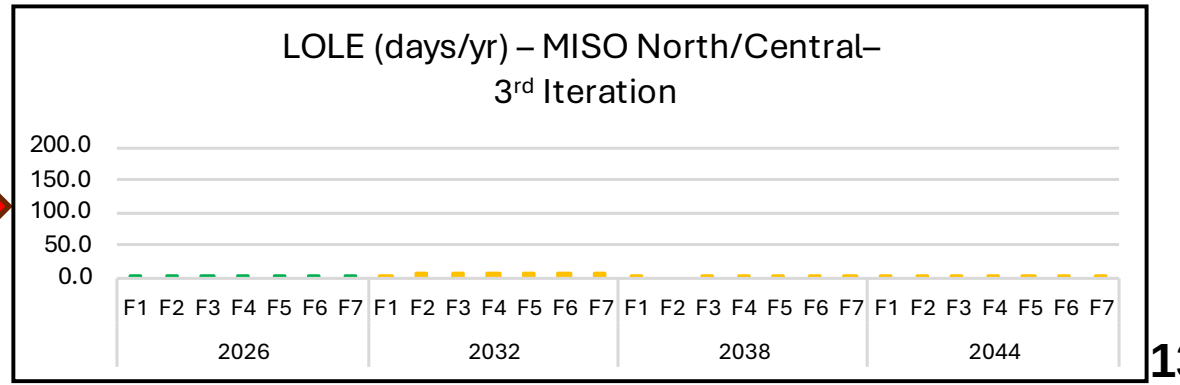






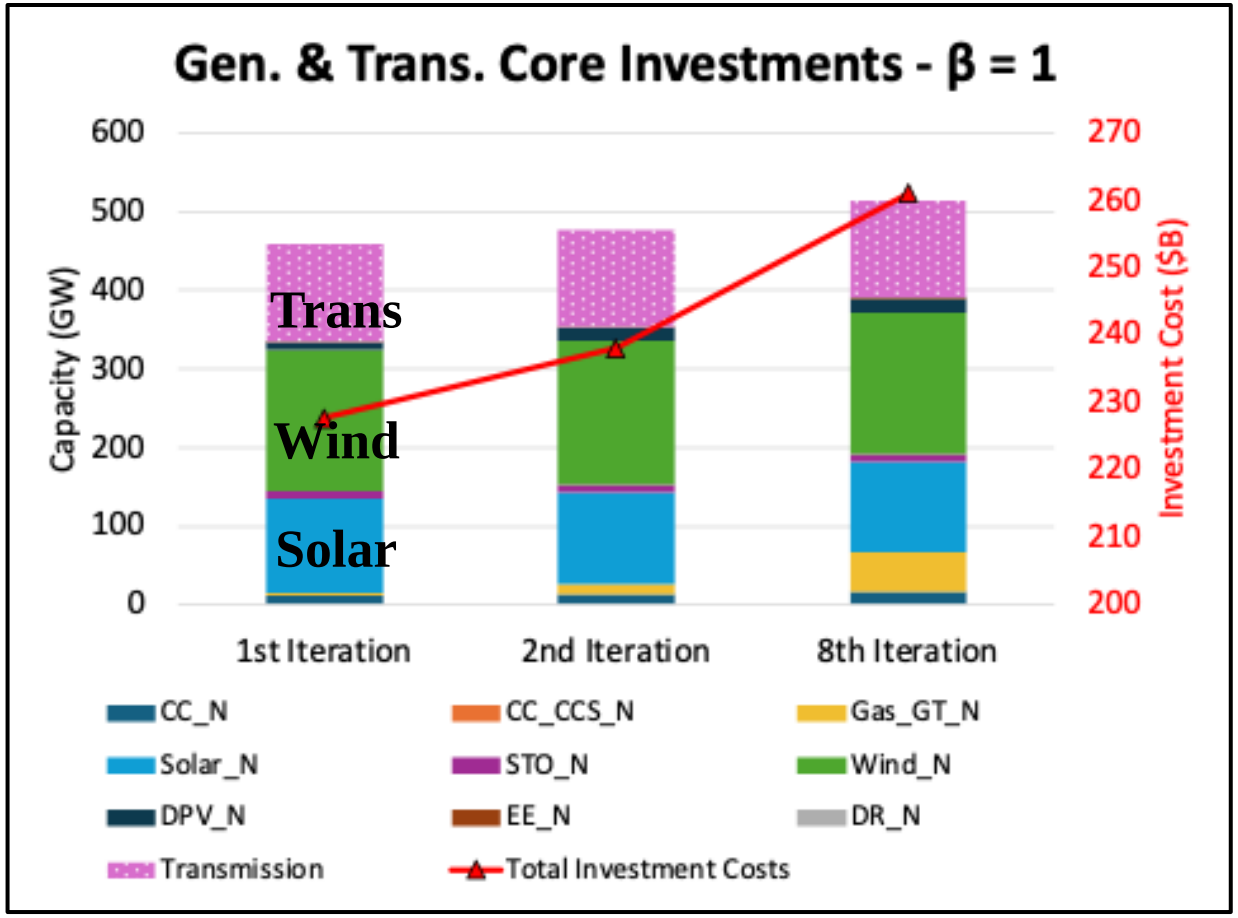


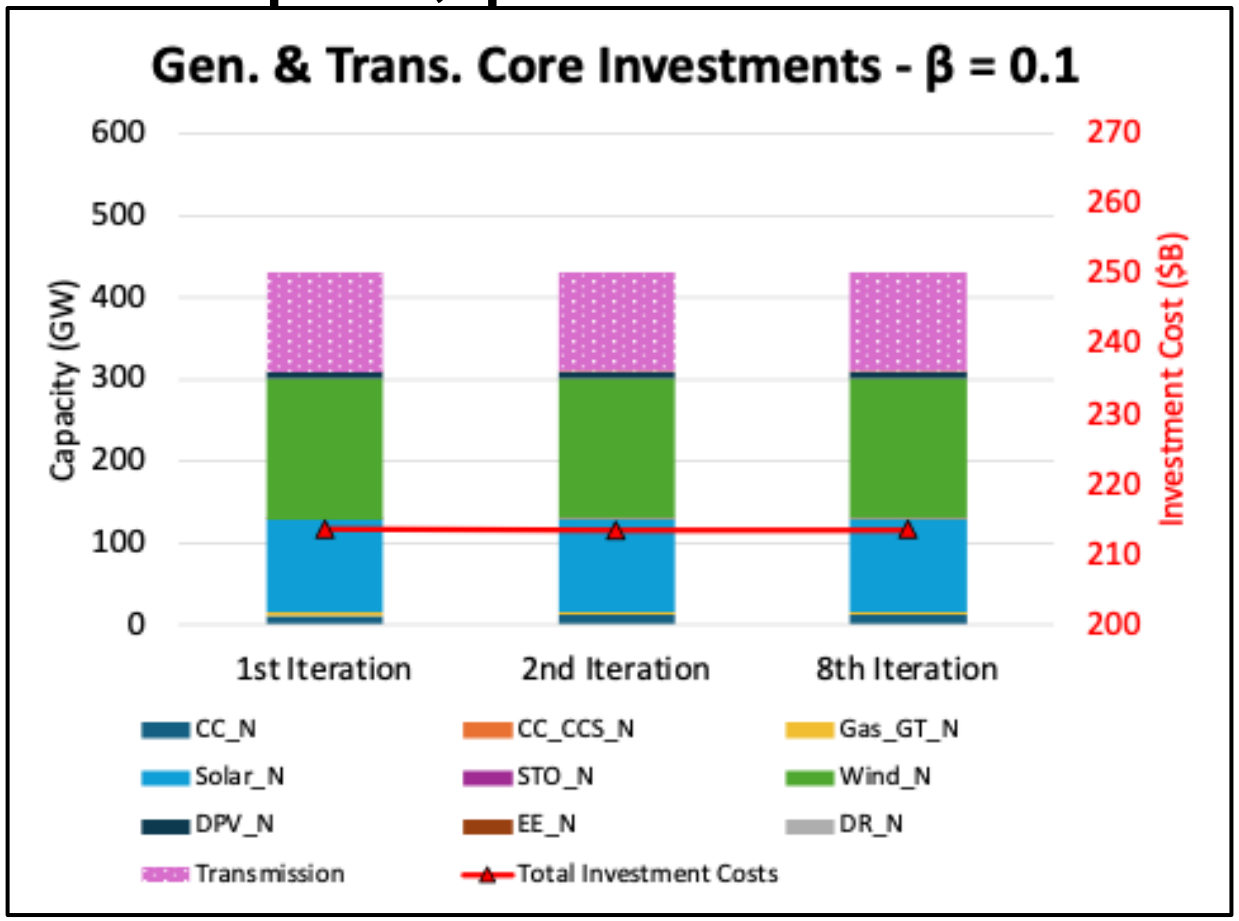




6. ACEP with resource adequacy

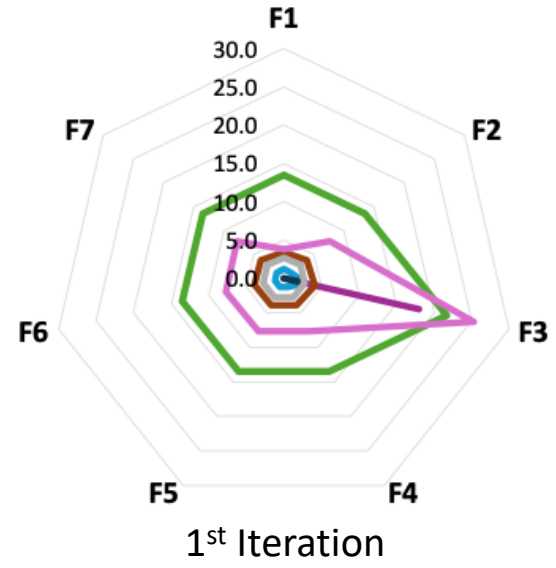
Core investments for β=1, β=0.1



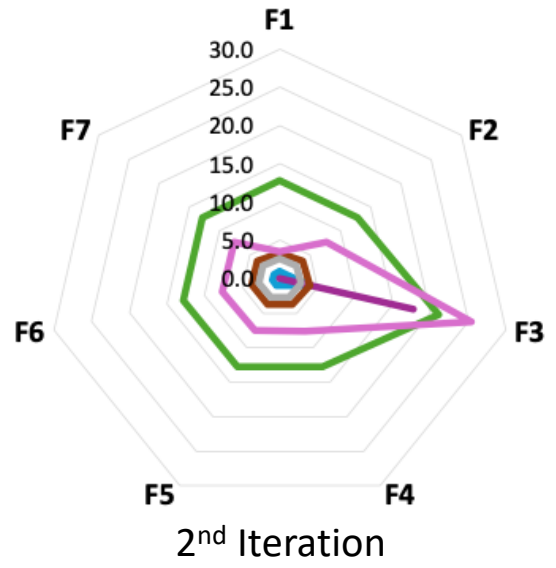


Sample Results: Adaptations by future for β=1, β=0.1

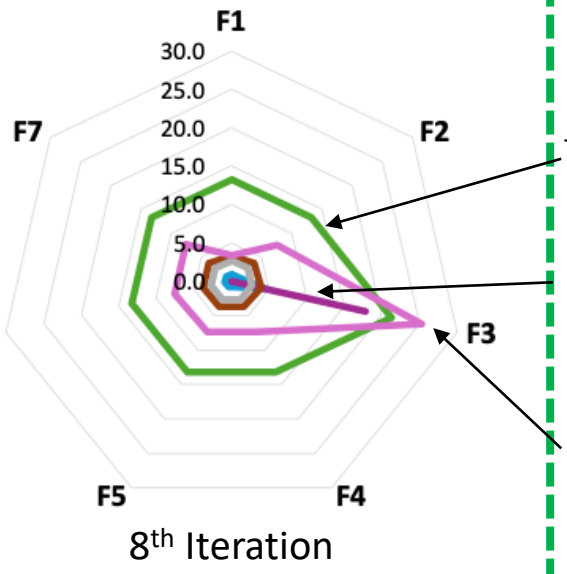
β = 1



1st Iteration



2nd Iteration



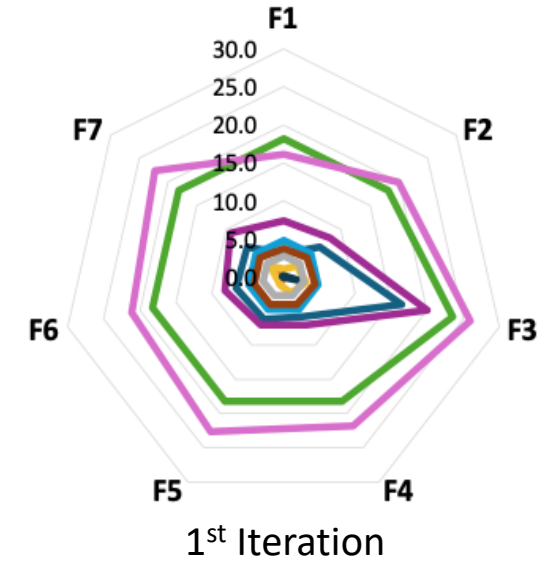
8th Iteration

Wind

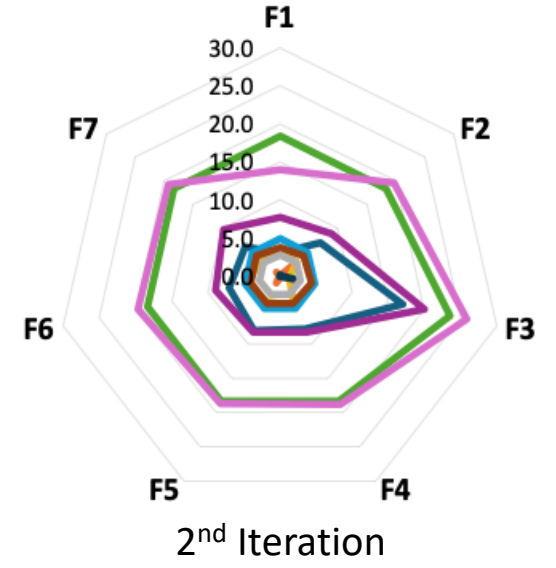
Storage

Trans

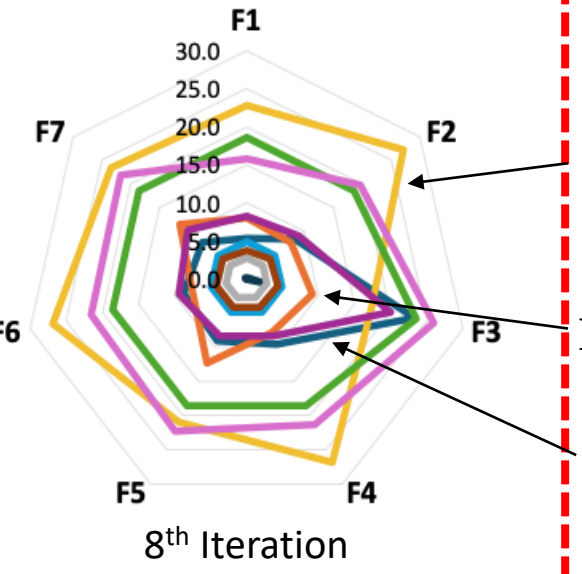
β = 0.1



1st Iteration



2nd Iteration



8th Iteration

Gas CT

NGCC-CCS

Gas CC

7. Conclusions

1. All RTOs plan with futures
2. Future: a trajectory through time
3. Plan: trajectory of what you build
4. Distinction:

   Future-specific build ←→ what is built (core)

   ➔Difference == Future-specific adaptation
5. ACEP identifies core and future-specific adaptations
6. Identification of “hedge” investments need multi-future optimization
7. ACEP can include resource adequacy; shows up in core or adaptations (either plan to build it or adapt when the time comes)