PIE Project, Report 5
Integration of ISO-RTO Planning Functions: Focus on Expansion Planning and Resource Adequacy

Task G6-2: Extending expansion planning applications to account for resource/energy adequacy

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RTO planning-related functions: Typical approach

Transmission Planning
- Scenarios and planning model development
- Identification of needs (reliability, economic, and policy)
- Transmission solution development
- Evaluation and cost/benefit analysis to rank the alternatives
- Cost allocation analysis and final approval

Generation Interconnection Planning
- Interconnection requests
- Verification of minimum requirements for a secure interconnection
- Identification of needed system upgrades
- Cost analysis
- Gen. Interconnection Agreement.

Adequacy Planning
- Load forecast
- Gathering information about the existing, planned and retired generation
- Resource adequacy assessment (probabilistic or deterministic)
- Identification of adequacy needs
- Capacity market

Interregional Planning
- Information exchange
- Identification of needs (reliability and economic) based on the interregional agreement
- Transmission solution development
- Evaluation and cost/benefit analysis to rank the alternatives
- Cost allocation analysis and final approval

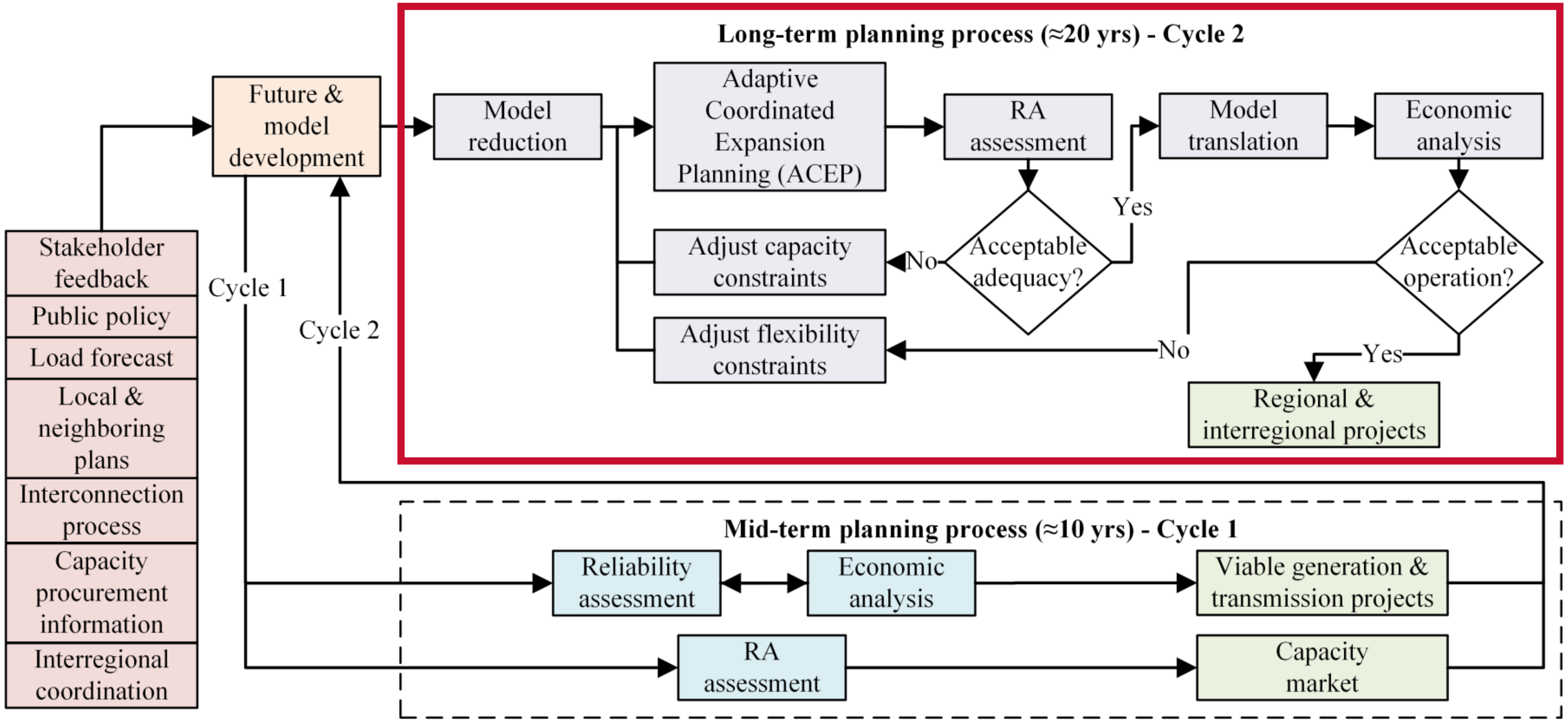
❖ Processes are conducted with limited integration, avoiding the assessment of portfolios addressing multiple needs simultaneously.

❖ ISO/RTO documentation reveals a consistent trend of employing a future or vision-based approach to consider diverse future conditions.

Challenges and potential solutions

Challenges	Description	Potential Solutions
Planning process coordination	• A need for integration and coordination among primary planning functions • Absence of established guidelines for long-term planning.	A framework for the integrated planning of power systems, including an automated long-term planning process.
Uncertainty	Increased uncertainty requires more complex analysis tools to co-optimize R&T investments over a long-term planning horizon while considering multiple futures.	Adaptive Coordinated Expansion Planning (ACEP)
Development of advanced simulation tools	There is a need to mature expansion planning tools that accurately consider the unreliability costs by using a probabilistic reliability approach.	Integration of expansion planning with Resource Adequacy tools: ACEP & GE-MARS

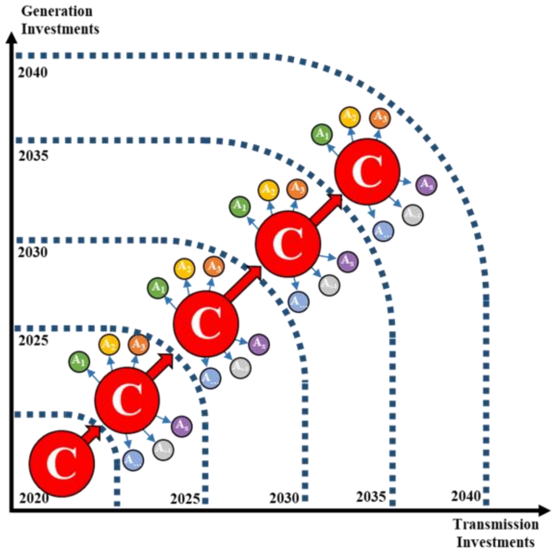
Proposed framework - Integrated planning of power systems:



Main Features of the Framework:

1. **Automated Process:** The Expansion Planning Modeling System (EPMS) employs an automated long-term planning process, including adaptive expansion planning, resource adequacy, and economic analysis tools.

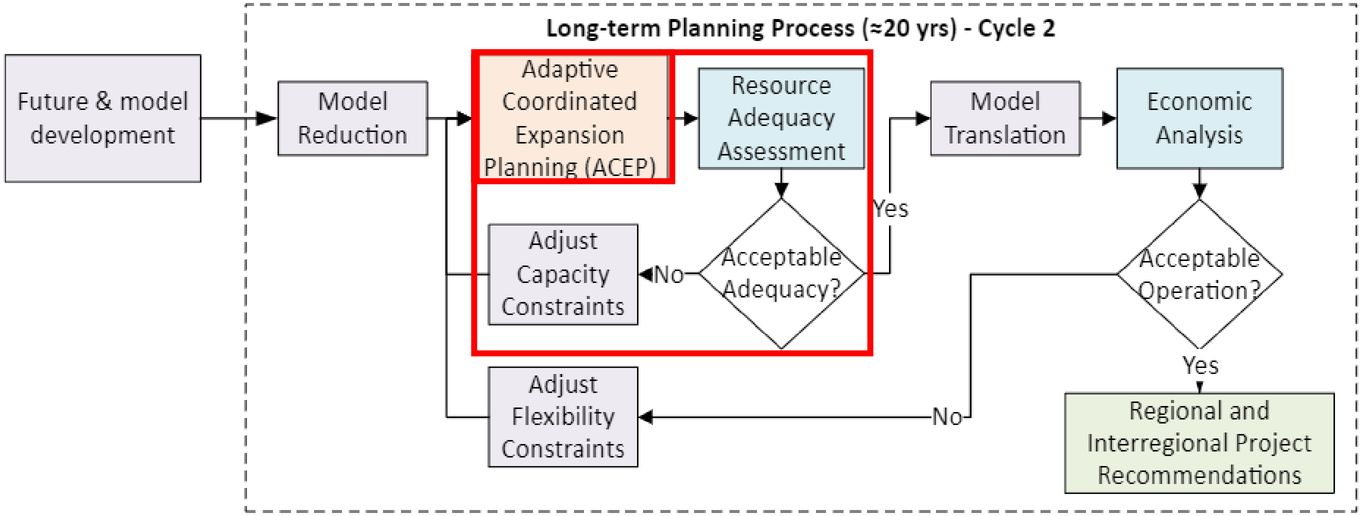
The Adaptive Coordinated Expansion Planning (ACEP) tool by ISU



[Taken from: C. Newlun, "Co-optimized expansion planning for power system resilience and adaptation," Ph.D. dissertation, Iowa State University, 2022.

$$\min NPV \left\{ \begin{array}{c} CoreCosts(x) \\ + \beta \left[\sum_k Pr_k \times AdaptionCosts(\Delta x_k) \right] \\ + \sum_k Pr_k \times OperationalCosts(\Delta x_k) \end{array} \right\}$$

$$\text{s.t. } Operational\ Constraints\ \forall\ future\ k = 1, \dots, n.$$



Potential enhancement:

- Refine the ACEP formulation **to shift** from a model considering a fixed system-wide Planning Reserve Margin (PRM) to **PRM values** that vary by **areas, futures, and years.** These values will be **iteratively updated** based on Resource Adequacy (RA) assessments until a given reliability criterion is satisfied.
- This refinement aims **to improve ACEP's accuracy in accounting for resource adequacy** by subjecting **each future portfolio** to a broader range of realistic scenarios through probabilistic RA tools.

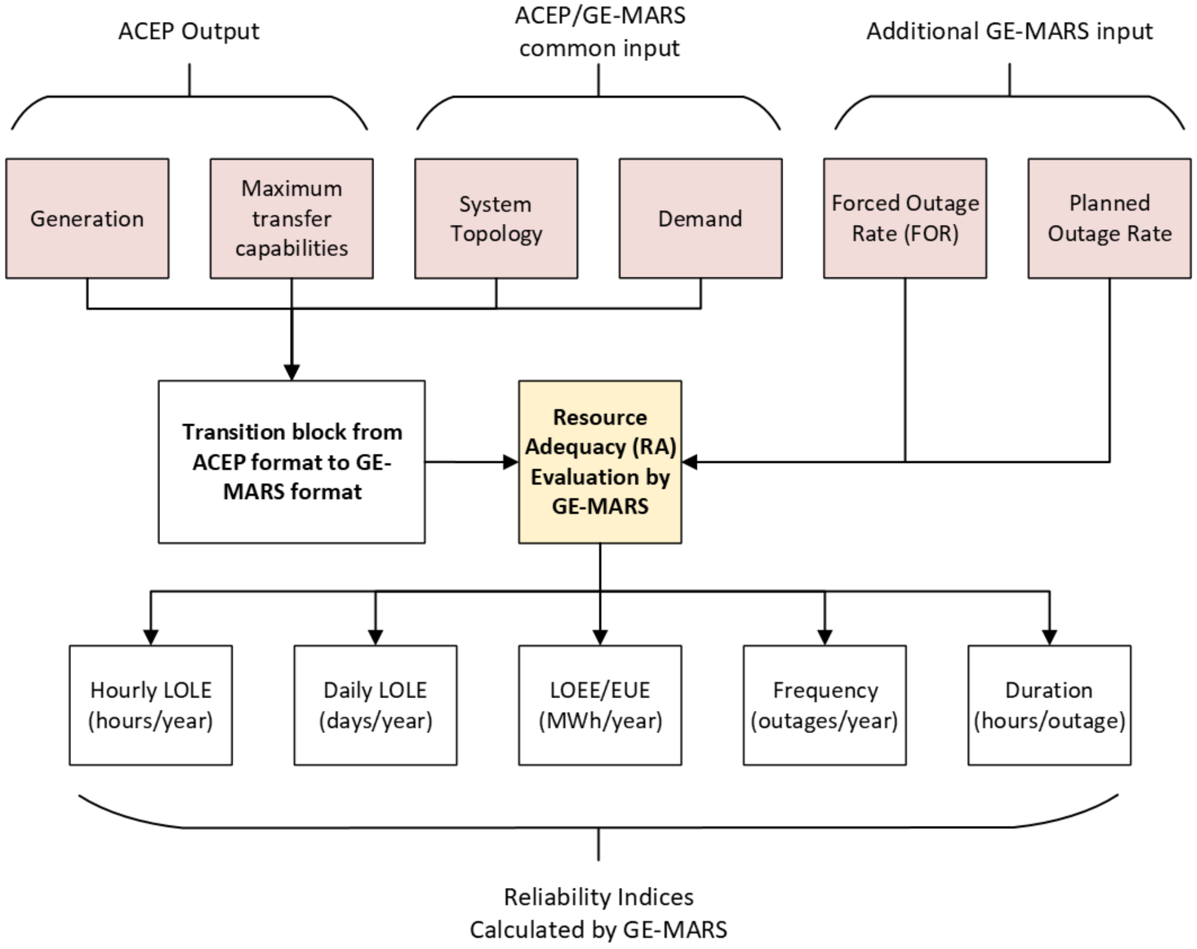
Current constraint

$$TotalAccreditedCapacity_{k,y} \geq PRM \times TotalPeakLoad_{k,y}$$
$$\forall\ future\ k = 1, \dots, n, \quad year\ y = 1, \dots, m.$$

New constraint

$$TotalAccreditedCapacity_{\boldsymbol{a},k,y} \geq \boldsymbol{PRM_{a,k,y}} \times TotalPeakLoad_{\boldsymbol{a},k,y}$$
$$\forall\ area\ a = 1, \dots, p, \quad future\ k = 1, \dots, n, \quad year\ y = 1, \dots, m.$$

Resource Adequacy Assessment – GE-MARS



GE's Multi Area Reliability Simulation (GE-MARS)

- GE MARS is a full sequential Monte Carlo simulation
- It calculates RA indices at the area level. Pool indices are derived from areas in each pool.
- Chronological system simulation performed by combining:

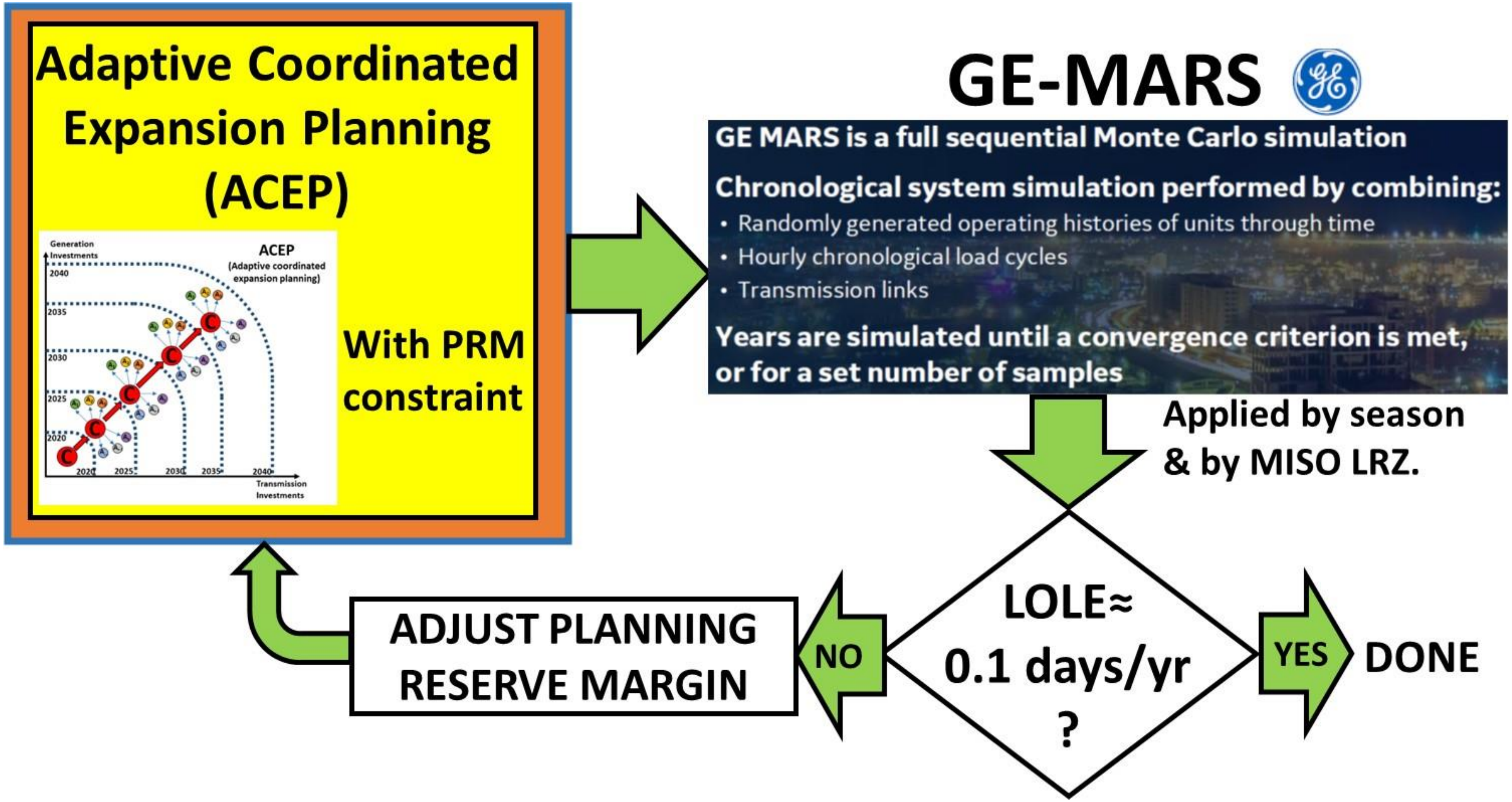
  - Randomly generated operating histories of units through time

  - Hourly chronological load cycles

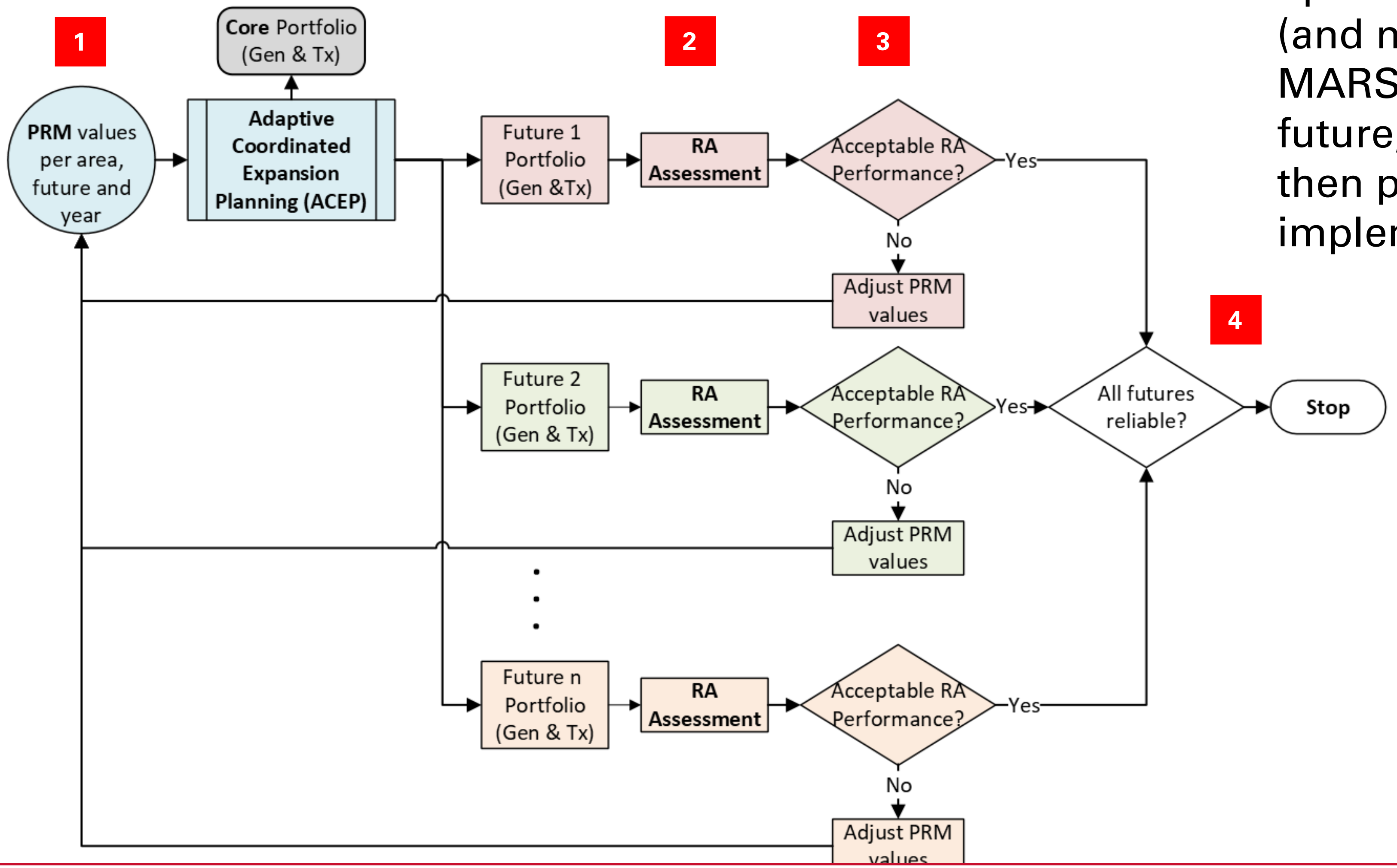
  - Transmission links
- Years are simulated until a convergence criterion is met, or for a set number of samples

[Taken from the GE-MARS tutorial slides, 2023]

Integration of ACEP with GE-MARS – Big Picture



Integration of ACEP with GE-MARS – Detailed Design

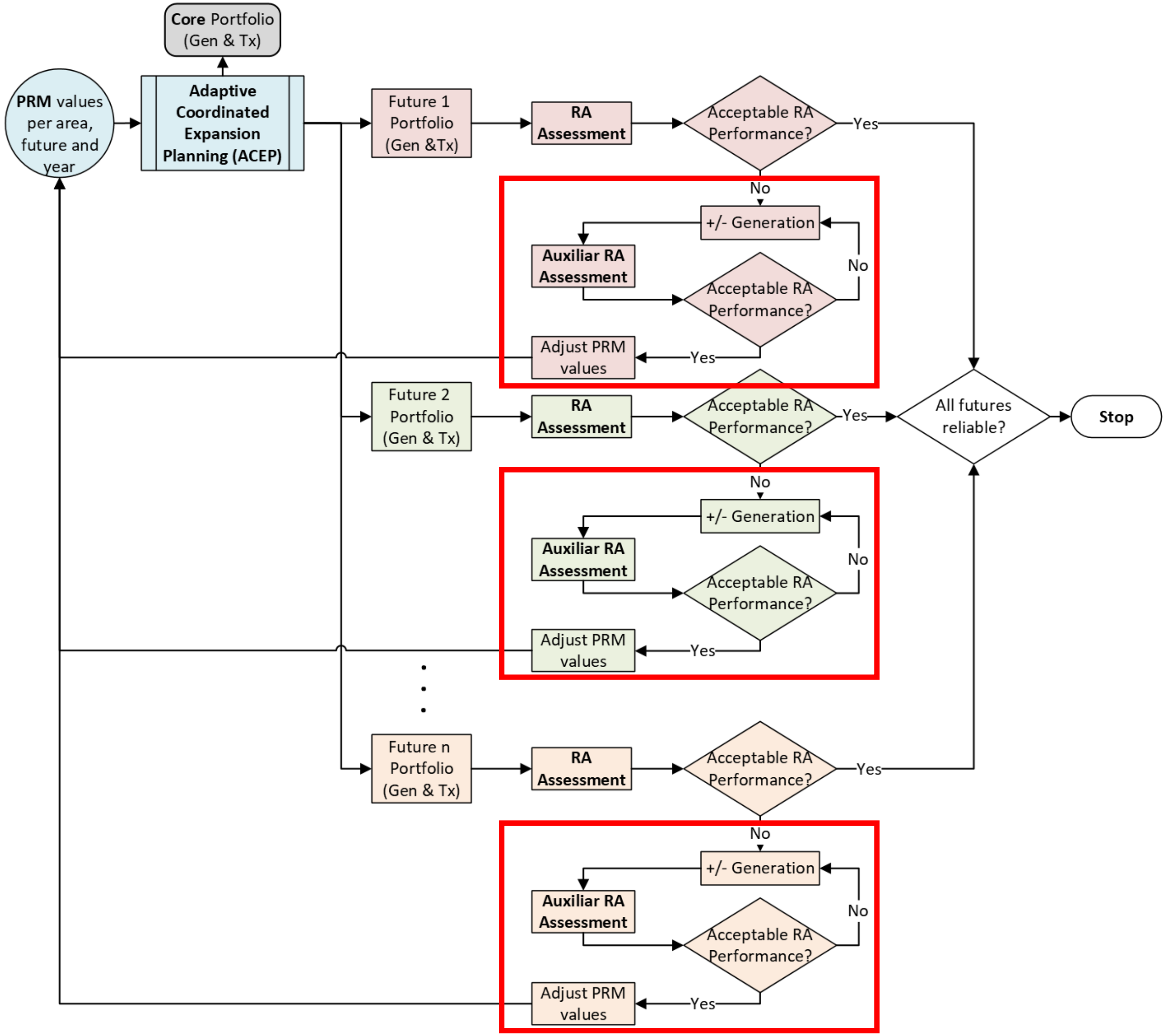


<u>KEY CONCEPT</u>: Because ACEP conducts operational analysis for specified futures (and not for "core build"), the RA tool (GE-MARS) needs to operate on each expanded future; the results of those expanded futures then provide for constraint modifications implemented in next iteration of ACEP.

1. ACEP is initially run with assumed PRM values per future and year.
2. Certain years from the span of 20 or 25 years will be assessed for each future investment (core + adaptation) using GE-MARS.
3. In general, an index that does not satisfy a given criterion will lead to adjusting the PRM values in the ACEP formulation.
4. The simulations stop when the resource adequacy level for each area, future, and year is acceptable.

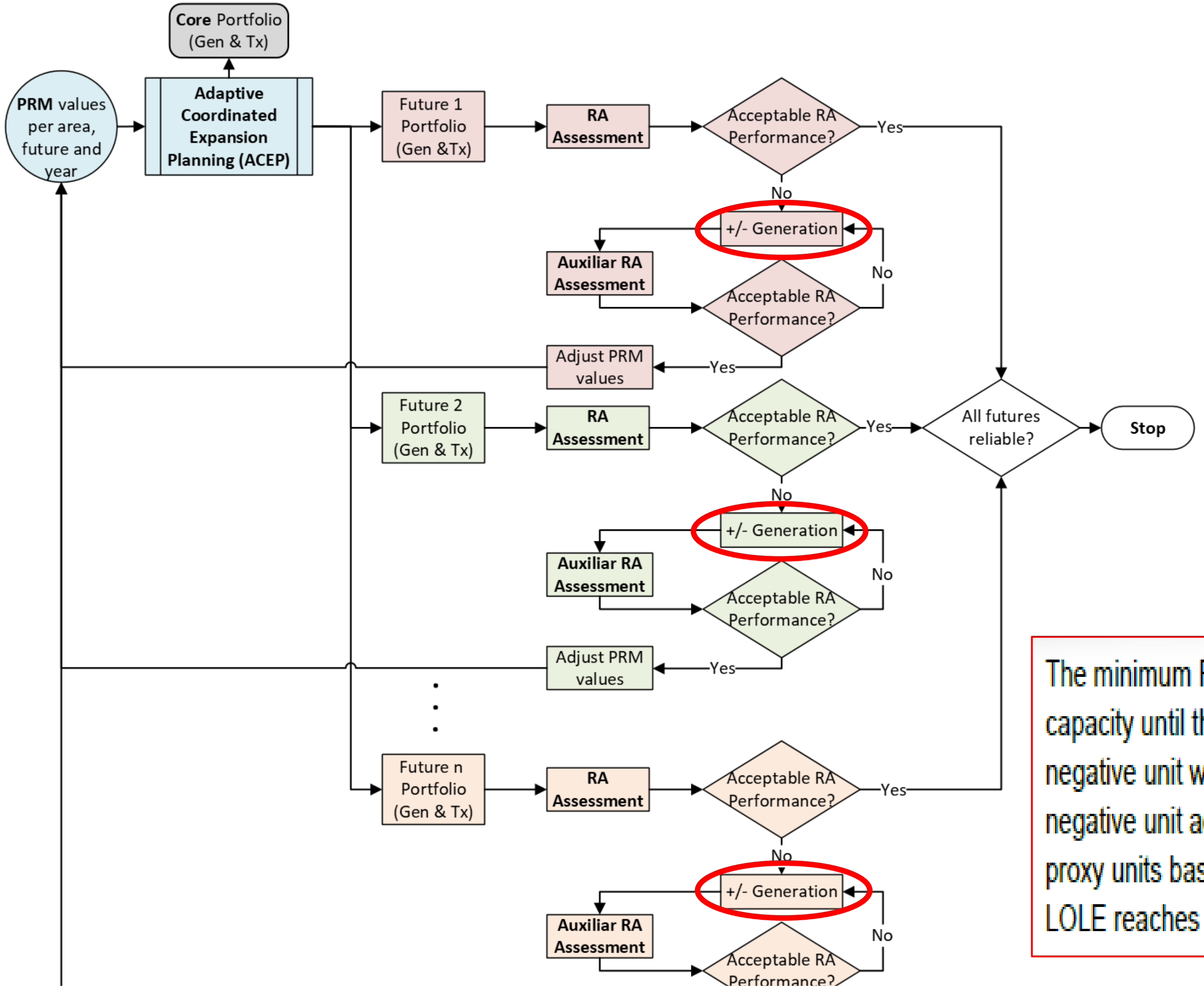
This approach will allow planners to fine-tune core investment **robustness** while understanding the additional **investments required to adapt the system** to specific future scenarios while **maintaining resource adequacy** in each scenario.

Integration of ACEP with GE-MARS



- A more detailed view of the previous slide.
- ACEP – Typical run time using the server: **7-8 hours.**
- GE-MARS – Typical run time using a desktop PC: **from 30 minutes to 3 hours.**
- The inner loop is expected to enhance processing time.

Integration of ACEP with GE-MARS



The "Add/Reduce Generation" block...

- Currently, MISO is doing this through:

1. Engineering judgement.
2. Trial and error.

0.1 LOLE ⟶ 100 MW of perfect cap.

The minimum PRM requirement is determined using the LOLE analysis by either adding or removing capacity until the LOLE reaches 0.1 day per year. If the LOLE is less than 0.1 day per year, a perfect negative unit with zero forced outage rate is added until the LOLE reaches 0.1 day per year. The perfect negative unit adjustment is akin to adding load to the model. If the LOLE is greater than 0.1 day per year, proxy units based on a unit of typical size and forced outage rate will be added to the model until the LOLE reaches 0.1 day per year.

Taken from the 2023 MISO Loss of Load Expectation Study Report:
https://cdn.misoenergy.org/PY%202022-23%20LOLE%20Study%20Report601325.pdf

Integration of ACEP with GE-MARS

- Options for considering PRM in planning studies are shown in the table.
- Complexity is measured on a scale from 1 to 6, with 1 indicating lower accuracy but less computational expense.
- Initially, our strategy involves considering PRM values by area annually, aiming to balance accuracy and computational burden.

AREA/TIME	Planning horizon	Annually	Seasonally
System-wide/ Pool	1	2	3
Area	2	4	5
Local Resource Zone (LRZ)	3	5	6

Integration of ACEP with GE-MARS - Results

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

- Two cases were simulated to demonstrate the impact of more accurately considering PRM constraints in expansion planning tools:

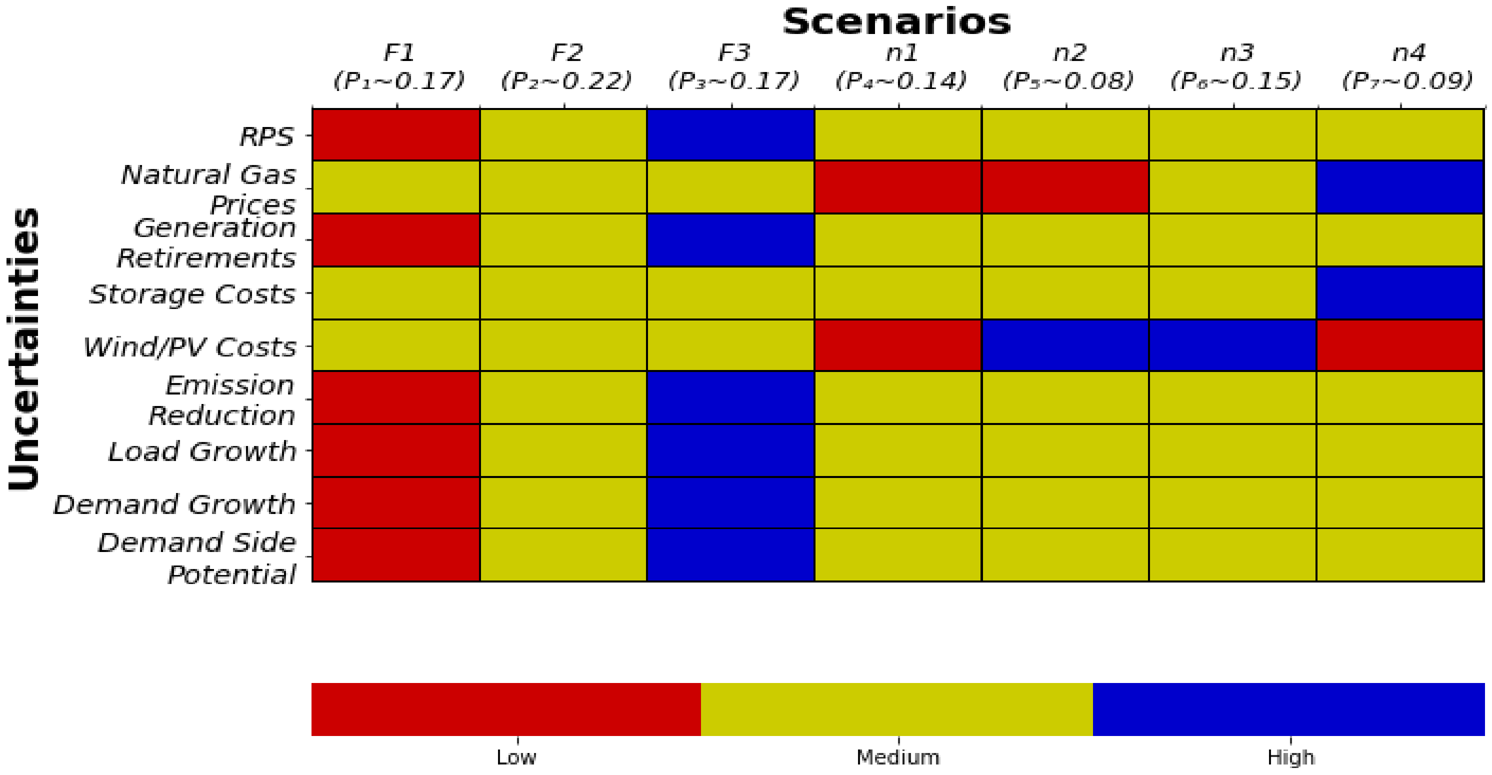
- ACEP with a high robustness parameter (Beta) equal to 1
- ACEP with a low robustness parameter (Beta) equal to 0.1

- The results of three iterations are shown to illustrate the approach.

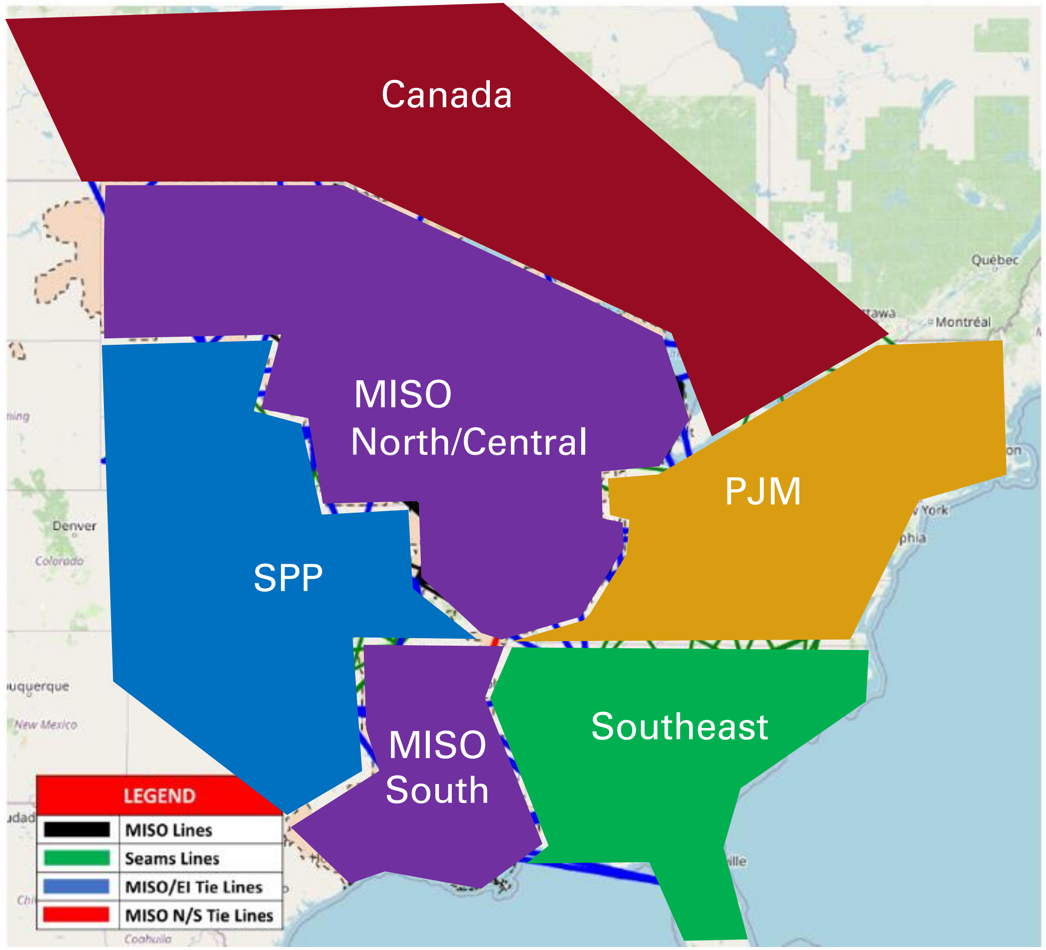
- These results showcase the interplay between investment robustness, resource adequacy, and operational flexibility, providing insights into the effectiveness of our application and its benefits for grid expansion planning.

Integration of ACEP with GE-MARS - Results

- Input/Assumptions:
- A planning horizon of 20 years was considered (2025-2044)
- Investments were allowed only in MISO.
- Seven futures were considered.



Integration of ACEP with GE-MARS - Results



Data conversion from ACEP to GE-MARS format:

- ACEP Topology:

Nodal model with buses distributed across states and regions.

- GE MARS Topology:

- 5 Pools: MISO, SPP, Canada, Southeast, and PJM.
- 6 Areas: MISO North/Central, MISO South, Canada, Southeast, and PJM.

- Buses and their information were mapped from states/regions in ACEP to corresponding areas in GE-MARS.

Integration of ACEP with GE-MARS – Results (Beta 0.1 case)

- PRM values per region, future, and year.
- An initial system-wide PRM of 17% was used throughout the planning horizon.
- Subsequently, PRM values were updated based on GE-MARS results.

Planning Reserve Margin (PRM) - Beta = 0.1

1st Iteration

Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%
MISO South	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%

2nd Iteration

Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%	29.2%	29.2%	25.0%	28.6%	28.0%	28.8%	29.4%	56.8%	57.4%	52.2%	58.3%	57.7%	57.2%	57.2%	55.4%	53.1%	47.0%	48.8%	52.1%	53.8%	53.8%
MISO South	19.4%	19.7%	19.5%	19.7%	19.7%	19.7%	19.7%	18.3%	20.8%	21.7%	20.8%	21.1%	19.9%	20.8%	50.9%	58.2%	61.0%	58.8%	58.9%	56.3%	56.8%	62.2%	63.4%	48.5%	62.4%	62.9%	62.2%	61.7%

3rd Iteration

Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	19.7%	19.7%	19.7%	19.7%	19.7%	19.7%	19.7%	36.5%	38.0%	31.6%	34.8%	34.9%	38.0%	36.7%	71.7%	64.2%	57.7%	69.0%	67.2%	63.9%	64.9%	60.0%	57.6%	99.7%	53.8%	56.3%	57.6%	58.2%
MISO South	23.8%	24.5%	24.8%	24.5%	24.5%	24.5%	24.5%	22.7%	26.9%	29.4%	26.1%	25.8%	26.0%	26.6%	72.8%	75.5%	72.9%	77.5%	78.6%	76.9%	78.6%	77.3%	69.9%	57.3%	71.4%	71.4%	71.3%	70.6%

Integration of ACEP with GE-MARS – Results (Beta 0.1 case)

- LOLE values
- The 1st iteration result shows that an assumed system-wide PRM is insufficient to satisfy resource adequacy criteria.
- LOLE values improve as PRM values are updated.

Loss of Load Expectation (LOLE - days/year) - Beta = 0.1

1st Iteration

Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	0.7	0.7	0.3	0.7	0.7	0.7	0.7	53.5	53.2	33.3	50.6	47.7	51.3	54.2	184.9	187.7	163.0	191.8	189.0	186.9	186.6	178.3	167.2	138.1	146.7	162.5	170.6	170.6
MISO South	6.6	7.9	7.0	7.9	7.9	7.9	7.9	1.5	13.3	17.7	13.5	14.8	8.9	13.5	156.6	191.6	204.8	194.5	194.8	182.3	184.8	210.7	216.0	145.3	211.5	213.7	210.3	207.9

2nd Iteration

Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	0.3	0.3	0.3	0.3	0.3	0.3	0.3	14.4	18.4	12.9	11.8	13.6	19.5	14.6	33.6	13.4	10.1	23.1	20.1	13.0	15.6	7.8	7.5	128.0	8.8	6.7	5.8	7.3
MISO South	7.5	8.5	9.7	8.5	8.5	8.5	8.5	7.2	11.6	15.6	9.4	8.1	11.8	10.7	51.2	39.5	26.0	43.0	45.6	48.0	50.9	34.1	12.8	18.3	18.8	17.7	19.2	18.8

3rd Iteration

Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	0.1	0.1	0.2	0.1	0.1	0.1	0.1	3.7	3.0	3.8	4.2	3.8	2.7	4.0	7.7	6.6	6.4	5.4	6.9	5.9	4.9	3.5	3.3	0.4	5.6	4.6	3.5	3.1
MISO South	4.3	5.4	5.5	5.4	5.4	5.4	5.4	1.0	4.4	3.7	5.7	3.8	1.8	6.8	9.5	9.3	6.4	8.9	11.0	9.0	4.5	16.5	3.5	18.0	4.4	7.1	4.7	4.0

Integration of ACEP with GE-MARS – Results (Beta 1 case)

- PRM values per region, future, and year.
- An initial system-wide PRM of 17% was used throughout the planning horizon.
- Subsequently, PRM values were updated based on GE-MARS results.

Planning Reserve Margin (PRM) - Beta = 1

1st Iteration

Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%
MISO South	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%

2nd Iteration

Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	17.0%	19.6%	19.9%	21.4%	19.9%	19.9%	19.9%	19.9%	31.6%	33.5%	35.3%	33.5%	33.5%	33.5%	33.5%	35.7%	36.6%	28.9%	36.6%	36.5%	36.6%	36.6%
MISO South	17.5%	18.0%	17.7%	18.0%	18.0%	18.0%	18.0%	19.0%	21.8%	20.7%	21.8%	21.8%	21.8%	21.8%	31.3%	35.1%	36.9%	35.0%	35.1%	35.1%	35.1%	31.7%	34.6%	28.7%	34.6%	34.7%	34.6%	34.7%

3rd Iteration

Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%	26.5%	28.2%	33.0%	28.2%	28.2%	28.2%	28.2%	49.3%	81.5%	64.7%	58.2%	58.3%	58.1%	58.7%	64.8%	78.2%	47.9%	78.3%	78.2%	78.4%	77.8%
MISO South	19.4%	20.2%	20.2%	20.3%	20.3%	20.3%	20.3%	24.1%	31.5%	32.0%	31.5%	31.5%	31.5%	31.5%	41.8%	59.7%	68.1%	58.2%	58.2%	58.2%	58.3%	52.3%	67.5%	50.4%	67.5%	66.9%	67.5%	67.4%

Integration of ACEP with GE-MARS – Results (Beta 1 case)

- LOLE values
- The 1st iteration result shows that an assumed system-wide PRM is insufficient to satisfy resource adequacy criteria.
- LOLE values improve as PRM values are updated.

Loss of Load Expectation (LOLE - days/year) - Beta = 1

1st Iteration

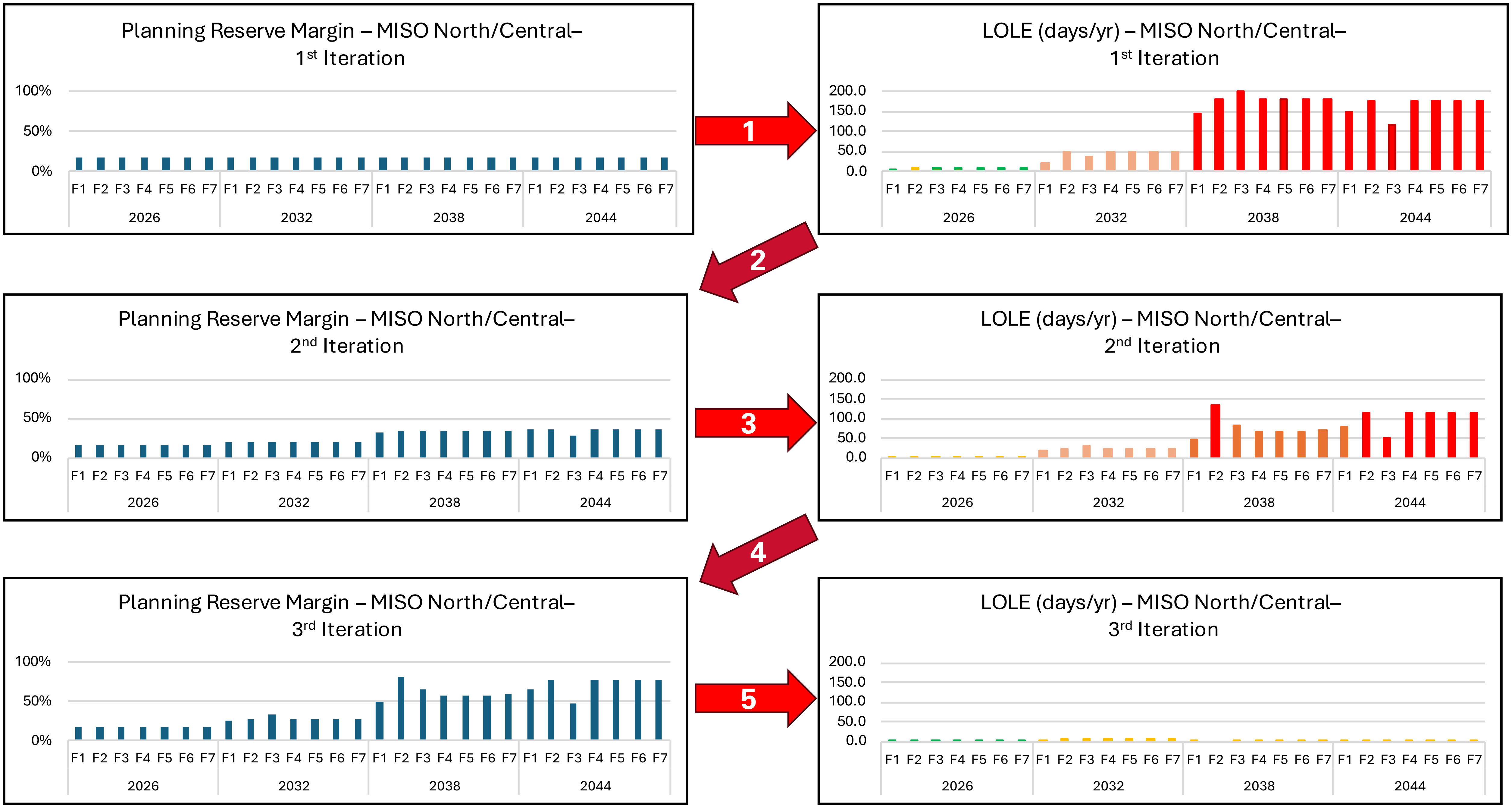
Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	0.1	0.1	0.2	0.1	0.1	0.1	0.1	25.8	29.2	43.5	29.2	29.2	29.2	29.2	145.9	165.1	182.8	164.9	165.1	165.1	165.1	187.1	195.8	119.3	195.8	194.5	195.8	195.6
MISO South	4.6	9.5	7.4	9.5	9.5	9.5	9.5	19.7	47.8	36.6	47.8	47.8	47.8	47.8	142.5	180.5	199.2	180.3	180.5	180.5	180.5	147.3	176.2	116.9	176.2	176.8	176.2	176.6

2nd Iteration

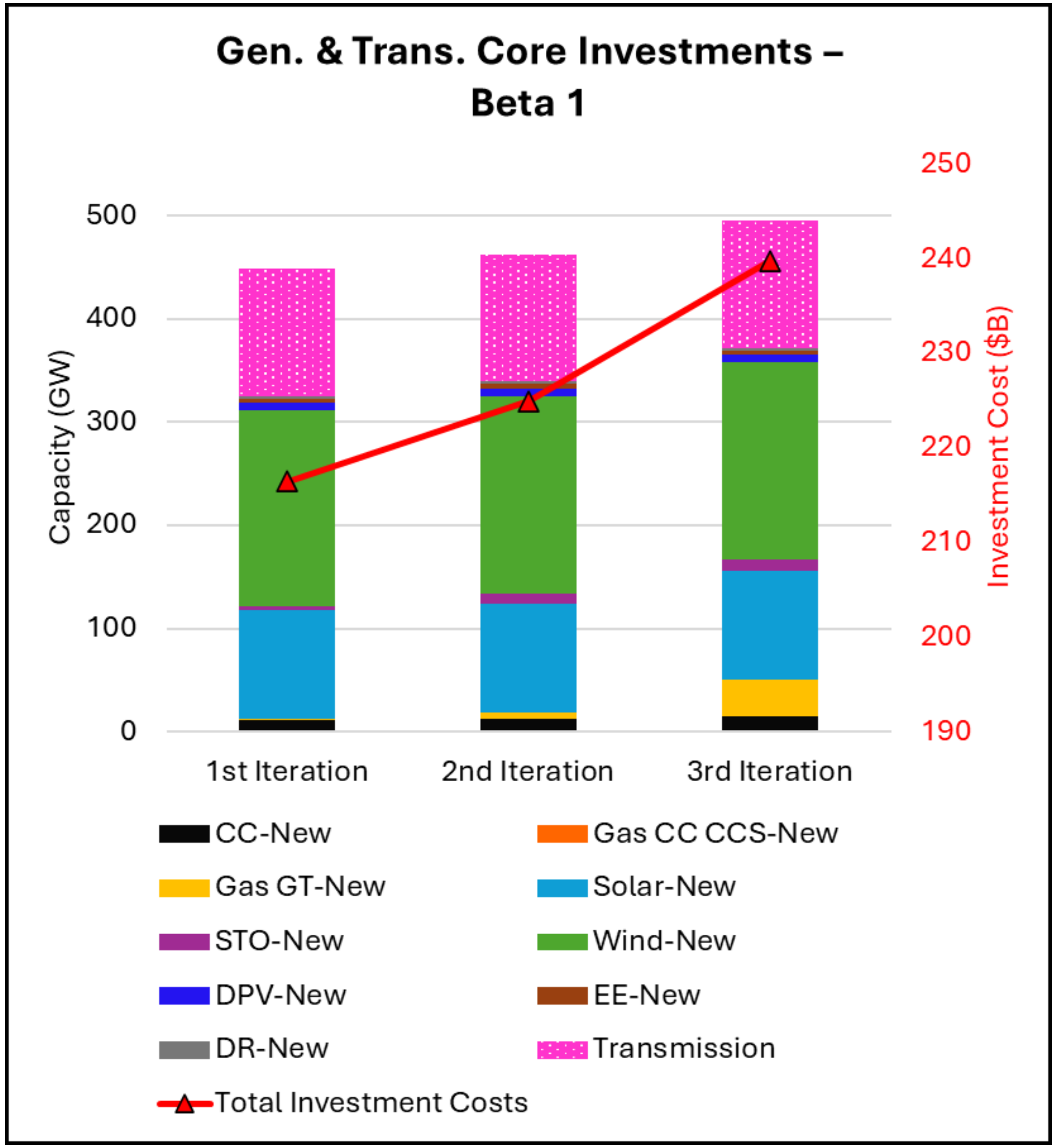
Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	0.2	0.2	0.2	0.2	0.2	0.2	0.2	16.8	20.8	30.3	20.8	20.8	20.8	20.8	47.6	134.3	81.1	67.7	68.1	67.5	69.0	80.3	116.0	51.3	116.4	116.5	116.5	115.0
MISO South	2.6	3.7	4.2	3.8	3.8	3.8	3.8	11.8	24.9	29.6	24.8	24.8	24.9	24.8	27.4	67.7	86.3	63.3	63.4	63.3	63.5	55.9	91.1	59.3	91.2	89.2	91.2	90.8

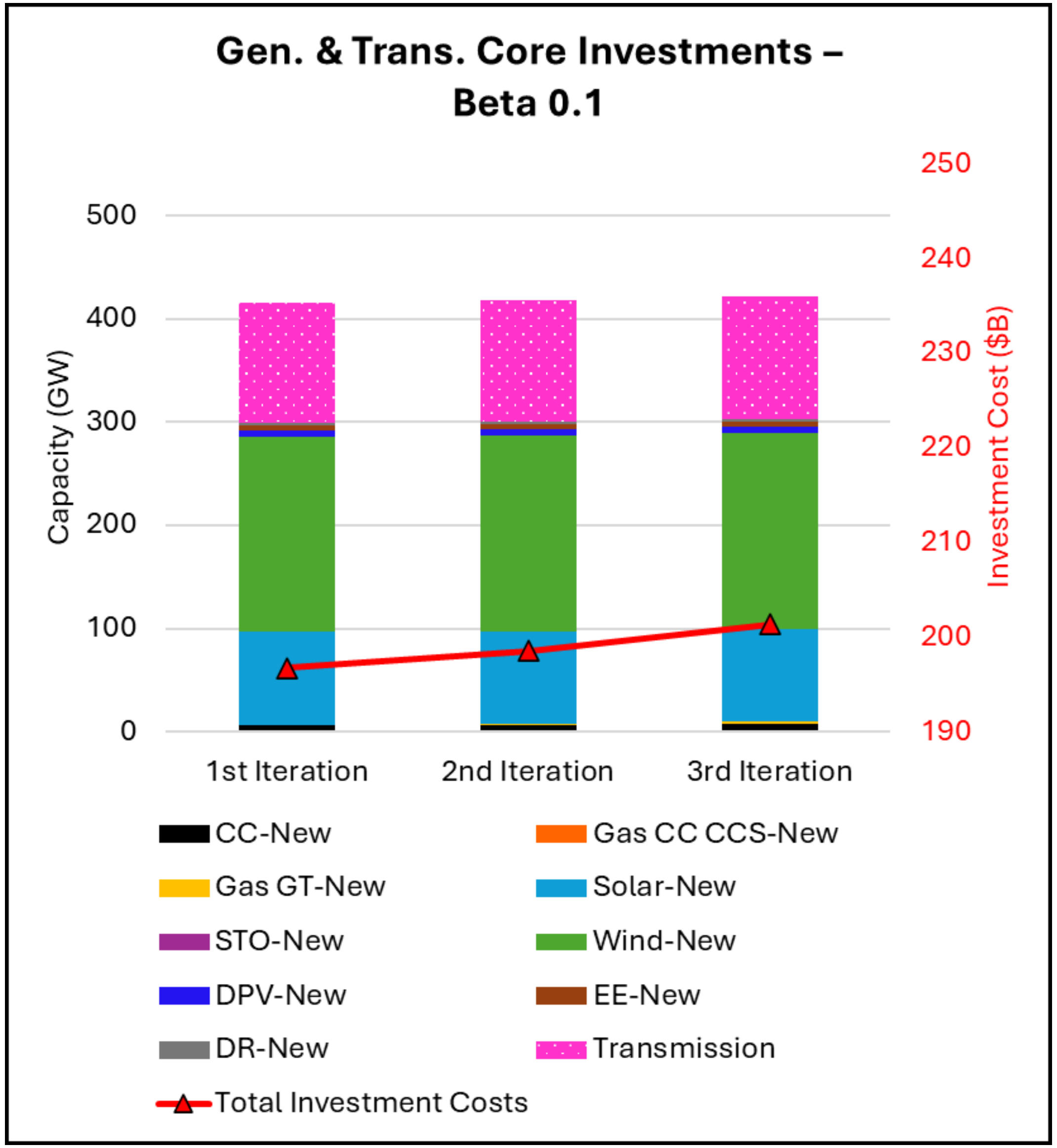
3rd Iteration

Area/Year-Future	2026							2032							2038							2044						
	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7	F1	F2	F3	F4	F5	F6	F7
MISO North/Central	0.1	0.1	0.1	0.1	0.1	0.1	0.1	4.2	6.6	6.0	7.1	7.1	7.1	7.1	0.8	0.0	2.8	2.4	2.3	2.4	2.4	4.0	0.3	0.4	0.3	0.3	0.5	0.4
MISO South	2.1	3.0	2.8	3.0	3.0	3.0	3.0	3.4	10.7	10.9	10.8	10.8	10.8	10.8	7.5	15.5	3.1	21.2	20.9	21.1	21.3	7.6	4.4	34.0	1.8	1.7	2.4	2.3

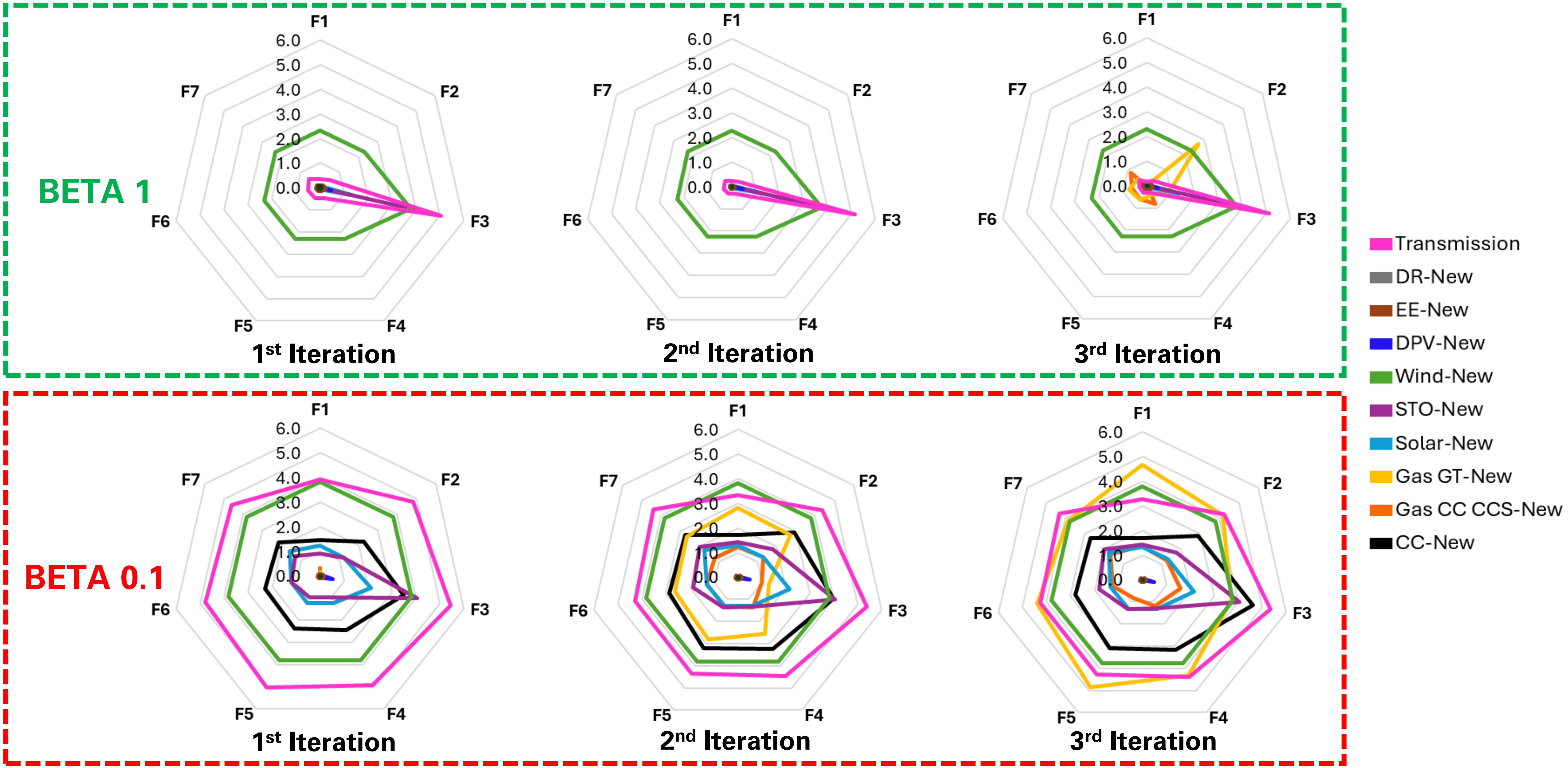

Planning Reserve Margin – MISO North/Central– 1st Iteration
100%
50%
0%
F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7
2026 2032 2038 2044
1
LOLE (days/yr) – MISO North/Central– 1st Iteration
200.0
150.0
100.0
50.0
0.0
F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7
2026 2032 2038 2044
2
Planning Reserve Margin – MISO North/Central– 2nd Iteration
100%
50%
0%
F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7
2026 2032 2038 2044
3
LOLE (days/yr) – MISO North/Central– 2nd Iteration
200.0
150.0
100.0
50.0
0.0
F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7
2026 2032 2038 2044
4
Planning Reserve Margin – MISO North/Central– 3rd Iteration
100%
50%
0%
F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7
2026 2032 2038 2044
5
LOLE (days/yr) – MISO North/Central– 3rd Iteration
200.0
150.0
100.0
50.0
0.0
F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7 F1 F2 F3 F4 F5 F6 F7
2026 2032 2038 2044

Core Investment Comparison

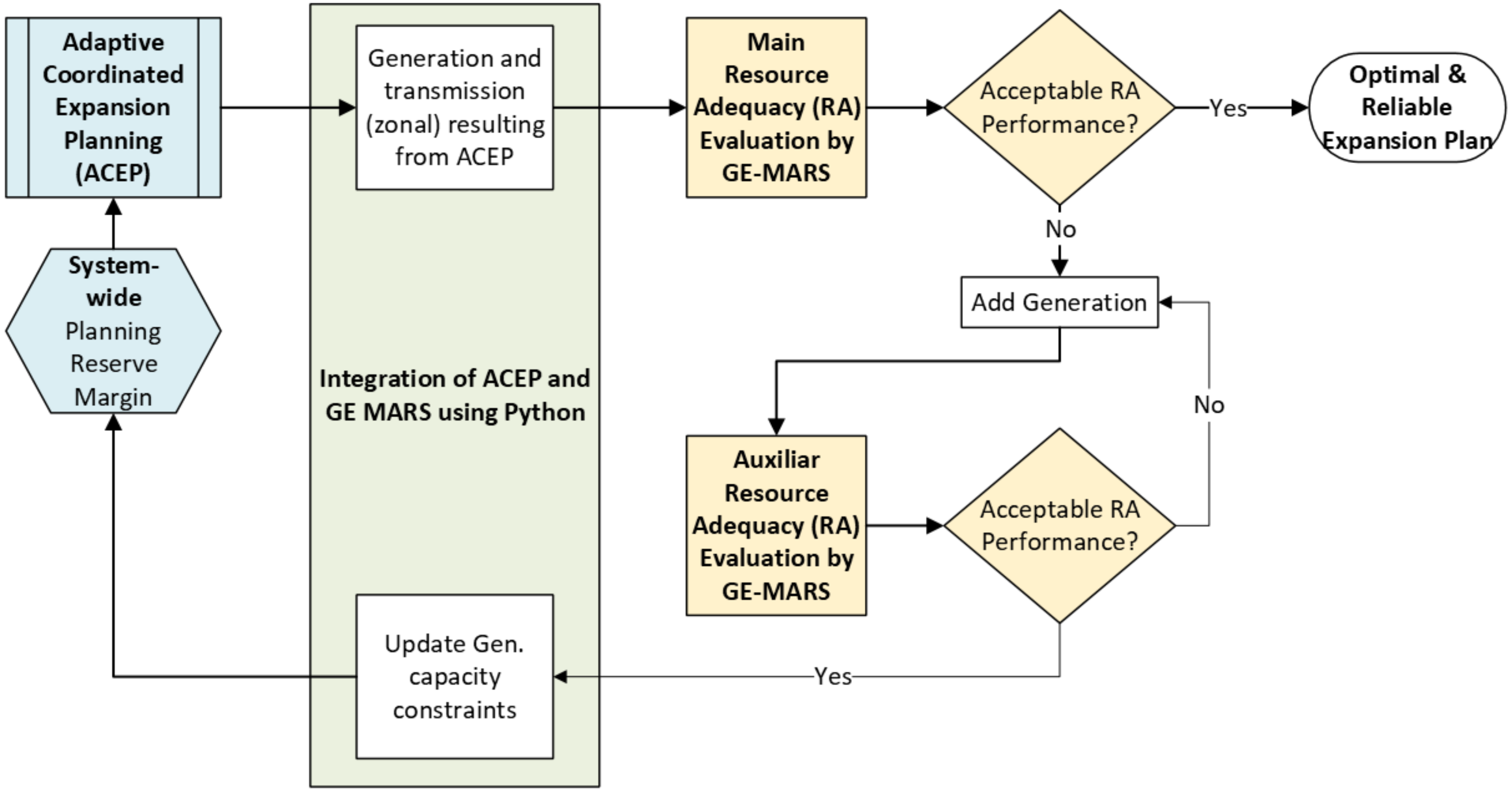




Adaptation Comparison - Time-Averaged Adaptation Investments (GW)



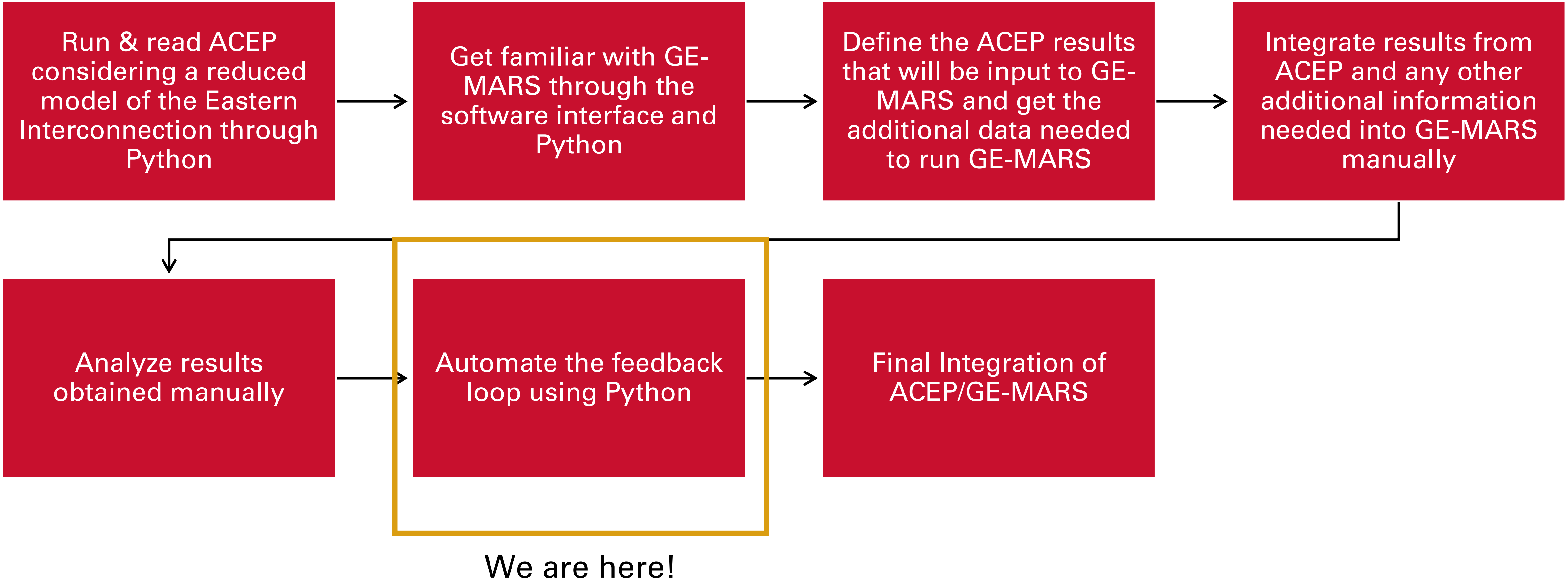
Integration of ACEP with GE-MARS: Next steps



$$\sum_{i,j} Cap_{i,j,t,\mathbf{w}} \geq (1+r)\sum_{i} \tilde{\mathbf{d}}_{i,\text{peak},t,\mathbf{w}}, \ \forall t.$$

- We will proceed with developing a Python code to extract data from ACEP and convert it to the GE-MARS format.
- Run ACEP considering investments in the rest of EI to analyze their impact on MISO's performance.
- Additionally, we will conduct simulations by adjusting the MISO PRM, running ACEP, and analyzing the results in GE-MARS to evaluate the behavior of the proposed loop.

Work Plan for this task



Conclusions

- This work aims to benefit ISO/RTOs by enabling exploration across a full spectrum of investment portfolios under a broader set of performance attributes, including energy cost, reliability, and adaptability.

- The proposed framework enhances the integration of key planning functions, guiding the development of advanced simulation tools that empower ISO/RTOs with superior decision-making capabilities.

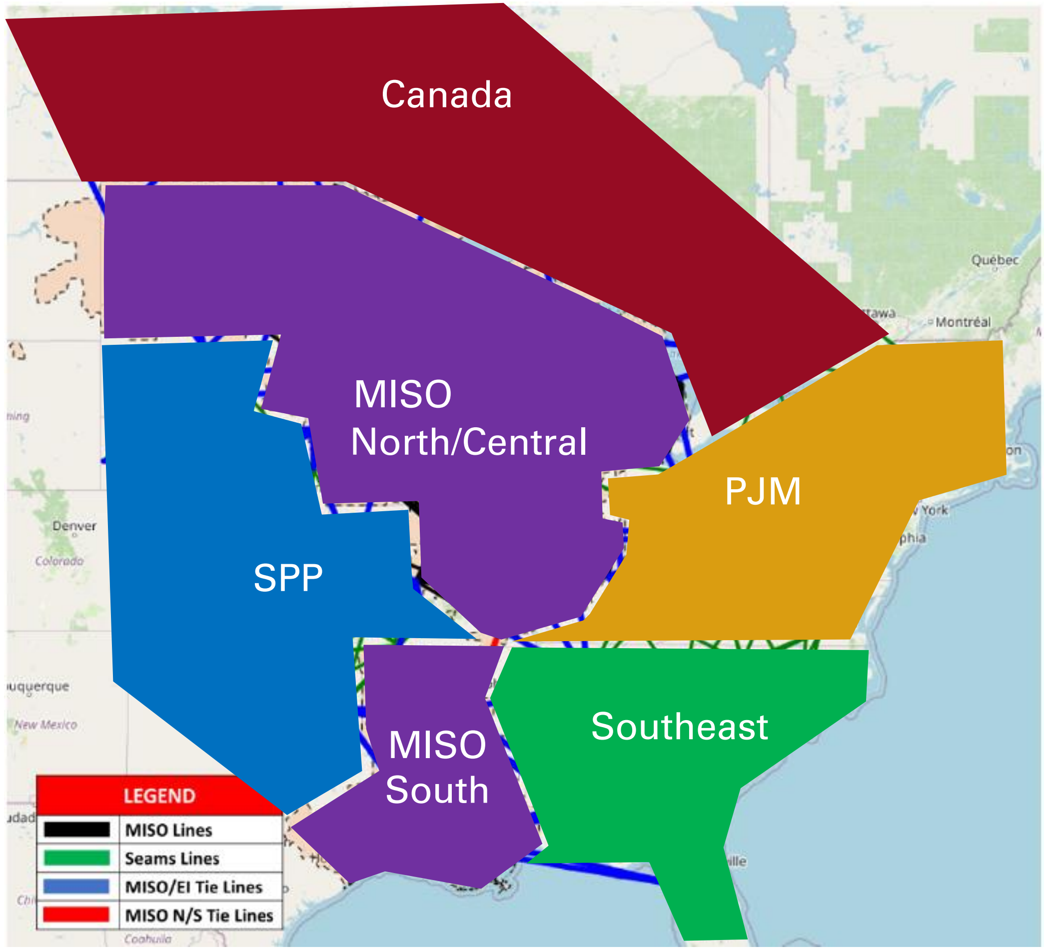
- The integration of ACEP with a resource adequacy assessment is designed to streamline the decision-making process in power system management by incorporating advanced simulation and optimization techniques.

APPENDIX
Further discussion and details about the integration process are provided in the coming slides

ACEP/GE-MARS Integration – Code Structure using Python

- Read ACEP input data (Excel) - DONE
- Create ACEP (GAMS) files and run ACEP - DONE
- Read ACEP results - DONE
- Create multiple dataframes (GE-MARS format) based on ACEP results - DONE
- Read additional GE-MARS input (Excel) - DONE
- Create GE-MARS files to run the RA simulation - DONE
- Run GE-MARS - DONE
- Read results from GE-MARS
- Check LOLE values
- Adjust PRM values in ACEP based on LOLE results obtained from GE-MARS
- Rerun ACEP and repeat steps until LOLE<0.1 days/yr is satisfied for each future, area, and year

Resource Adequacy Assessment – Topology and Transfer Capabilities



- **Fixed** transmission limits between areas as in ACEP.

Interface	AreaFrom	AreaTo	PositiveRating (GW)	NegativeRating (GW)
Interf_1	MISO_NCA	MISO_SA	2.50	1.50
Interf_2	MISO_NCA	CA_A	1.29	3.78
Interf_3	MISO_NCA	SE_A	3.80	1.75
Interf_4	MISO_NCA	PJM_A	5.10	7.05
Interf_5	MISO_NCA	SPP_A	2.80	3.78
Interf_6	MISO_SA	SE_A	2.13	2.65
Interf_7	MISO_SA	SPP_A	0.34	0.88
Interf_8	PJM_A	SE_A	41.29	41.29
Interf_9	PJM_A	CA_A	11.96	11.96

- Values obtained from ACEP input data.

Resource Adequacy Assessment – Demand

- In ACEP, the demand data is entered by bus, year, and season.
- GE-MARS requires **annual peak and energy values per area**, as well as the load shape (hourly load for 1 year) per area.
- The tables show some of the data used in GE-MARS.
- The demand of buses in the same area was aggregated to obtained the demand as needed in GE-MARS.

Time	MISO_NCA	MISO_SA	SPP_A	PJM_A	SE_A	CA_A
1/1/2018 0:00	73265.0	13761.0	24641.7	119655.4	85379.6	20118.6
1/1/2018 1:00	72262.3	13572.7	20351.2	116353.3	83782.3	19182.3
1/1/2018 2:00	71677.2	13462.8	20070.7	113190.2	82013.3	18614.7
1/1/2018 3:00	71418.7	13414.3	19862.3	110522.8	81267.7	18167.0
1/1/2018 4:00	71619.9	13452.1	19867.7	109672.4	81279.8	17791.8
1/1/2018 5:00	72178.9	13557.1	20143.3	110114.9	82642.9	17642.6
1/1/2018 6:00	73569.7	13818.3	20680.9	112301.9	85057.1	17676.8
1/1/2018 7:00	75033.7	14093.3	21462.3	115158.7	87704.2	18089.2
1/1/2018 8:00	75904.2	14256.8	22204.2	117733.0	91005.1	18471.5
1/1/2018 9:00	76780.6	14421.4	22611.0	119852.0	92298.9	18895.2
1/1/2018 10:00	77452.4	14547.6	22751.2	122237.9	91285.1	19483.9
1/1/2018 11:00	77337.9	14526.1	22520.7	124036.9	90251.0	20065.7
1/1/2018 12:00	76492.7	14367.3	22293.5	125218.3	90167.1	20671.0

Year	Area	Peak	Energy
2025	MISO_NCA	98,744.0	554,671,261.0
2031	MISO_NCA	105,693.5	597,593,487.3
2037	MISO_NCA	113,132.2	643,837,172.1
2043	MISO_NCA	121,094.3	693,659,340.2
2049	MISO_NCA	129,616.9	747,336,906.2
2025	MISO_SA	34,718.0	195,020,255.2
2031	MISO_SA	37,161.4	210,111,542.8
2037	MISO_SA	39,776.8	226,370,642.2
2043	MISO_SA	42,576.3	243,887,922.5
2049	MISO_SA	45,572.8	262,760,745.6
2025	SPP_A	55,144.4	270,180,161.3
2031	SPP_A	57,741.6	280,555,180.8
2037	SPP_A	60,461.2	291,328,604.8
2043	SPP_A	63,308.8	302,515,732.4
2049	SPP_A	66,290.5	314,132,449.8
2025	PJM_A	151,257.2	815,134,133.0
2031	PJM_A	158,381.2	846,435,589.1
2037	PJM_A	165,840.7	878,939,032.8
2043	PJM_A	173,651.6	912,690,620.9
2049	PJM_A	181,830.3	947,738,282.7
2025	SE_A	176,291.4	907,365,561.1
2031	SE_A	184,594.5	942,208,738.5
2037	SE_A	193,288.6	978,389,907.1
2043	SE_A	202,392.3	1,015,960,446.0
2049	SE_A	211,924.6	1,054,973,707.8
2025	CA_A	61,157.8	201,783,946.4
2031	CA_A	64,038.3	209,532,525.5
2037	CA_A	67,054.4	217,578,653.0
2043	CA_A	70,212.5	225,933,754.8
2049	CA_A	73,519.4	234,609,695.6

Table showing data for a "**Medium" load growth scenario**

Resource Adequacy Assessment – Generation

ACEP model	ACEP Capacity Credit	GE-MARS names (1)	GE-MARS model	Description
Biomass	1	Biomass	TH	Thermal
CC	1	CC	TH	Thermal
Coal ST	1	Coal_ST	TH	Thermal
Gas GT	1	Gas_GT	TH	Thermal
Gas IC	1	Gas_IC	TH	Thermal
Gas ST	1	Gas_ST	TH	Thermal
Nuclear	1	Nuclear	TH	Thermal
Oil GT	1	Oil_GT	TH	Thermal
Oil IC	1	Oil_IC	TH	Thermal
Oil ST	1	Oil_ST	TH	Thermal
Waste	1	Waste	TH	Thermal
CC-New	1	CC_N	TH	Thermal
Gas CC CCS-New	1	CC_CCS_N	TH	Thermal
Gas GT-New	1	Gas_GT_N	TH	Thermal
Hydro	1	Hydro	EL2	Energy Limited Unit (Type 2): Unit with specified capacity and available monthly energy scheduled deterministically.
PS	0	PS	ES	Energy Storage Unit: Unit with specified generating and charging capacity and storage capacity scheduled as needed subject to storage limitations.
Wind	0.4	Wind	DS	Demand Side Hourly Modifier: Each unit specifies a net hourly load modification.
Solar	0.25	Solar	DS	Demand Side Hourly Modifier: Each unit specifies a net hourly load modification.
STO	0.94	STO	ES	Energy Storage Unit: Unit with specified generating and charging capacity and storage capacity scheduled as needed subject to storage limitations.
Wind-New	0.4	Wind	DS	Demand Side Hourly Modifier: Each unit specifies a net hourly load modification.
Solar-New	0.25	Solar	DS	Demand Side Hourly Modifier: Each unit specifies a net hourly load modification.
STO-New	0.94	STO	ES	Energy Storage Unit: Unit with specified generating and charging capacity and storage capacity scheduled as needed subject to storage limitations.
DPV-New	0.4	DPV	DS	Demand Sider Hourly Modifier: Each unit specifies a net hourly load modification.
EE-New	1	EE	EL3	Energy Limited Unit (Type 3): Unit with specified capacity and available monthly energy scheduled as-needed.
DR-New	1	DR	EL3	Energy Limited Unit (Type 3): Unit with specified capacity and available monthly energy scheduled as-needed.

- (1) Name modifications are necessary in GE-MARS due to character count restrictions.

Resource Adequacy Assessment – Generation

FROM ACEP				
ID	Bus	Technology	Year	Capacity (GW)
1	249516	CC	2025	0.959
1	249516	CC	2031	0.959
1	249516	CC	2037	0.529
1	249516	CC	2043	0.529
2	249516	Coal ST	2025	1.76696
2	249516	Coal ST	2031	1.76696
2	249516	Coal ST	2037	1.74265
2	249516	Coal ST	2043	1.6483
3	249516	Gas GT	2025	1.45019
3	249516	Gas GT	2031	0.863313
3	249516	Gas GT	2037	0.755
3	249516	Gas GT	2043	0.755
4	249516	Gas ST	2025	0.74374
4	249516	Gas ST	2031	0.74374
4	249516	Gas ST	2037	0.74374
4	249516	Gas ST	2043	0.74374
5	249516	STO	2025	0.02
5	249516	STO	2031	0.02
5	249516	STO	2037	0.02
5	249516	STO	2043	0.02
6	249516	Wind	2025	0.7345
6	249516	Wind	2031	0.7345
6	249516	Wind	2037	0.7345
6	249516	Wind	2043	0.7345
7	249521	CC	2025	0.5682
7	249521	CC	2031	0.5682
7	249521	CC	2037	0.3456
7	249521	CC	2043	0.3456

→

TO GE-MARS					
Unit	UnitType	SummaryType	Area	Year	Capacity (MW)
U-1	TH	CC	MISO_NCA	2025	959
U-1	TH	CC	MISO_NCA	2031	959
U-1	TH	CC	MISO_NCA	2037	529
U-1	TH	CC	MISO_NCA	2043	529
U-2	TH	Coal_ST	MISO_NCA	2025	1766.96
U-2	TH	Coal_ST	MISO_NCA	2031	1766.96
U-2	TH	Coal_ST	MISO_NCA	2037	1742.65
U-2	TH	Coal_ST	MISO_NCA	2043	1648.3
U-3	TH	Gas_GT	MISO_NCA	2025	1450.19
U-3	TH	Gas_GT	MISO_NCA	2031	863.313
U-3	TH	Gas_GT	MISO_NCA	2037	755
U-3	TH	Gas_GT	MISO_NCA	2043	755
U-4	TH	Gas_ST	MISO_NCA	2025	743.74
U-4	TH	Gas_ST	MISO_NCA	2031	743.74
U-4	TH	Gas_ST	MISO_NCA	2037	743.74
U-4	TH	Gas_ST	MISO_NCA	2043	743.74
U-5	ES	STO	MISO_NCA	2025	20
U-5	ES	STO	MISO_NCA	2031	20
U-5	ES	STO	MISO_NCA	2037	20
U-5	ES	STO	MISO_NCA	2043	20
U-6	DS	Wind	MISO_NCA	2025	734.5
U-6	DS	Wind	MISO_NCA	2031	734.5
U-6	DS	Wind	MISO_NCA	2037	734.5
U-6	DS	Wind	MISO_NCA	2043	734.5
U-7	TH	CC	MISO_NCA	2025	568.2
U-7	TH	CC	MISO_NCA	2031	568.2
U-7	TH	CC	MISO_NCA	2037	345.6
U-7	TH	CC	MISO_NCA	2043	345.6

- The generation data (existing + core + adaptation - retirements) for each future are obtained from the variable Gen_Build_ALL.
- Periods of study: 2025, 2031, 2037, 2043, and 2049
- The table shows a section of this data and illustrates how it is converted to the GE-MARS format.

Resource Adequacy Assessment – Generation (Thermal Defaults)

Summary Type	Description	Forced Outage Rate	Number Transitions	Planned Outage Rate (2)	Details
Biomass	Biomass	0.0904 **(1)**	2	0.1142	Biomass
CC	CC	0.0585 **(1)**	2	0.0863	Combined Cycle
Coal_ST	Coal ST	0.0904 **(1)**	2	0.1285	Conventional Steam Coal
Gas_GT	Gas GT	0.0593	2	0.0602	Natural Gas Combustion Turbine
Gas_IC	Gas IC	0.0593	2	0.0602	Natural Gas Internal Combustion
Gas_ST	Gas ST	0.1184 **(1)**	2	0.1413	Natural Gas Steam Turbine
Nuclear	Nuclear	0.0295	2	0.0637	Nuclear
Oil_GT	Oil GT	0.0511	2	0.0602	Oil-fueled Combustion Turbine
Oil_IC	Oil IC	0.0511	2	0.0400	Oil-fueled Internal Combustion
Oil_ST	Oil ST	0.0511	2	0.1393	Oil-fueled Steam Turbine
Waste	Waste	0.0904	2	0.1142	Waste-to-energy plants
CC_N	CC - New	0.0585 **(1)**	2	0.0863	New Combined Cycle
CC_CCS_N	Gas CC CCS - New	0.0511	2	0.0863	New Natural Gas Combined Cycle with Sequestration
Gas_GT_N	Gas GT - New	0.0593	2	0.0602	New Natural Gas Combustion Turbine

(1) Values updated according to the MISO 2022-2023 LOLE Study Report.
(2) Values obtained from the GE-MARS training data.

- FOR and POR are simplified values that do not consider the size of plants (capacity).
- FOR are considered the same for both existing units and new units.
- MISO uses FOR and POR values for each unit.
- Values in this table are critical in reliability indices calculation.

Resource Adequacy Assessment – Generation (Thermal Units)

- This table shows a section of the data used in GE-MARS to model Thermal Units.

Unit	Unit Type	Summary Type	Area	InstallDate	RetireDate	Cap 2025 (MW)	Cap 2031 (MW)	Cap 2037 (MW)	Cap 2043 (MW)	Cap 2049 (MW)	2031 OverrideDate	2037 OverrideDate	2043 OverrideDate	2049 OverrideDate
U-1	TH	CC	MISO_NCA	1/1/2000	12/12/2100	959	959	529	529	529	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-2	TH	Coal_ST	MISO_NCA	1/1/2000	12/12/2100	1766.96	1766.96	1742.65	1648.3	1648.3	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-3	TH	Gas_GT	MISO_NCA	1/1/2000	12/12/2100	1450.19	863.313	755	755	755	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-4	TH	Gas_ST	MISO_NCA	1/1/2000	12/12/2100	743.74	743.74	743.74	743.74	743.74	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-7	TH	CC	MISO_NCA	1/1/2000	12/12/2100	568.2	568.2	345.6	345.6	345.6	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-8	TH	Coal_ST	MISO_NCA	1/1/2000	12/12/2100	4458.01	4458.01	4377.11	3883.5	3883.5	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-9	TH	Gas_GT	MISO_NCA	1/1/2000	12/12/2100	501.7	354.54	337.95	337.95	337.95	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-10	TH	Coal_ST	MISO_NCA	1/1/2000	12/12/2100	297.731	297.731	243	221.5	221.5	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-11	TH	Gas_GT	MISO_NCA	1/1/2000	12/12/2100	500	499.932	260.5	260.5	260.5	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-13	TH	CC	MISO_NCA	1/1/2000	12/12/2100	538.8	538.8	388.8	388.8	388.8	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-14	TH	Coal_ST	MISO_NCA	1/1/2000	12/12/2100	1339.03	1339.03	1223.63	1191.5	1191.5	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-15	TH	Gas_GT	MISO_NCA	1/1/2000	12/12/2100	25.4	25.4	20	20	20	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-17	TH	Coal_ST	MISO_NCA	1/1/2000	12/12/2100	1505.52	1505.52	783.716	783.5	783.5	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-18	TH	Gas_GT	MISO_NCA	1/1/2000	12/12/2100	136	136	136	136	136	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-19	TH	Coal_ST	MISO_NCA	1/1/2000	12/12/2100	1140.4	1140.4	644.502	631	631	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-20	TH	CC	MISO_NCA	1/1/2000	12/12/2100	72.7	72.7	40.1537	40.1537	40.1537	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-21	TH	Coal_ST	MISO_NCA	1/1/2000	12/12/2100	94.9	94.9	92.111	47.45	47.45	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-22	TH	Gas_GT	MISO_NCA	1/1/2000	12/12/2100	86.5	82.745	81.4493	81.4	81.4	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-23	TH	Gas_IC	MISO_NCA	1/1/2000	12/12/2100	24	24	24	24	24	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-26	TH	Waste	MISO_NCA	1/1/2000	12/12/2100	42.74	42.74	42.74	42.74	42.74	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-27	TH	Biomass	MISO_NCA	1/1/2000	12/12/2100	53	53	53	53	53	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-28	TH	CC	MISO_NCA	1/1/2000	12/12/2100	123	123	77.1066	77	77	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-29	TH	Coal_ST	MISO_NCA	1/1/2000	12/12/2100	60	60	60	60	60	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-30	TH	Gas_GT	MISO_NCA	1/1/2000	12/12/2100	129.45	72.731	71.45	71.45	71.45	1/1/2031	1/1/2037	1/1/2043	1/1/2049

Resource Adequacy Assessment – Generation (Wind and Solar)

- Below is a section of the data used in GE-MARS to model Wind and Solar.

- For now, wind and solar profiles per area from GE-MARS training data are being used while a better calculation method for these values is being developed.

Unit	Unit Type	Summary Type	Area	Shape	Install Date	Retire Date	Cap 2025 (MW)	Cap 2031 (MW)	Cap 2037 (MW)	Cap 2043 (MW)	Cap 2049 (MW)	2025 Factor	2031 Factor	2037 Factor	2043 Factor	2049 Factor	2031 Override Date	2037 Override Date	2043 Override Date	2049 Override Date
U-54	DS	Solar	MISO_NCA	S_MISO_N	1/1/2000	12/12/2100	100	100	100	100	100	0.1	0.1	0.1	0.1	0.1	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-62	DS	Solar	MISO_NCA	S_MISO_N	1/1/2000	12/12/2100	50	50	50	50	50	0.05	0.05	0.05	0.05	0.05	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-108	DS	Solar	MISO_SA	S_MISO_S	1/1/2000	12/12/2100	52	52	52	52	52	0.052	0.052	0.052	0.052	0.052	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-127	DS	Solar	MISO_SA	S_MISO_S	1/1/2000	12/12/2100	81	81	81	81	81	0.081	0.081	0.081	0.081	0.081	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-130	DS	Solar	MISO_NCA	S_MISO_N	1/1/2000	12/12/2100	5.7	5.7	5.7	5.7	5.7	0.0057	0.0057	0.0057	0.0057	0.0057	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-201	DS	Solar	MISO_NCA	S_MISO_N	1/1/2000	12/12/2100	1	1	1	1	1	0.001	0.001	0.001	0.001	0.001	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-214	DS	Solar	MISO_NCA	S_MISO_N	1/1/2000	12/12/2100	62	62	62	62	62	0.062	0.062	0.062	0.062	0.062	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-481	DS	Solar	PJM_A	S_PJM	1/1/2000	12/12/2100	11559	11559	11559	11559	11559	11.5597	11.5597	11.5597	11.559	11.559	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-493	DS	Solar	SE_A	S_SE	1/1/2000	12/12/2100	1993.5	1993.5	1993.5	1993.5	1993.5	1.9935	1.9935	1.9935	1.9935	1.9935	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-512	DS	Solar	SE_A	S_SE	1/1/2000	12/12/2100	1975.6	1975.6	1975.6	1975.6	1975.6	1.9756	1.9756	1.9756	1.9756	1.9756	1/1/2031	1/1/2037	1/1/2043	1/1/2049

Resource Adequacy Assessment – Generation (Hydro, DR, and EE)

- These tables show sections of the data used in GE-MARS to model Hydro, DR, and EE.

Unit	Unit Type	Summary Type	Area	Install Date	Retire Date	Cap 2025 (MW)	Cap 2031 (MW)	Cap 2037 (MW)	Cap 2043 (MW)	Cap 2049 (MW)	2031 Override Date	2037 Override Date	2043 Override Date	2049 Override Date
U-12	EL2	Hydro	MISO_NCA	1/1/2000	12/12/2100	144.00	144.00	144.00	72.00	72.00	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-24	EL2	Hydro	MISO_NCA	1/1/2000	12/12/2100	53.30	53.30	53.30	26.65	26.65	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-31	EL2	Hydro	MISO_NCA	1/1/2000	12/12/2100	27.93	27.93	27.93	13.97	13.97	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-36	EL2	Hydro	MISO_NCA	1/1/2000	12/12/2100	39.77	39.77	39.77	19.89	19.89	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-44	EL2	Hydro	MISO_NCA	1/1/2000	12/12/2100	4.96	4.96	4.96	2.48	2.48	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-1778	EL3	DR	MISO_NCA	1/1/2000	12/12/2100	0.00	0.00	0.00	0.68	0.68	1/1/2031	1/1/2037	1/1/2043	1/1/2049
U-1633	EL3	EE	MISO_SA	1/1/2000	12/12/2100	0.00	0.00	0.00	40.22	40.22	1/1/2031	1/1/2037	1/1/2043	1/1/2049

Resource Adequacy Assessment – Generation (Hydro, DR, and EE)

- **Capacity and available monthly energy** are required in GE-MARS to model Energy Limited Units.
- Currently, we are considering **20 hours** per day for Hydro units and **5 hours** per day for DR (Demand Response) and EE (Energy Efficiency) units.

Hydro Units modeling:

Month	Year	Date	Unit	MinRating	MaxRating	Energy	DaysPerYear	HoursPerDay	EnergyPerDay
JAN	2025	JAN2025	U-12	0.00	144.00	103680.00	8760	20	2880
JAN	2031	JAN2031	U-12	0.00	144.00	103680.00	8760	20	2880
JAN	2037	JAN2037	U-12	0.00	144.00	103680.00	8760	20	2880
JAN	2043	JAN2043	U-12	0.00	72.00	51840.00	8760	20	1440
JAN	2049	JAN2049	U-12	0.00	72.00	51840.00	8760	20	1440

DR and EE modeling:

Month	Year	Date	Unit	MinRating	MaxRating	Energy	DaysPerYear	HoursPerDay	EnergyPerDay
JAN	2025	JAN2025	U-1760	0.00	0.00	0.00	8760	5	0
JAN	2031	JAN2031	U-1760	0.00	0.00	0.00	8760	5	0
JAN	2037	JAN2037	U-1760	0.00	0.00	0.00	8760	5	0
JAN	2043	JAN2043	U-1760	0.00	0.00	0.00	8760	5	0
JAN	2049	JAN2049	U-1760	0.00	0.00	0.00	8760	5	0

Resource Adequacy Assessment – Generation (Storage)

- **Capacity, duration and efficiency** are required in GE-MARS to model Energy Storage Units.
- Currently, we are considering **4 hours** as the duration and **0.85 as the efficiency** of all storage units.
- GE-MARS has a **limit** to model **up to 100 energy storage units**. ACEP is currently considering 222 units.

Unit	Unit Type	Summary Type	Area	Install Date	Retire Date	Cap 2025 (MW)	Cap 2031 (MW)	Cap 2037 (MW)	Cap 2043 (MW)	Cap 2049 (MW)	2031 Override Date	2037 Override Date	2043 Override Date	2049 Override Date	Storage Duration (hrs)	2025 Storage	2031 Storage	2037 Storage	2043 Storage	2049 Storage	Efficiency
U-5	ES	STO	MISO_NCA	1/1/2000	12/12/2100	20.00	20.00	20.00	20.00	20.00	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	80	80	80	80	80	0.85
U-25	ES	STO	MISO_NCA	1/1/2000	12/12/2100	1.10	1.10	1.10	1.10	1.10	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	4.4	4.4	4.4	4.4	4.4	0.85
U-102	ES	STO	MISO_SA	1/1/2000	12/12/2100	0.50	0.50	0.50	0.50	0.50	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	2	2	2	2	2	0.85
U-148	ES	STO	MISO_NCA	1/1/2000	12/12/2100	7.00	7.00	7.00	7.00	7.00	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	28	28	28	28	28	0.85
U-164	ES	STO	MISO_NCA	1/1/2000	12/12/2100	0.30	0.30	0.30	0.30	0.30	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	1.2	1.2	1.2	1.2	1.2	0.85
U-215	ES	STO	MISO_NCA	1/1/2000	12/12/2100	1.10	1.10	1.10	1.10	1.10	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	4.4	4.4	4.4	4.4	4.4	0.85
U-223	ES	STO	MISO_NCA	1/1/2000	12/12/2100	12.00	12.00	12.00	12.00	12.00	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	48	48	48	48	48	0.85
U-278	ES	STO	MISO_NCA	1/1/2000	12/12/2100	1.10	1.10	1.10	1.10	1.10	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	4.4	4.4	4.4	4.4	4.4	0.85
U-1274	ES	STO	MISO_NCA	1/1/2000	12/12/2100	0.00	32.83	32.83	32.83	32.83	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	0	131.3144	131.3144	131.3144	131.3144	0.85
U-1275	ES	STO	MISO_NCA	1/1/2000	12/12/2100	0.00	18.52	18.52	18.52	18.52	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	0	74.0936	74.0936	74.0936	74.0936	0.85
U-1276	ES	STO	MISO_NCA	1/1/2000	12/12/2100	0.00	38.53	38.53	38.53	38.53	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	0	154.1096	154.1096	154.1096	154.1096	0.85
U-1277	ES	STO	MISO_NCA	1/1/2000	12/12/2100	0.00	0.00	0.00	0.00	0.00	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	0	0	0	0	0	0.85
U-1278	ES	STO	MISO_NCA	1/1/2000	12/12/2100	0.00	36.15	36.15	36.15	36.15	1/1/2031	1/1/2037	1/1/2043	1/1/2049	4.0	0	144.5944	144.5944	144.5944	144.5944	0.85

Resource Adequacy Assessment – Main findings, questions, and challenges

ACEP:

1. In this initial simulation, ACEP focused its investments on MISO and neglected the rest of the EI, resulting in high LOLE in SPP and Canada. Consequently, MISO is not receiving external support. To address this issue, we can consider implementing new "investments" in the external grid within ACEP to incorporate external support to MISO in GE-MARS, similar to MISO LOLE studies.
2. Another scenario would involve evaluating the impact of allowing interregional transmission investment. How would this affect the RA indices?...
3. Modify the formulation in ACEP by splitting the system-wide PRM constraint into two separate constraints: one for the North/Central area and another for the South area. DONE
4. Update the data considering a planning horizon from 2025 to 2050. DONE
5. ACEP data should be calibrated to be consistent with MISO’s data. DONE

Resource Adequacy Assessment – Main findings, questions, and challenges

GE-MARS:

1. Hourly solar and wind profiles for each area over a year are needed to model solar and wind units accurately. DONE for solar. This can be improved later.

2. FOR and POR values of thermal units should be revised.

Resource Adequacy Assessment – Main findings, questions, and challenges

GE-MARS/ACEP:

1. 122 storage units were not modeled in GE-MARS due to software limitations, which restrict modeling up to 100 units. Two solutions can be implemented: 1) restrict ACEP to model only 100 storage units, or 2) aggregate storage units in GE-MARS. Option 2 has been used so far.

2. An improved method for calculating the monthly available energy of energy-limited units is needed to keep consistency between ACEP and GE-MARS.

3. Maximum transfer limits between areas should be revised.

4. Should we consider the impact of changing capacity credit values over the 20-year study period in our simulations?

Resource Adequacy Assessment – Main findings, questions, and challenges

Main question:

What is the most efficient method for adjusting the PRM on ACEP to achieve the desired level of RA in GE-MARS?

Integration of ACEP with GE-MARS: Integration interface

- Python codes for running ACEP and GE-MARS using python.

```python
import os
import sys
sys.path.append(r'C:\Users\alij\portables\GAMS\41\apifiles\Python\api_310')
sys.path.append(r'C:\Users\alij\portables\GAMS\41\apifiles\Python\gams')

import gams
import gamstransfer as gt


def writing_gdx(ws, data, gdxfile):
    """write a dictioanry of dataframes to a gdxfile"""
    # create empty gdx container
    gdx = gt.GdxContainer(ws.system_directory)
    gdx.rgdx()
    gdx.validate(data)
    std_data = gdx.standardize(data)
    gdx.add_to_gdx(std_data, standardize_data=True, inplace=True)
    gdx.write_gdx(gdxfile)
    return


def read_gdx(ws, gdxfile):
    rdgdx = gt.Container( gdxfile, ws.system_directory)
    df = rdgdx.data
    return df

gamsdir = r"C:\Users\alij\portables\GAMS\41"
ws = gams.GamsWorkspace( working_directory=os.getcwd(), system_directory=gamsdir, debug=0)
opt = ws.add_options()
opt.optfile = 1

# run Gams from Python
print("running CEP round {0}".format(i))
tt0 = time.time()
t1 = ws.add_job_from_file(r"CEPAllReserve.gms")
t1.run(opt)
tt1 = time.time()
print("CEP done in {0} seconds.".format(tt1 - tt0))

df = read_gdx('Ali_p.gdx')


# manipulate the results and data input


# write_gdx()



import ipdb; ipdb.set_trace()

```

```python
# -*- coding: utf-8 -*-
"""
Created on Wed Jun 21 16:31:02 2023

Running MARS with SNAPPY

@author: gcuello
"""

import snappy
import os

#%% MARS license files
LICENSE_LOC = r'C:\Users\gcuello\Box\ISU\Research\GE-MARS\2-InstallationFiles\7-LicenseFile\MARS-LIC'
MARS_EXE_LOC = r'C:\Users\gcuello\Box\ISU\Research\GE-MARS\Results\Binaries\MARS\MARS-4.12.2091-win64\mars\mars-4.12.2091.exe'
MARS_OUT_LOC = r'C:\Users\gcuello\Box\ISU\Research\GE-MARS\Results\Binaries\MARS\MARS-4.12.2091-win64\mars\mars-out-4.12.2091.exe'


#%% MIF files
MIF_FILES_LIST = [
    r'C:\Users\gcuello\Box\ISU\Research\GE-MARS\3. Tutorials\February2023MARSTraining\TrainingData\00-MARS_Options.mif',
    r'C:\Users\gcuello\Box\ISU\Research\GE-MARS\3. Tutorials\February2023MARSTraining\TrainingData\01-SystemTopology.mif',
    r'C:\Users\gcuello\Box\ISU\Research\GE-MARS\3. Tutorials\February2023MARSTraining\TrainingData\02-Load_Forecast.mif',
    r'C:\Users\gcuello\Box\ISU\Research\GE-MARS\3. Tutorials\February2023MARSTraining\TrainingData\03-ThermalUnit.mif',
    r'C:\Users\gcuello\Box\ISU\Research\GE-MARS\3. Tutorials\February2023MARSTraining\TrainingData\04-Transmission.mif'
    ]

#%% Load files and Shape files
LOAD_FILES_LIST = [ r'C:\Users\gcuello\Box\ISU\Research\GE-MARS\3. Tutorials\February2023MARSTraining\TrainingData\2006LoadShapes.c
SHAPE_FILES_LIST = []

#%% Conversion relative paths to absolute paths
MIF_FILES_LIST = [os.path.join(os.getcwd(), f) for f in MIF_FILES_LIST]
LOAD_FILES_LIST = [os.path.join(os.getcwd(), f) for f in LOAD_FILES_LIST]
SHAPE_FILES_LIST = [os.path.join(os.getcwd(), f) for f in SHAPE_FILES_LIST]

#%% Name of the job (running)
job = snappy.MARSJob('My first job', 2)

#%% Set general parameters for the job
job.set_mars_executable(MARS_EXE_LOC)
job.set_mars_out_executable(MARS_OUT_LOC)
job.set_mars_license(LICENSE_LOC)
job.set_run_folder (r'C:\Users\gcuello\Box\ISU\Research\GE-MARS\Results\my_first_job')

#%% Add the data needed for the runs
job.add_mif(MIF_FILES_LIST)
job.add_load_shapes(LOAD_FILES_LIST)
job.add_modifier_shapes(SHAPE_FILES_LIST)

#%% Enter the year of the database and the years to be simulated
job.set_year_of_database(2006)
job.add_mars_case(2024, 1, 1) # Run 2024 with 1 replication

#%% Run
os.getcwd()
job.run()
```