



MISO TRANCHE 1

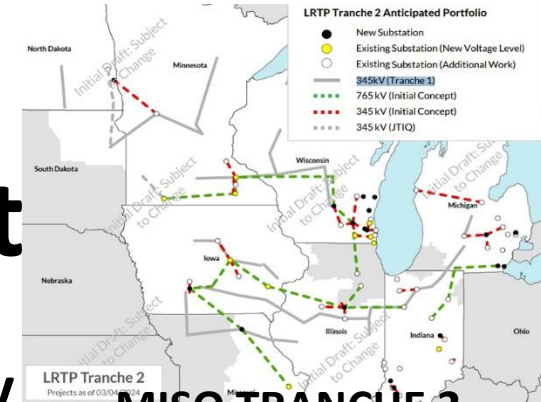
# IOWA STATE UNIVERSITY

## OF SCIENCE AND TECHNOLOGY

# Plan Iowa Energy (PIE) Project

3-Year Project

Funded by the Iowa Economic Development Authority



MISO TRANCHE 2



## Electric Power Forum 2025

EPRC Annual Business Meeting and Conference

Tuesday, May 20, 2025

James McCalley, Iowa State University

Contact info: [jdm@iastate.edu](mailto:jdm@iastate.edu); 515-294-4844

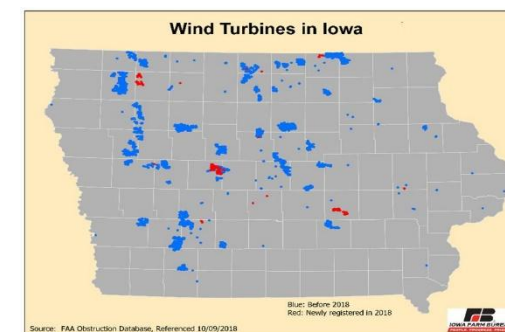
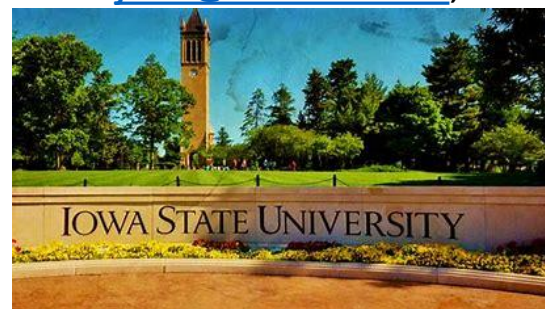


Figure 2: Wind Turbines in Iowa



J. McCalley,  
Distinguished  
Professor



C. Christy,  
Research  
faculty.  
Project Lead



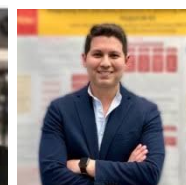
A. Jahanbani,  
Research  
Faculty



Y. Jiang,  
Ph. D.  
Student



A.  
Venkatraman,  
Ph.D. Student



G. Cuello-  
Polo  
Ph.D.  
Student



Z. Parvini  
Ph.D  
Student



C. Phillips  
Ph.D  
Student



D. Ajang  
Ph. D.  
student



E. Goossen,  
MS Student



A. Adam,  
MS  
Student



M. Elnasry,  
PhD Student

# 1. Overview

## 1. **PIE project objective & motivation**

## 2. **Key tools**

- a. Futures development
- b. Model reduction
- c. Adaptive coordinated expansion planning (ACEP)
- d. ACEP with GE-MARS

## 3. **ACEP Results**

- a. 250-bus model, pre-tranche 1: validation, resource adequacy, storage effects/H2+epri rppt
- b. 1800 bus model, post-tranche 1, no 765kV investment options: validation
- c. 2298 bus model, post-tranche 1, w/ 765kV investment options: comparison

## 4. **Ongoing work:**

- a. Additional ACEP features
- b. Resilience studies
- c. Other studies

## 5. **Visions and survey results**

# 1. PIE Project Objective and Motivation

- Objective:
  - Identify several 20-year plans
    - (what, when, where, how much GTD)
    - to position Iowa's low carbon electric infrastructure to perform well
      - under normal and climate-influenced extreme events & conditions.
        - Compare/contrast to RTO/utility plans.
- Why?
  - Energy planning is done for region, for utility areas, but not for **Iowa**.
  - Iowans have different **visions** for what they want.
  - Can we “build in” to our models/analyses ability to handle **uncertainty**?
  - And address **climate change & resilience** in power system planning?
    - Some new technological options of interest:
      - Storage (battery and H<sub>2</sub>)
      - Small modular reactors
      - HVDC
      - Data centers
      - Demand control
      - Small ICE's burning renewable fuels (renewable natural gas, hydrogen, efuels, biofuels)

# Iowa's Energy Visions

## Vision 1 →

Emphasize energy cost

Maintain avg annual R/C/I cost of 12, 10, 6 ¢/kwh (EIA).

Uncertainties
Policies (i.e. emissions, RPS)
Demand growth
Retirements
Fuel price
Technology investment costs

FERC Order 1920

Future 1

Future 2

⋮

Future n-1

Future n

PLAN 1

## Vision 2 →

Emphasize CO<sub>2</sub> reduction

Cut 2038 CO<sub>2</sub> levels by 80% of 2005 levels

Uncertainties
Policies (i.e. emissions, RPS)
Demand growth
Retirements
Fuel price
Technology investment costs

Future 1

Future 2

⋮

Future n-1

Future n

PLAN 2

## Vision 3 →

Emphasize energy export

Produce 2 times in-state electric energy requirements.

Uncertainties
Policies (i.e. emissions, RPS)
Demand growth
Retirements
Fuel price
Technology investment costs

Future 1

Future 2

⋮

Future n-1

Future n

PLAN 3

## Vision 4 →

Emphasize resilience

Reduce extreme event cost of electric outages by 60%.

Uncertainties
Policies (i.e. emissions, RPS)
Demand growth
Retirements
Fuel price
Technology investment costs

Future 1

Future 2

⋮

Future n-1

Future n

PLAN 4

## Vision 5 →

Balanced

Seek a balanced portfolio of above 4 features.

Uncertainties
Policies (i.e. emissions, RPS)
Demand growth
Retirements
Fuel price
Technology investment costs

Future 1

Future 2

⋮

Future n-1

Future n

PLAN 5

### EVALUATE PLANS:

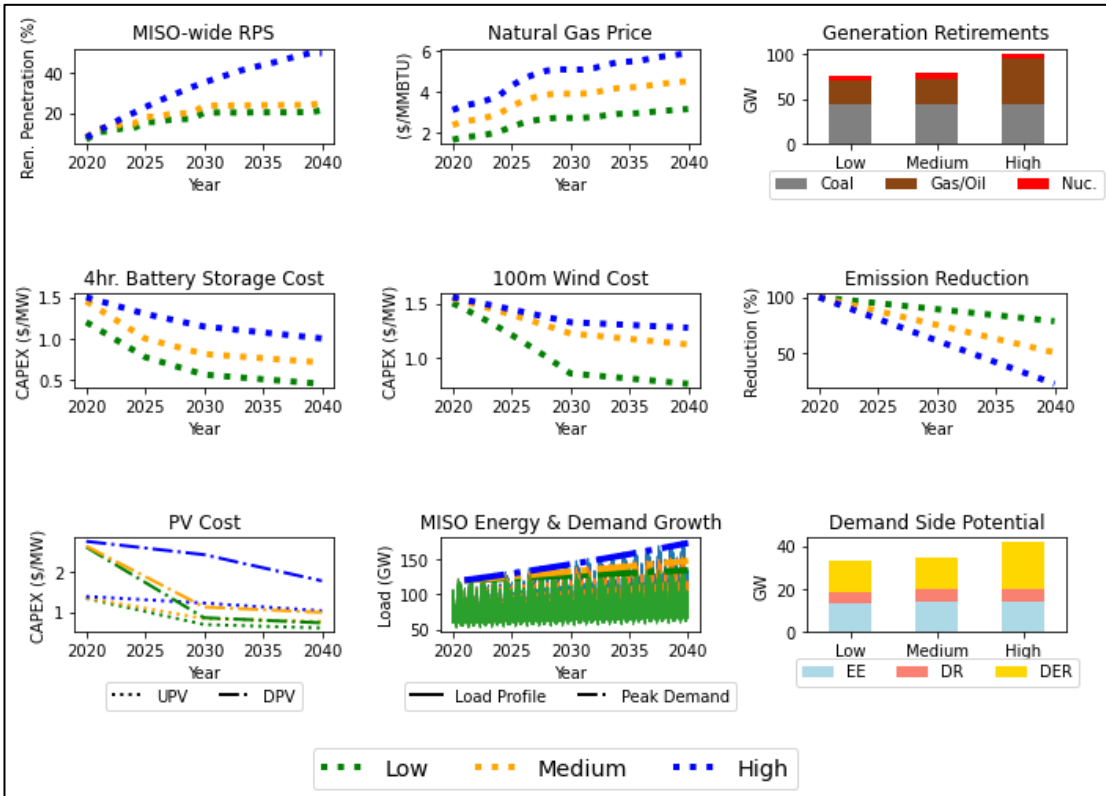
- Reliability
- Investment & Op cost
- Resilience
- Losses
- Congestion costs
- Econ. dvlpmnt impact
- Environmental impact
- Robustness



# 2a. Key tools: futures development

## Uncertainty Characterization

- Adapted from MTEP19 and MTEP21 studies [1],[2]
- MISO evaluates scenarios to bookend uncertainties
- MISO's bookending used to develop low/medium/high values [3]



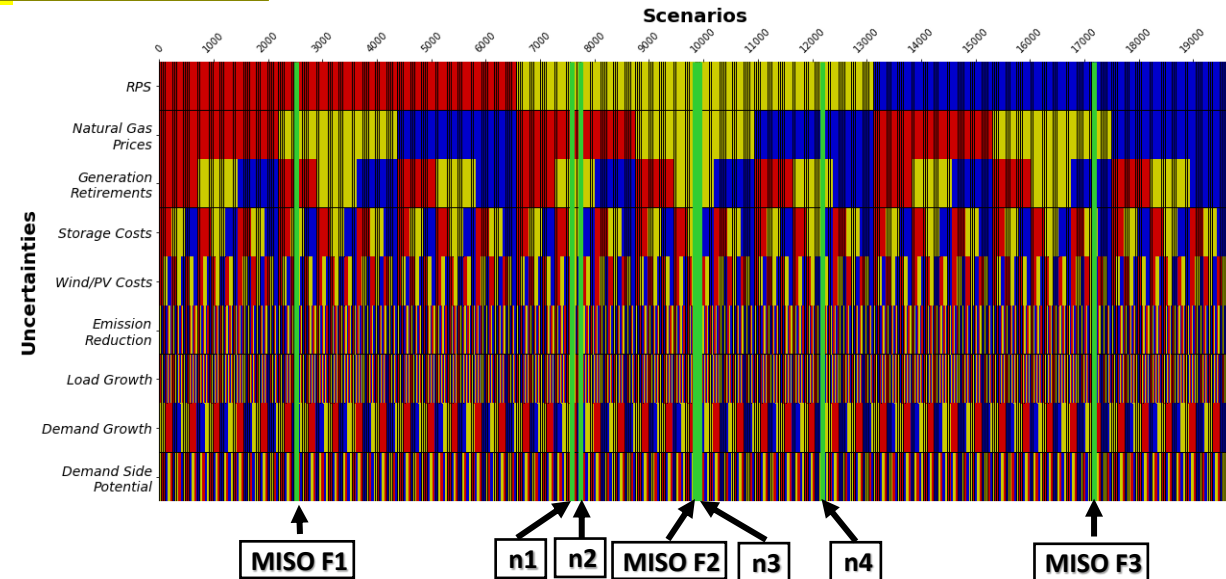
## References:

- Midcontinent Independent Systems Operator, "MTEP18: MISO Trans-mission Enhancement Plan," 2018. [Online]. Available: <https://www.misoenergy.org/planning/planning/>.
- Midcontinent Independent Systems Operator, "Appendix E: MTEP19EGEAS Assumptions Document," 2019. [Online]. Available: <https://www.misoenergy.org/planning/planning/>.
- National Renewable Energy Laboratory, "2020 Annual Technology Baseline (ATB)," Jul. 2020. [Online]. Available: [atb.nrel.gov](https://atb.nrel.gov)
- GAMS, Gams scenred2, 2021. [Online]. Available: [https://www.gams.com/latest/docs/T\\_SCENRED2.html](https://www.gams.com/latest/docs/T_SCENRED2.html).

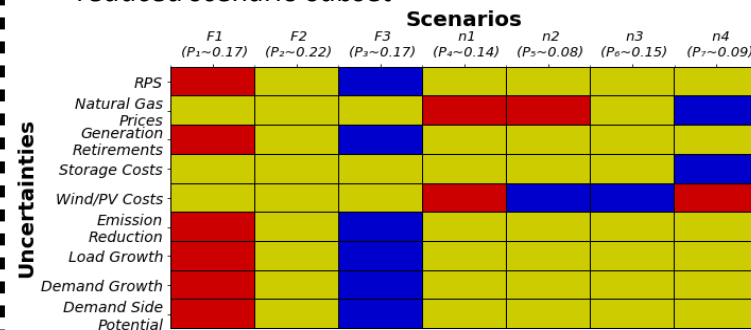
## Scenario reduction

Entire Uncertainty Space:

LOW MED HIGH



- $3^9 = 19,683$  total futures/ 9 uncertainties and low/medium/high
- GAMS ScenRed2 function – input-based methods [4]
- MISO futures (F1/F2/F3) were weighted heavier than other scenarios to force MISO scenarios to be in reduced scenario subset



## Reduced Scenario 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

LOW MED HIGH

## 70,000 bus model

### 0. Initial model

- Obtain network model
- Perform load forecast
- Forecast weather cndts
- Identify futures
- Remove radial paths

## 39,000 bus model

## 2b. Key tools: model reduction

A.  
Jahanbani,  
Research  
Faculty



Y. Jiang,  
Ph. D.  
Student  
(now at  
CAISO)



Z. Parvini  
Ph.D  
Student

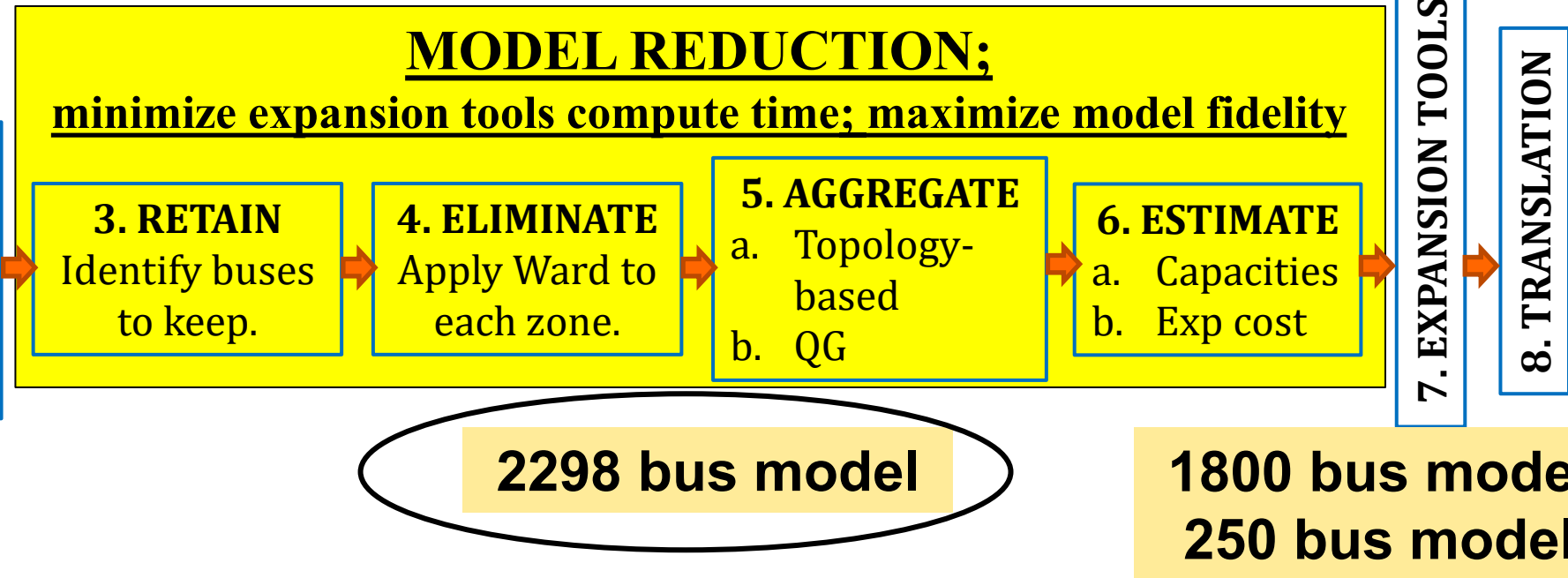
### 1. PREPROCESS

- Trim & map
- Identify study system
- Reduce ext & LV system

### 2. DIVIDE

- Key branch ID using rolling sim
- Identify zones

## 9891 bus model



Above model reduction procedure implemented twice to build 2 reduced models

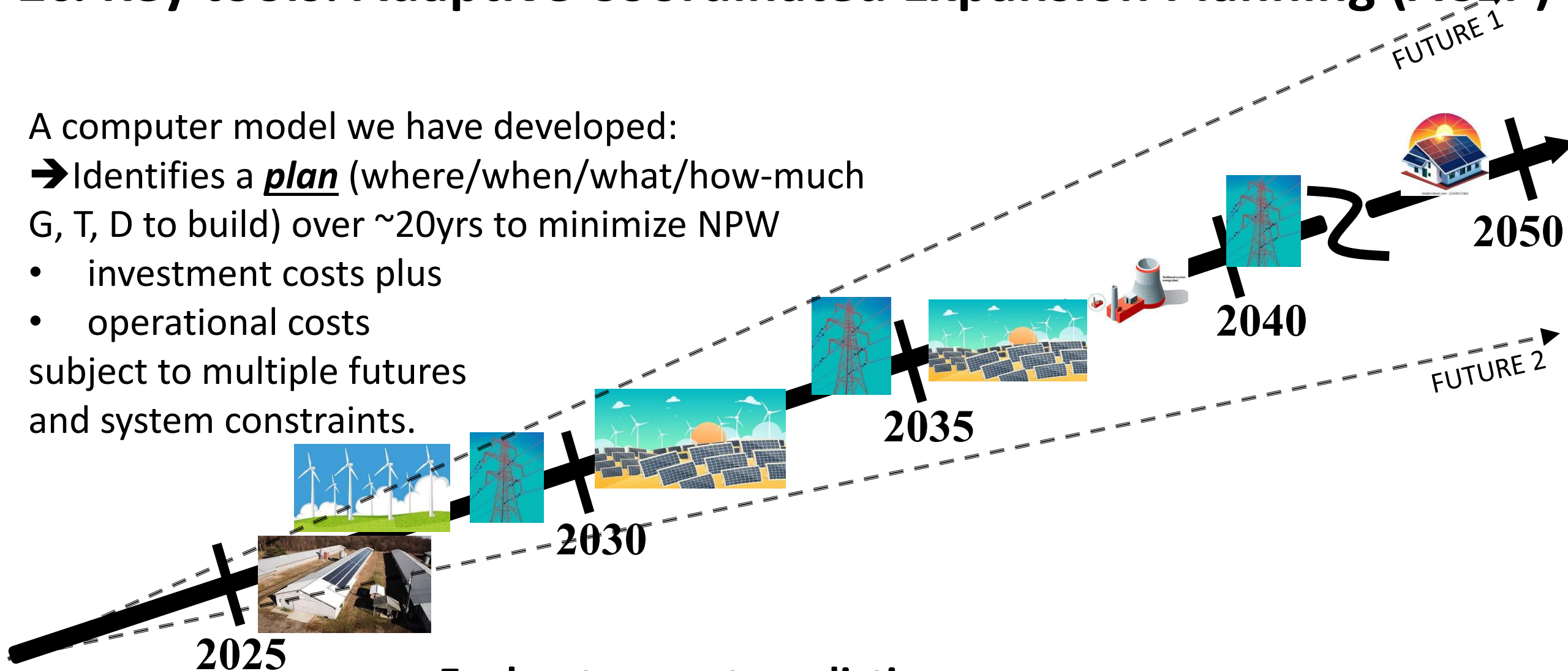
# of buses	Source of full network	Compare to...	Purpose	Fidelity level
250	From 2024 HS MMWG	Tranche 1	Tool testing/refinement	Medium
1800	From MISO, w/ Tranche 1	Tranche 2	Final PIE project results	High

# 2c. Key tools: Adaptive Coordinated Expansion Planning (ACEP)

A computer model we have developed:

→ Identifies a **plan** (where/when/what/how-much G, T, D to build) over ~20yrs to minimize NPW

- investment costs plus
  - operational costs
- subject to multiple futures and system constraints.



TODAY

2025

2030

2035

2040

2050

FUTURE 1

FUTURE 2

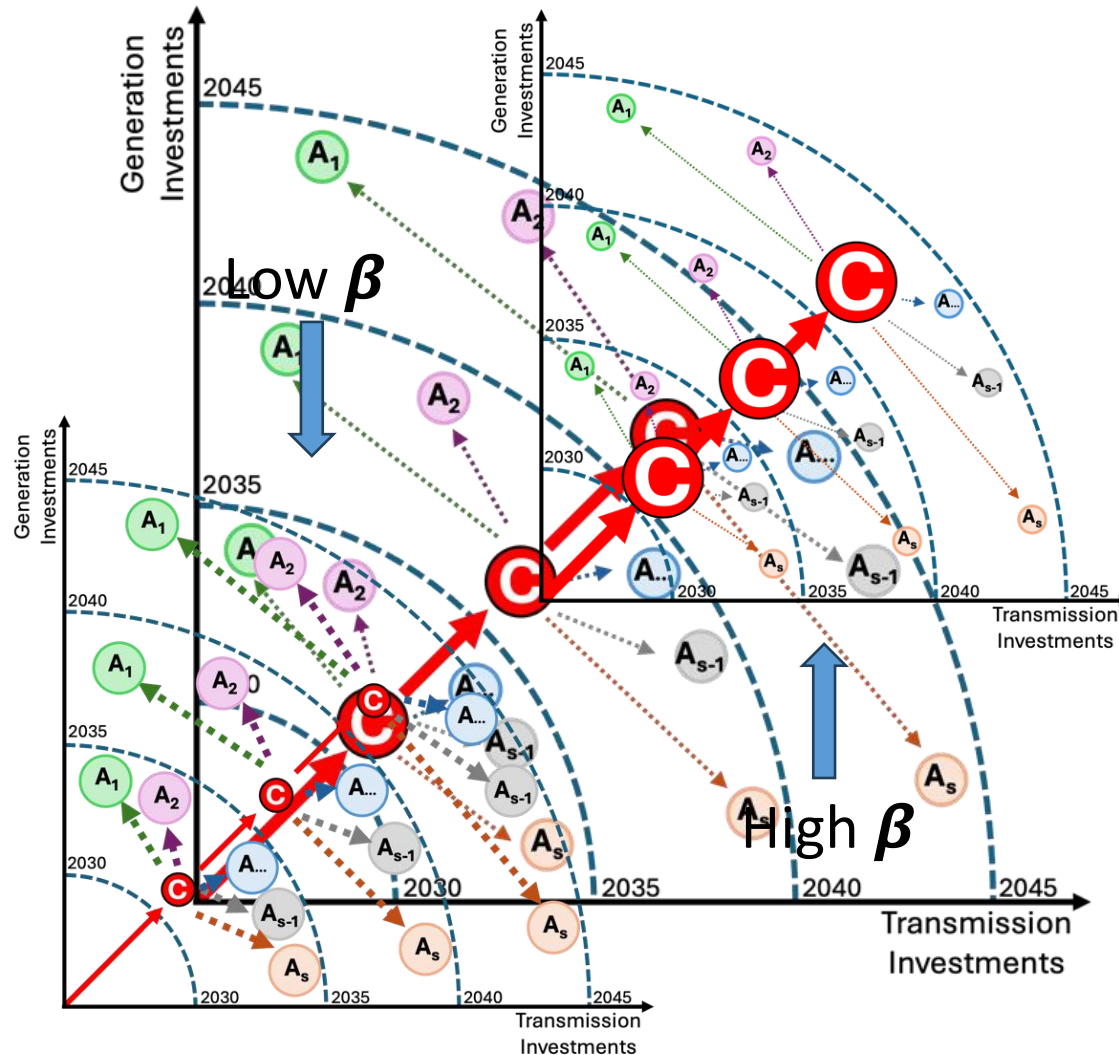
**Exploratory, not predictive:**

“Point it” in the direction of a particular vision.

Identify several “futures”.

It gives least-cost G,T,D plan for that vision subject to specified futures & sys constraints.

# 2c. Key tools: Adaptive Coordinated Expansion Planning (ACEP)



## Approach:

Identify generation & transmission investments to:

*MINIMIZE*

[Cost of Core (**red**)] +

$\beta \times [Prob\{Fut\} \times$

(Cost of Adapting Core{Fut}  
+ Cost of Operations{Fut}) ]

*SUBJECT TO* (for each Fut)

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

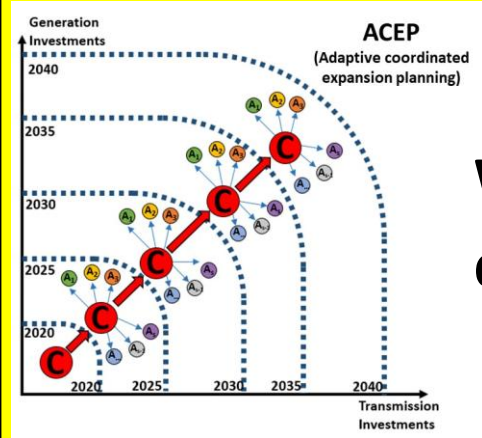


# 2d. Key tools: ACEP with resource adequacy (RA)



G. Cuello-Polo  
Ph.D.  
Student

## Adaptive Coordinated 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.

ADJUST  
CAPACITY CREDITS (D-LOL) &  
PLANNING RESERVE MARGIN

NO

LOLE  $\approx$   
0.1 days/yr  
?

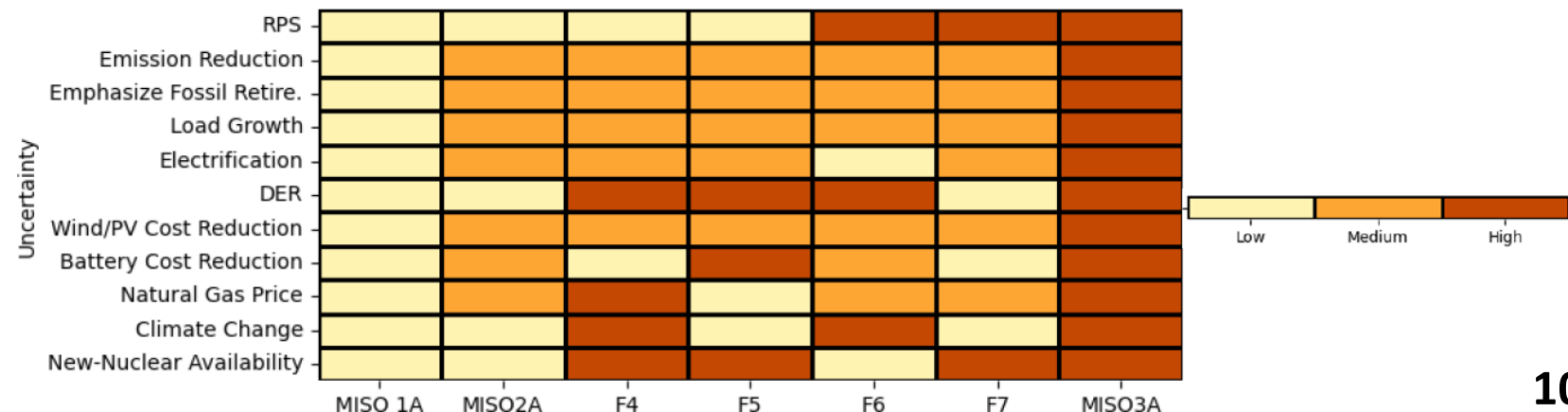
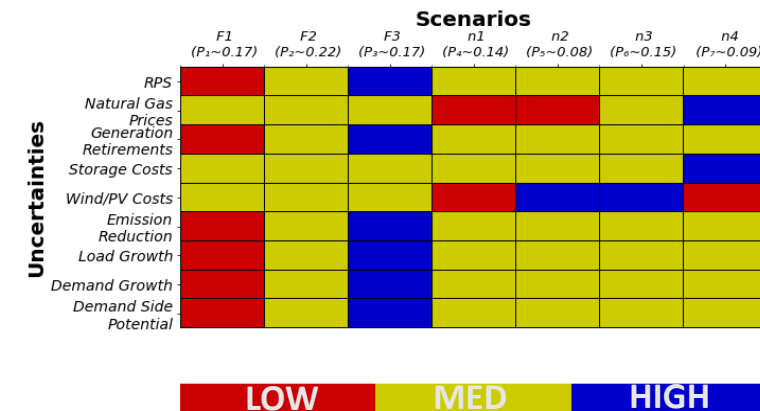
YES

DONE

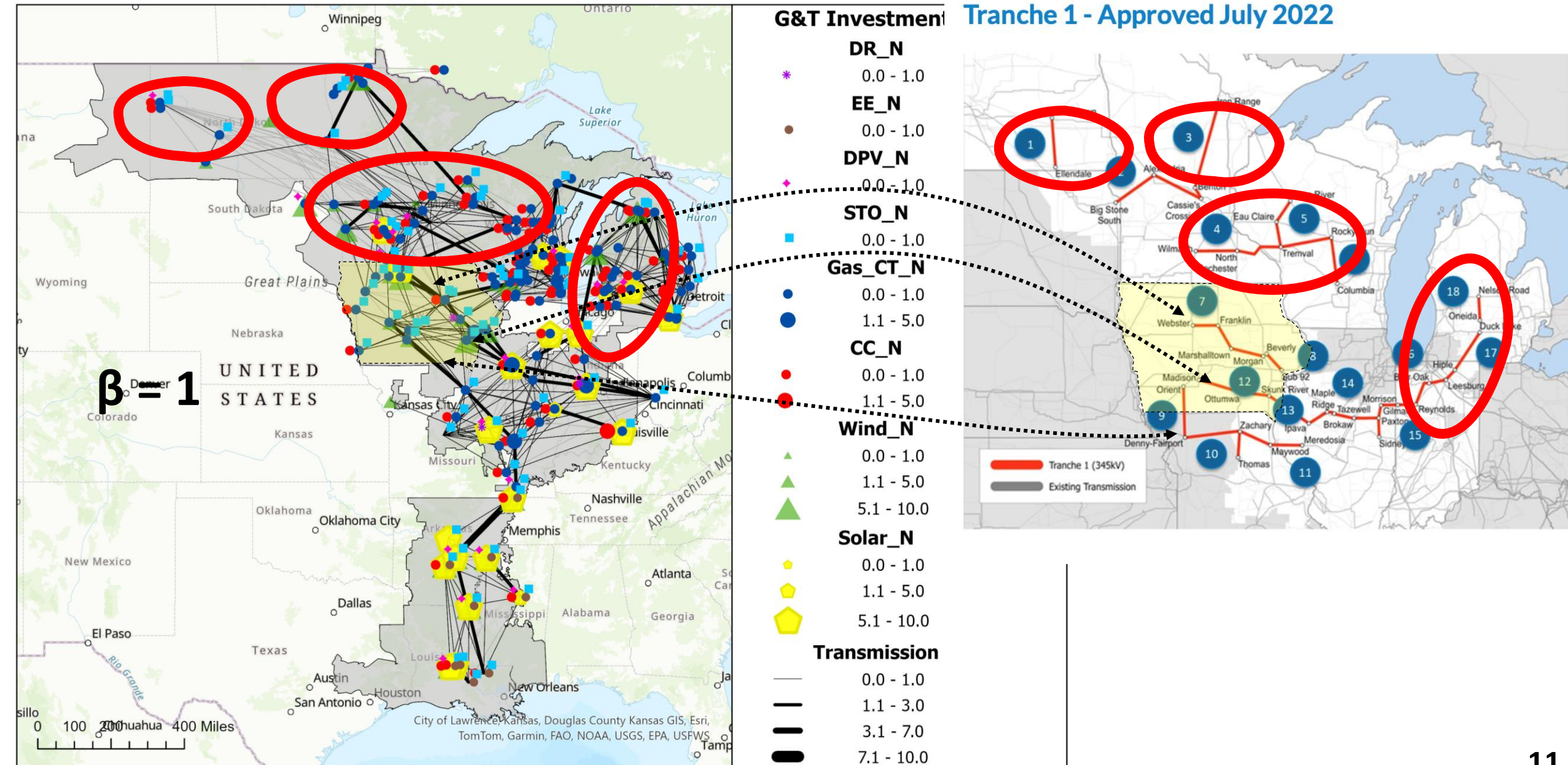
Could also include EUE here,  
for energy adequacy.

# 3. ACEP results: summary

# of buses	Tranche 1?	Tranche 2.1 Ccts	GE-MARS?	Robustness parameter	Futures	Purpose
250	No	No	Yes	$\beta=1$	MISO F1, F2, F3 + 4 more	Validation, Storage effects
1800	Yes	No	No	$\beta=5$	MISO 1A, 2A, 3A + 4 more	Validation
2298	Yes	Yes	No	$\beta=4$	MISO 1A, 2A, 3A + 4 more	Validation, Effects of RPS
2298	Yes	Yes	No	$\beta=4, 2, 0.5$	MISO 1A, 2A, 3A + 4 more	Illustrate ACEP concept, Identify important investments



### 3a. 250 bus model, ACEP with RA, 7 futures, $\beta=1$ Core Investments - compare to Tranche 1



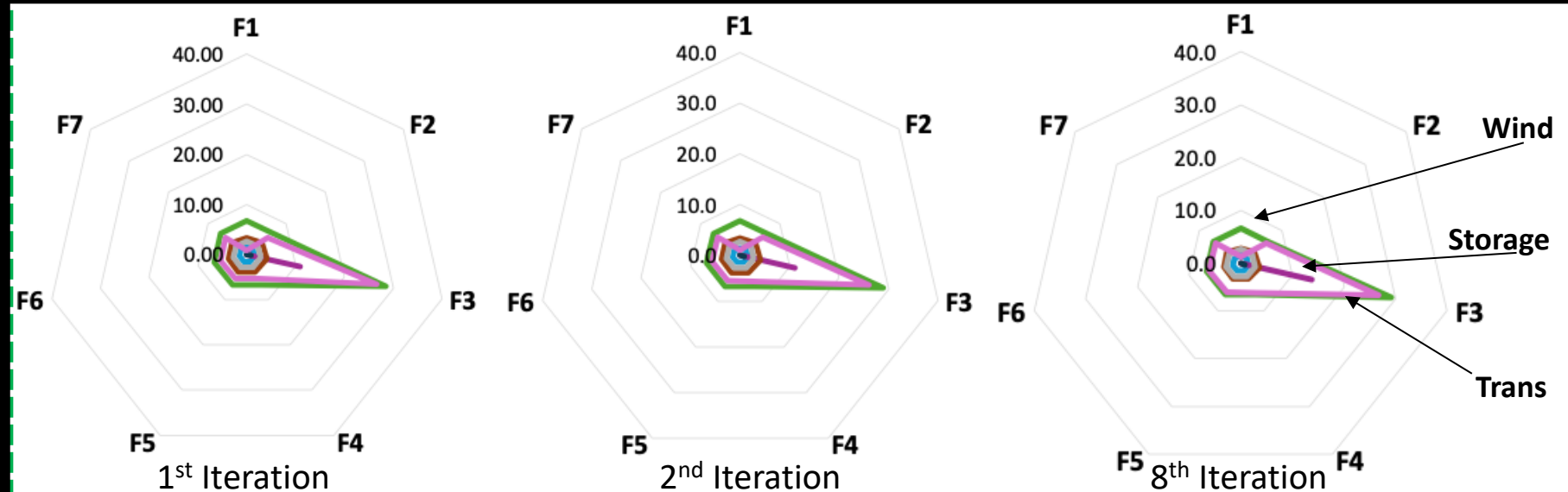
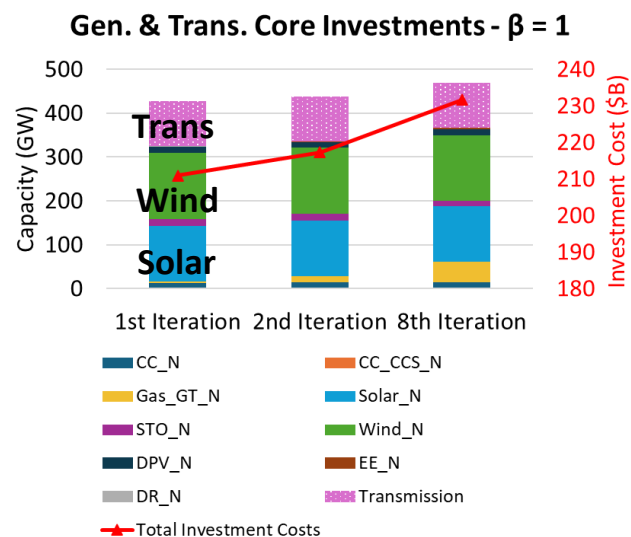


# 3a. 250 bus model, ACEP with RA, 7 futures: core vs. adaptations

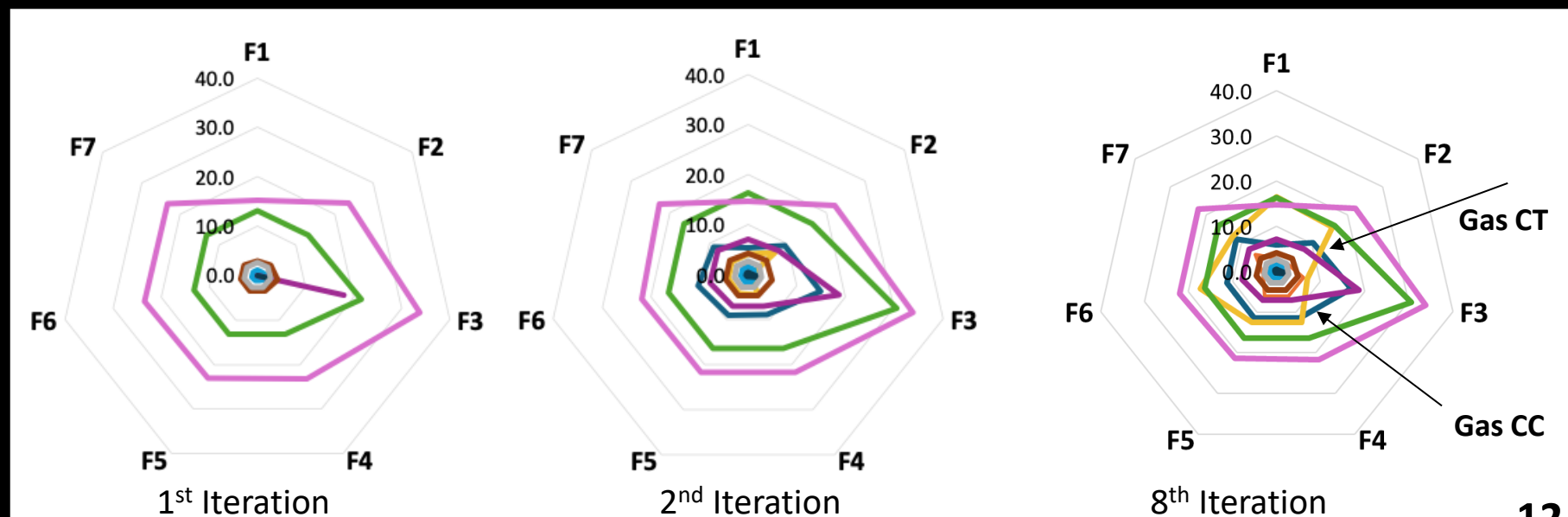
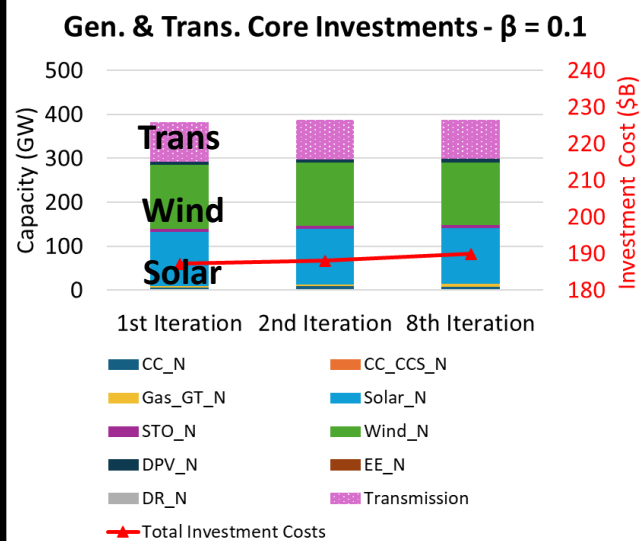
## CORE

## ADAPTATIONS

$\beta = 1$

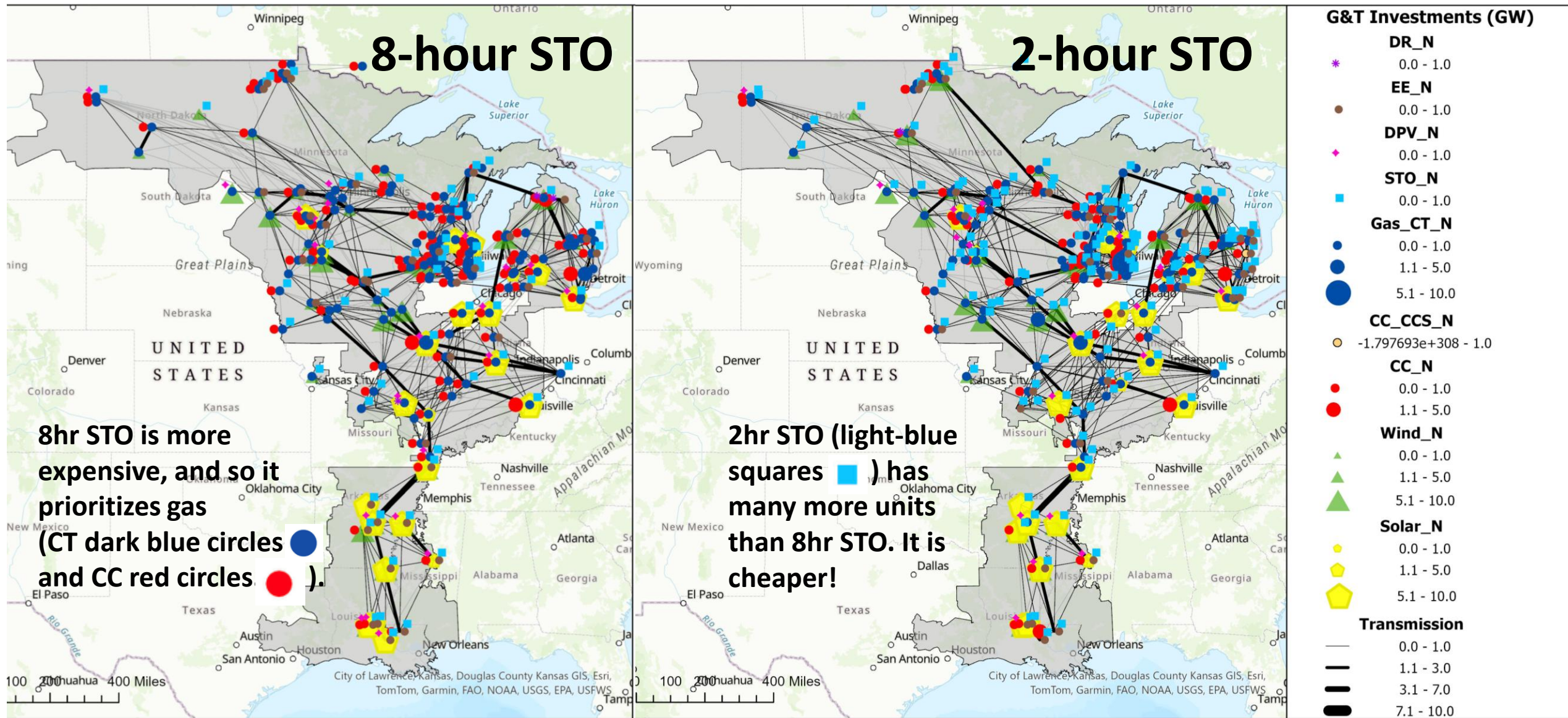


$\beta = 0.1$

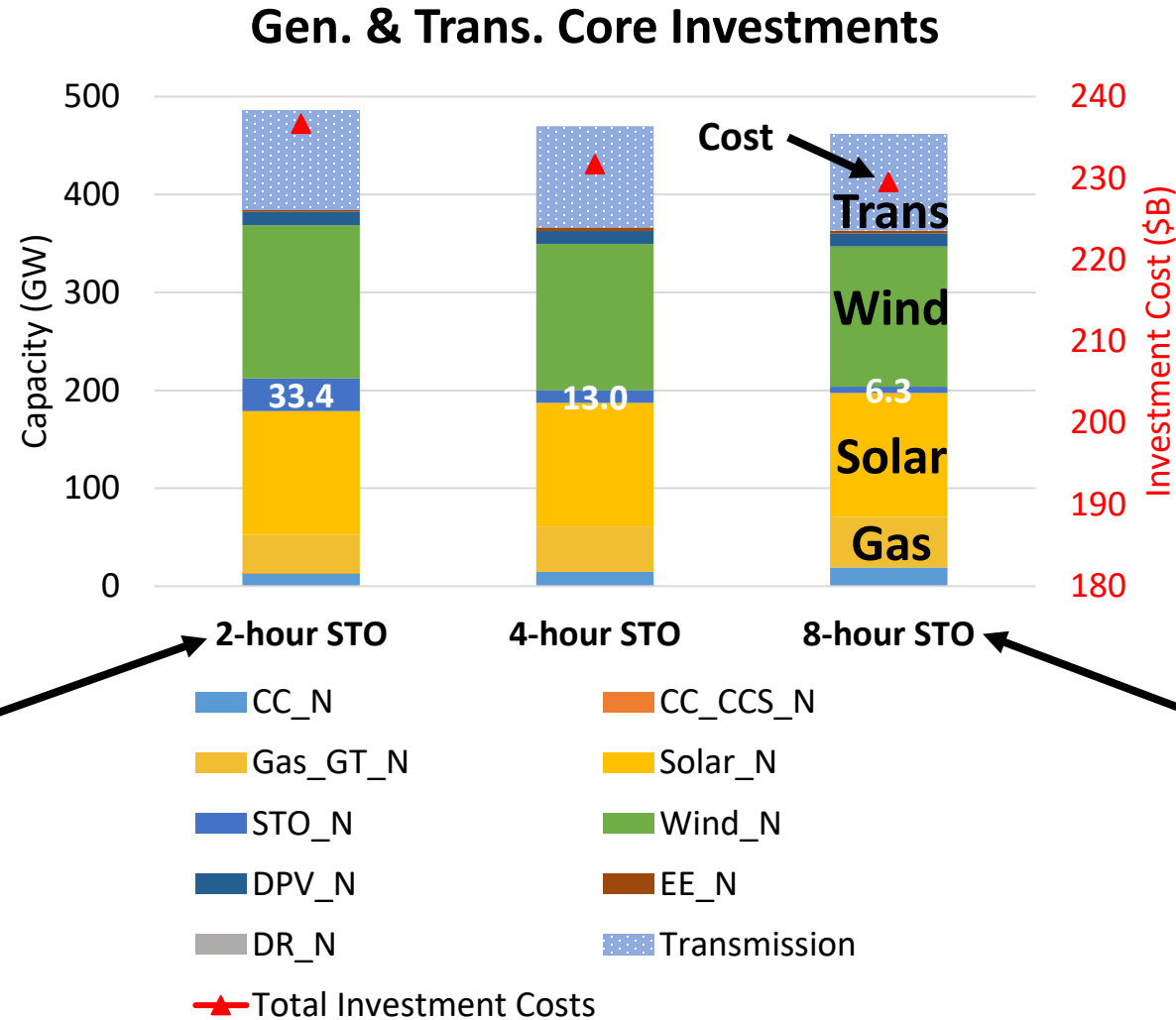




# 3a. 250-bus model, ACEP w/RA, 7 futures, $\beta=1$ : storage effect of on core



# 3a. 250 bus model, ACEP with RA, 7 futures: $\beta=1$ , effect of storage



## 2-hr Storage:

- Lowest \$/MWhr cost and so invests more
- but is less effective in satisfying LOLE requirements, and so total capacity (and cost) is highest

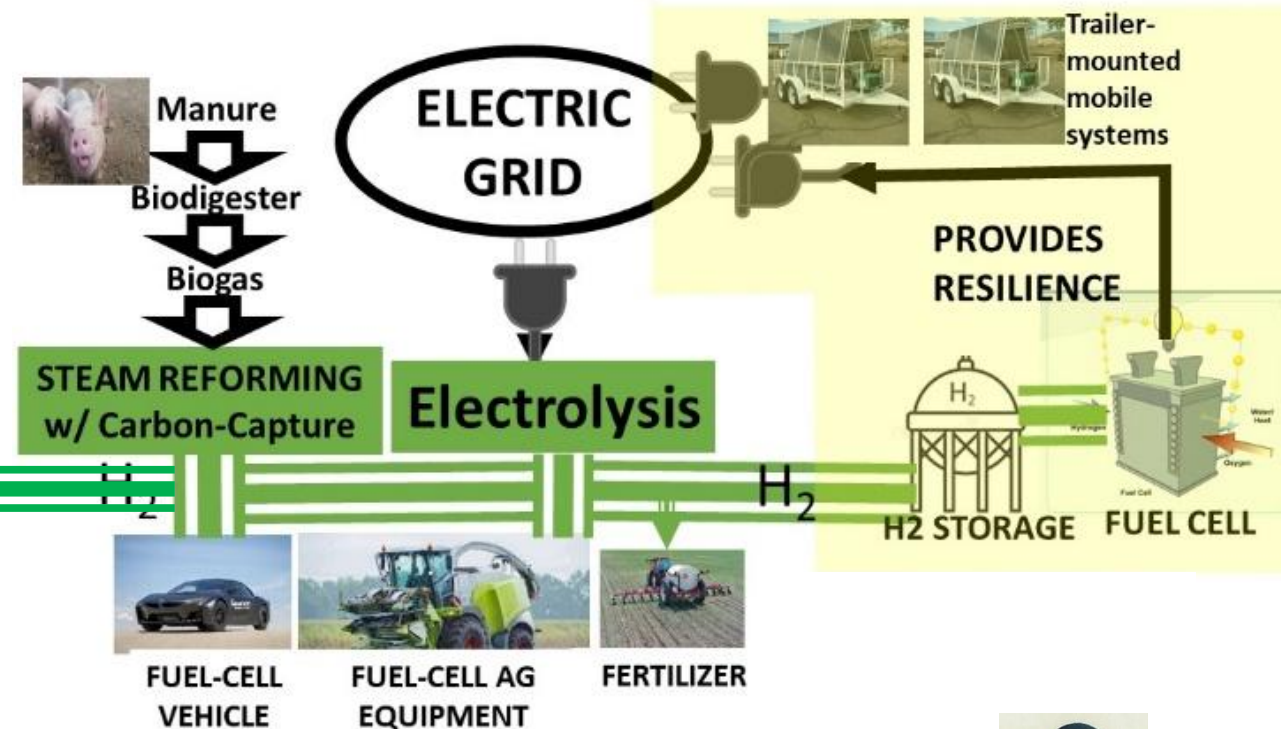
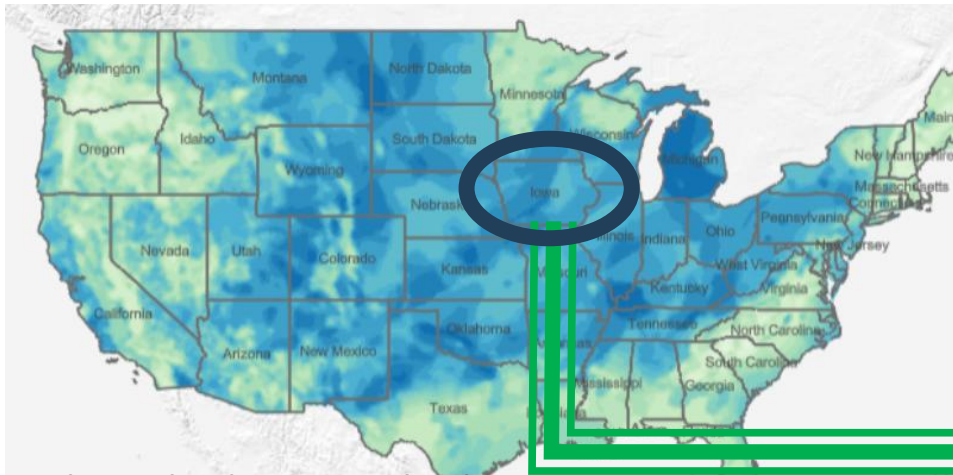
## 8-hr Storage:

- highest \$/MWhr cost and so invests less;
- But longer duration & shifts reserve needs to gas which is more effective in satisfying LOLE than 2-hr storage;
- 8-hr price point (NREL) is important for this;
- Lowest total capacity and cost.



# Hydrogen: other end of storage duration spectrum

H<sub>2</sub> production via wind/solar-driven electrolysis, biodigester-driven steam reforming, and geologically, producing elect energy via fuel cells during normal & extreme cndts.



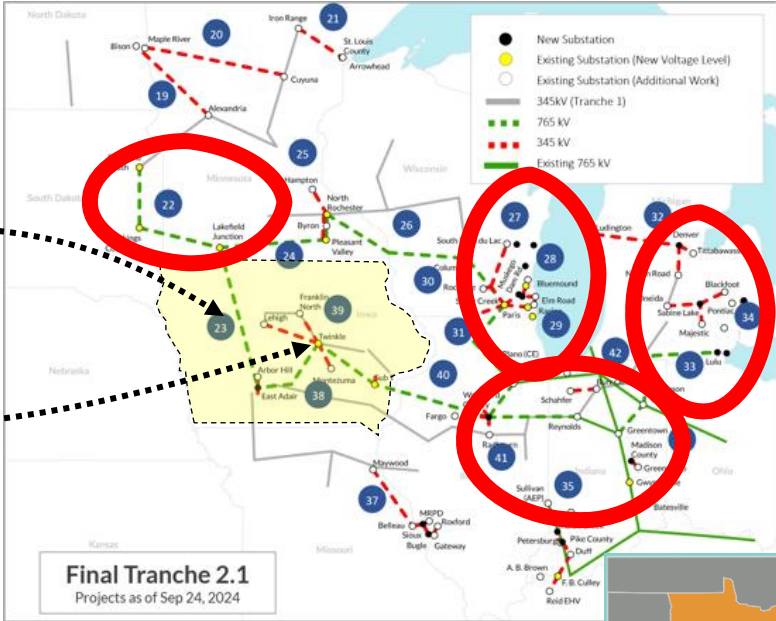
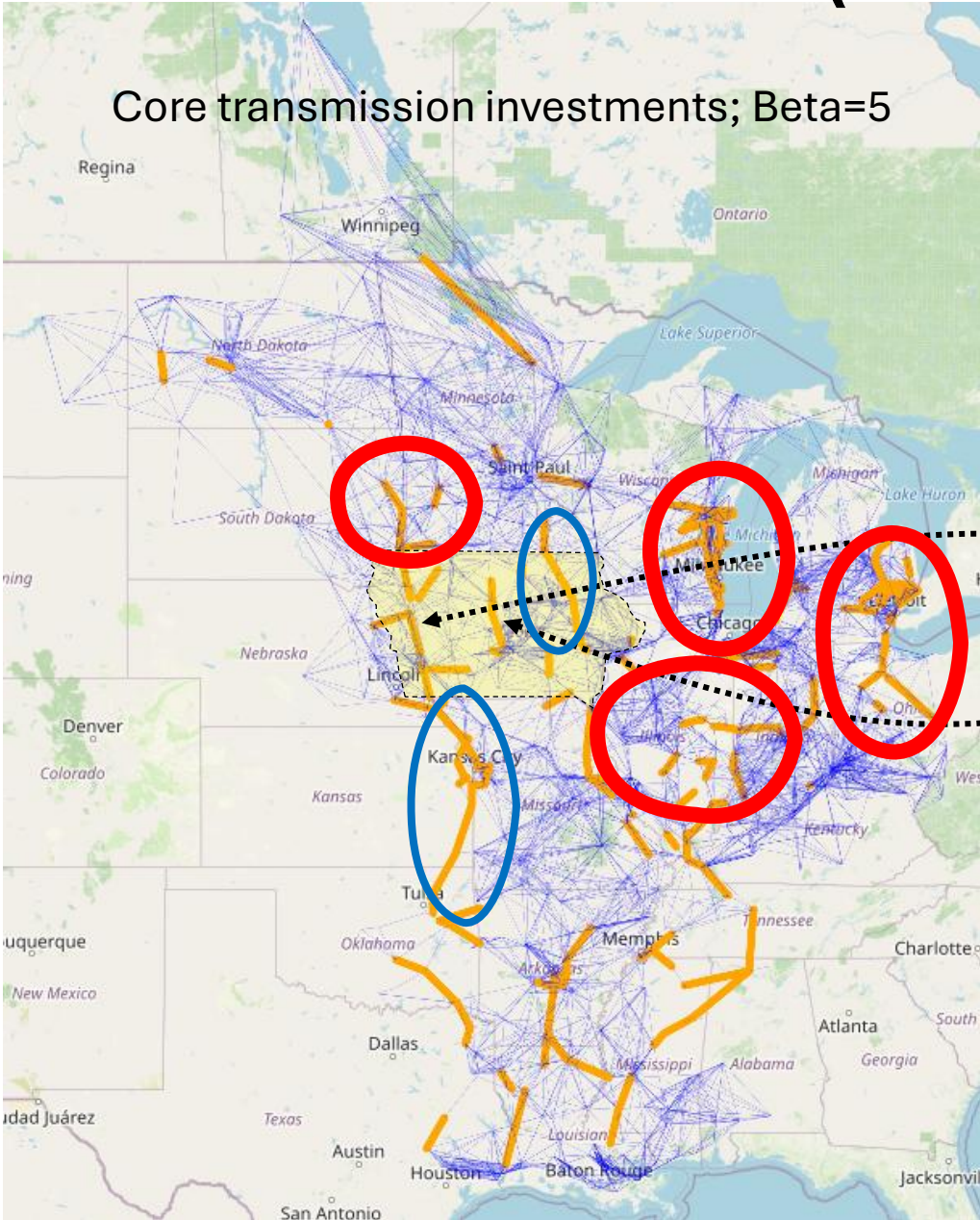
Geologic hydrogen is hydrogen gas that is naturally found below the surface of the Earth. Unlike hydrogen produced through industrial processes, geologic hydrogen is sourced by, and stored in, rocks in the ground, similar to natural gas resources. **Iowa is thought to have a lot of it!**

[www.usgs.gov/publications/prospectivity-mapping-geologic-hydrogen](http://www.usgs.gov/publications/prospectivity-mapping-geologic-hydrogen)



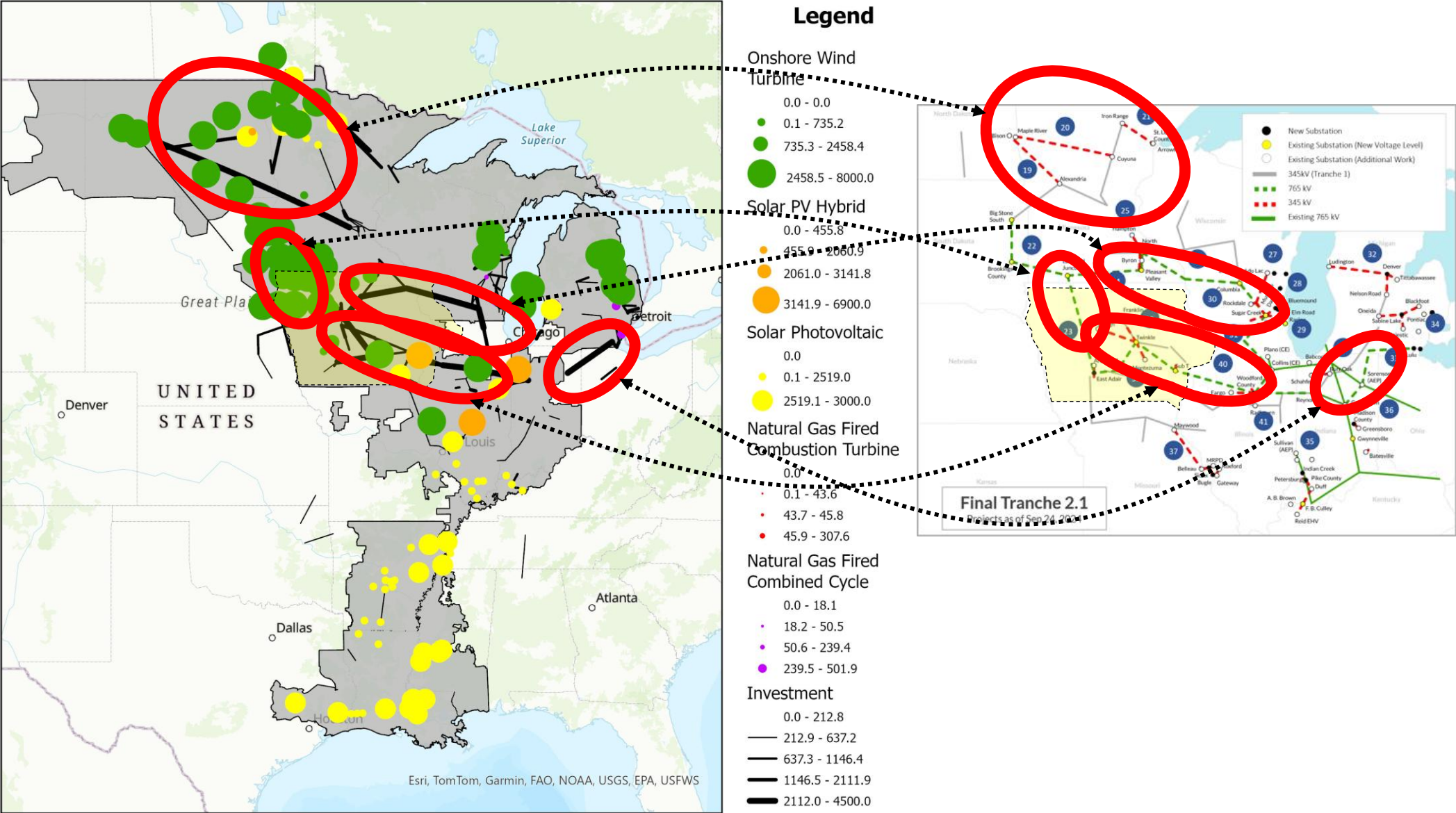
# 3b. 1800 bus model (with Tranche 1), ACEP with 3 futures, $\beta=5$

Core transmission investments; Beta=5



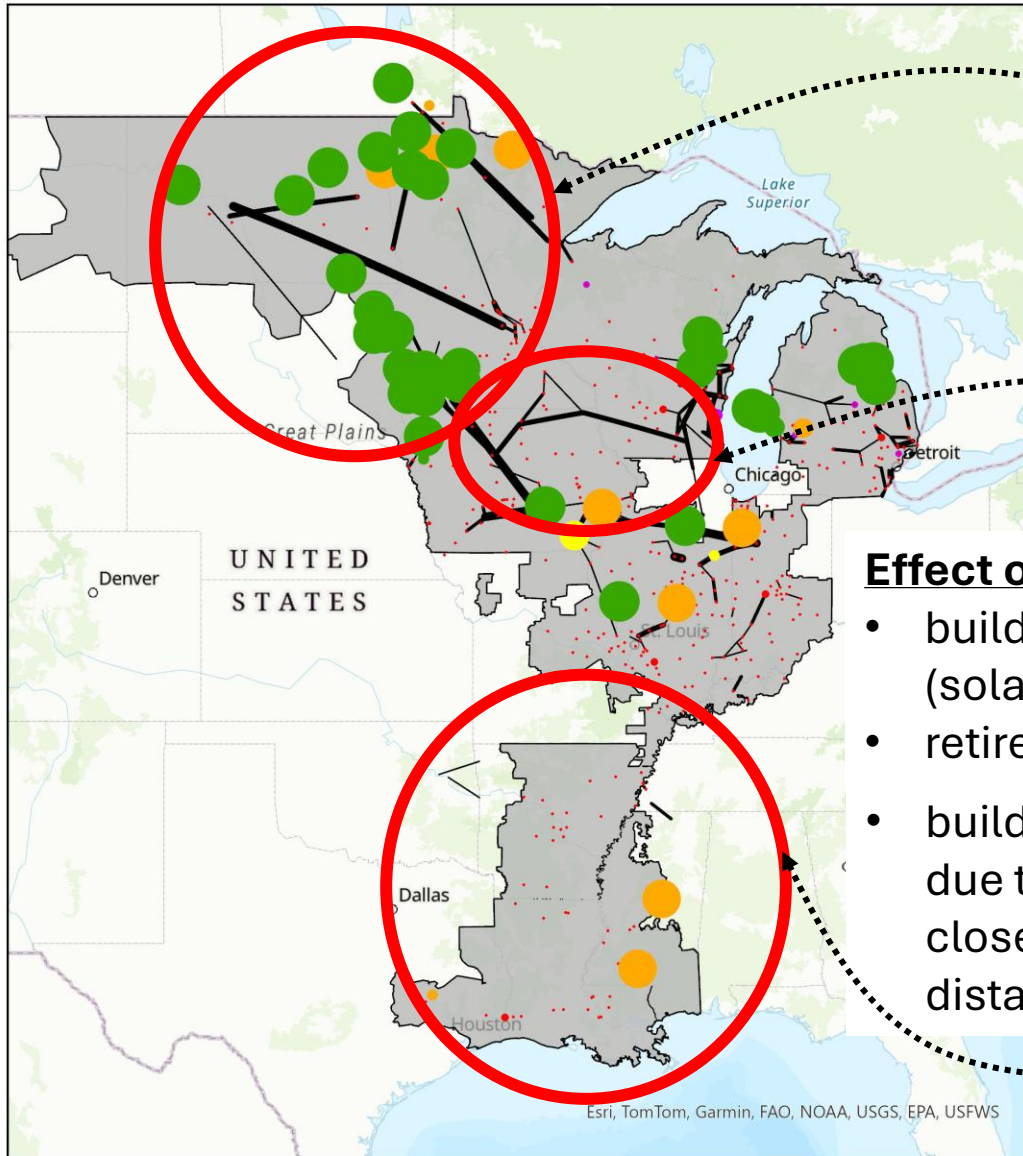


# 3c. 2298 bus model (with Tranche 1), ACEP with 7 futures, $\beta=4$



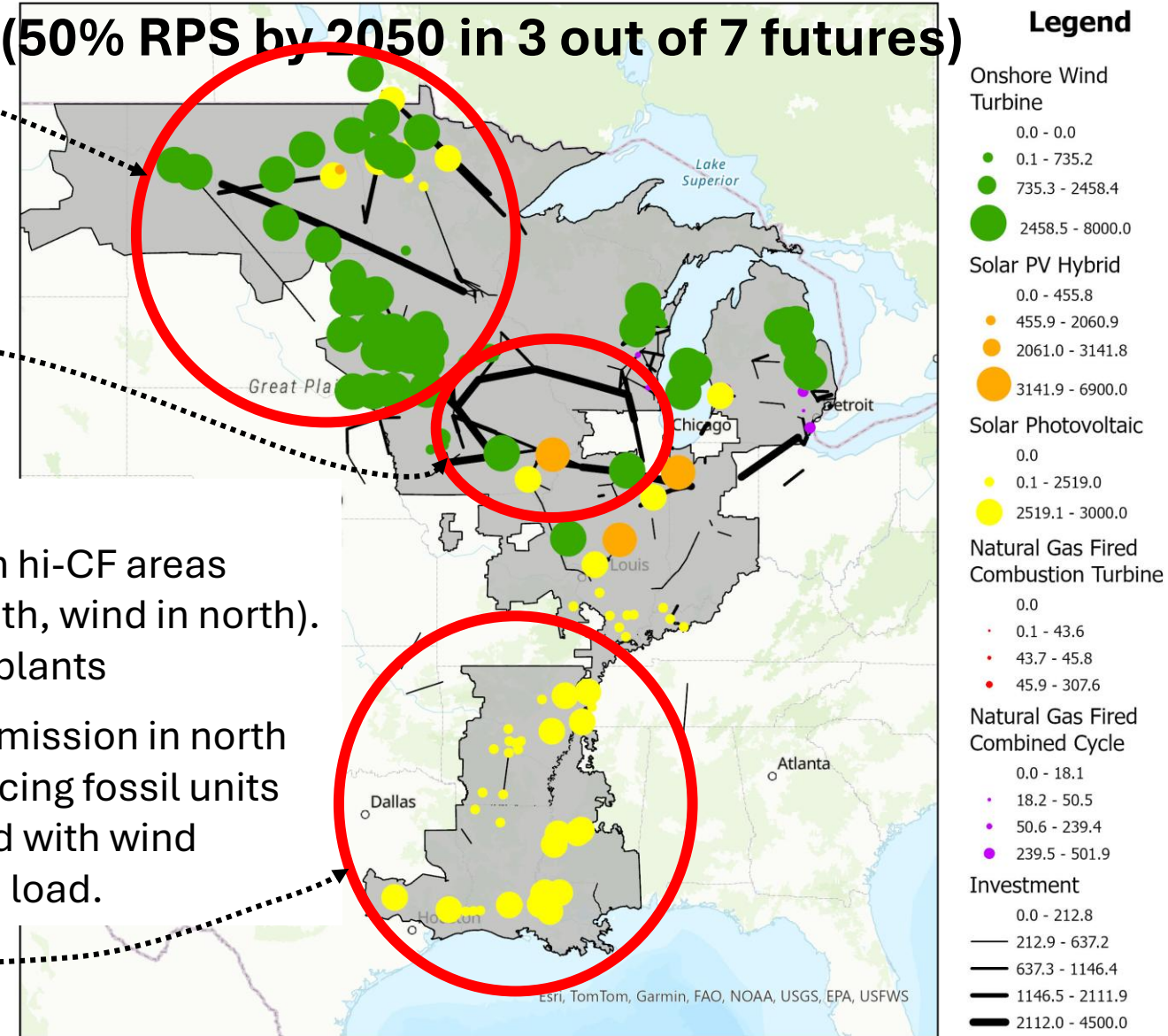
# 3c. 2298-bus model (with Tranche 1), $\beta = 4$

RPS not modeled



MISO-wide RPS modeled

(50% RPS by 2050 in 3 out of 7 futures)



## Effect of RPS:

- builds gen in hi-CF areas (solar in south, wind in north).
- retires coal plants
- builds transmission in north due to replacing fossil units close to load with wind distant from load.

### 3. Reasons for differences between LRTP and ACEP

**Our results are close to MISO's LRTP results, but differences exist, due to:**

#### **A. Modeling differences:**

1. RPS: We used MISO-wide RPS; LRTP used RPS state-by-state.
2. CO<sub>2</sub>: We used MISO-wide CO<sub>2</sub> constraint; LRTP used CO<sub>2</sub> constraint state-by-state
3. Reduction: We had some modeling differences via model reduction process

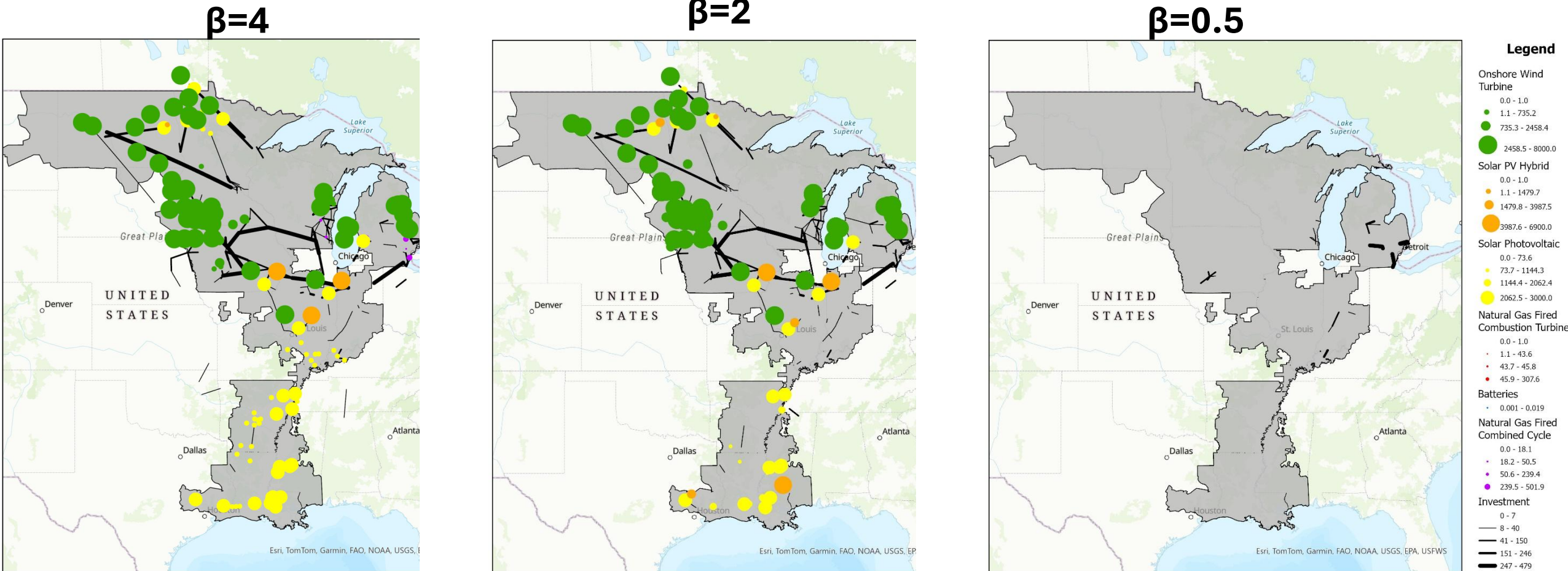
#### **B. Expansion differences:**

1. Generation allowed to expand:
  - We expanded gen according to what was least-cost, cooptimized w/ transmission;
  - LRTP used GIQ, and after that, what was least-cost.
2. Transmission allowed to expand:
  - We allowed all 765 kV, 345 kV circuits to expand according to what was least-cost;
  - LRTP had 345 kV expansion but only to the extent that it was necessary to support intended 765 kV design.
3. How much transmission was allowed to expand:
  - We expanded transmission to MW level needed to supply load thru 2050.
  - LRTP expanded transmission to number of lines needed to supply load thru 2050<sub>19</sub>



# 3c. 2298 bus model (with Tranche 1), ACEP with 7 futures

Core investments, for  $\beta=4, 2, 0.5$   
to show circuits of increasing importance



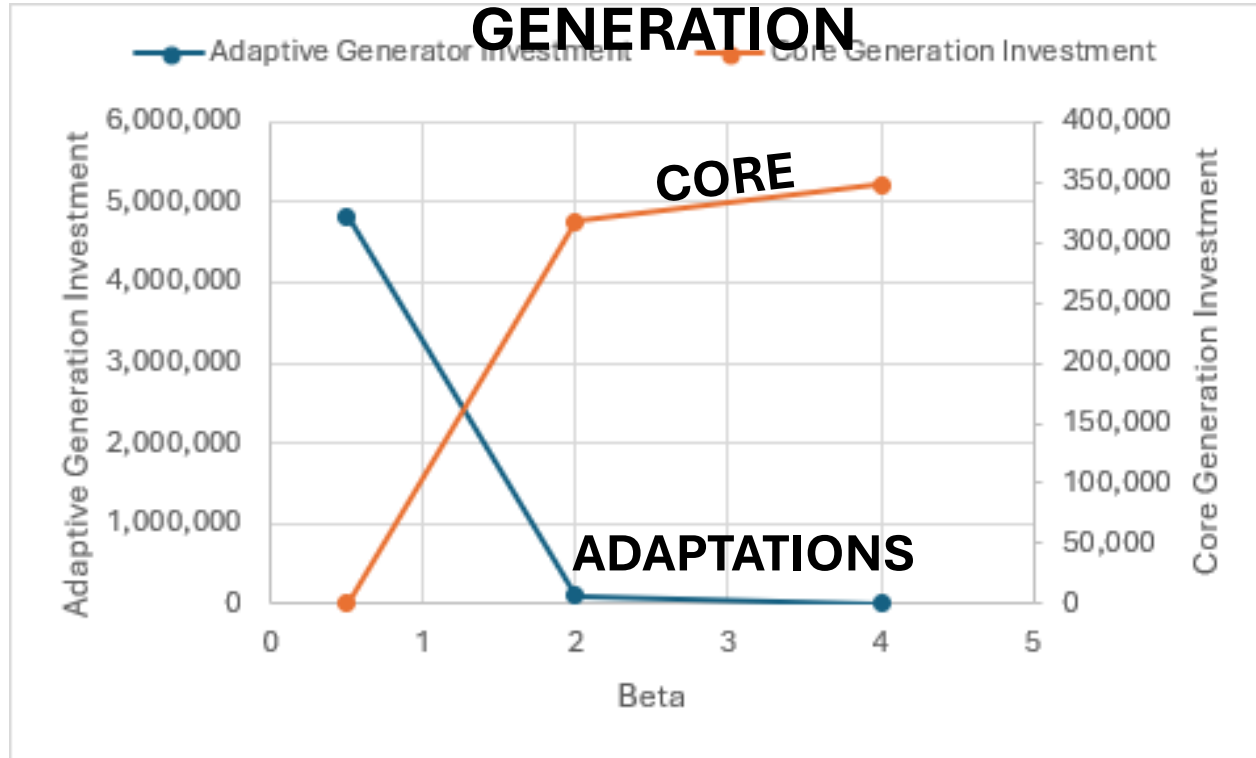
Note: To make all transmission investments visible, line thickness in one map has different meaning than line thickness in another map.



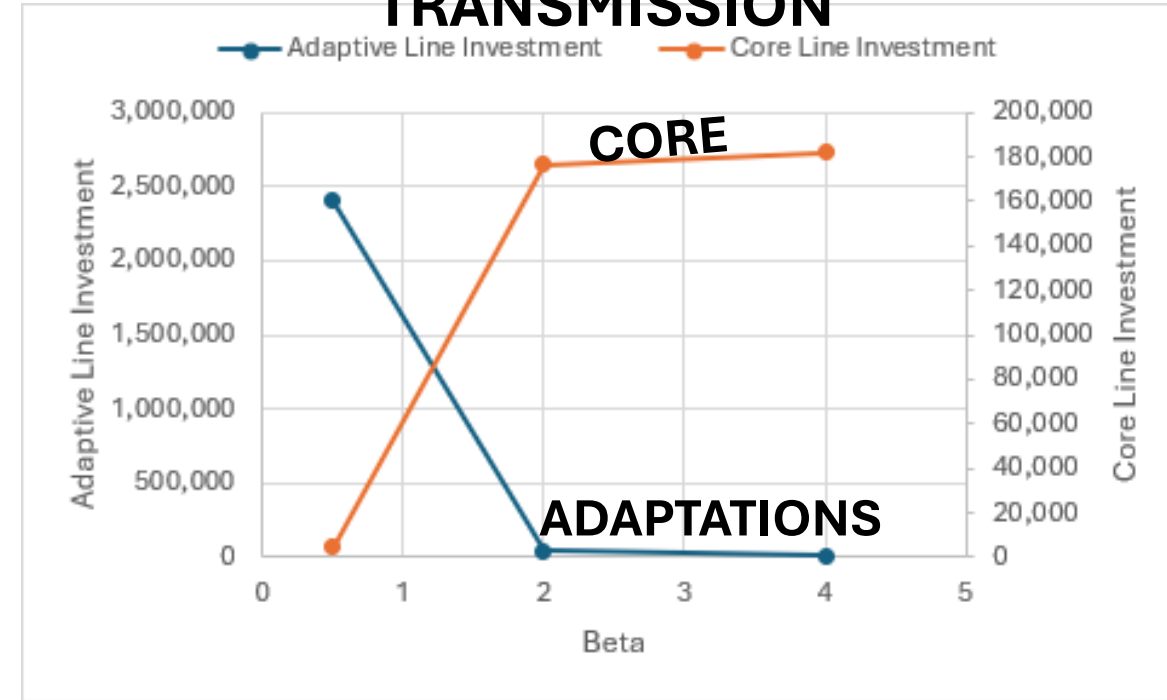
# 3c. 2298 bus model (with Tranche 1), ACEP with 7 futures

Core investments, for  $\beta=4, 2, 0.5$   
to show circuits of increasing importance

## INVESTMENTS VS BETA, GENERATION



## INVESTMENTS VS BETA, TRANSMISSION



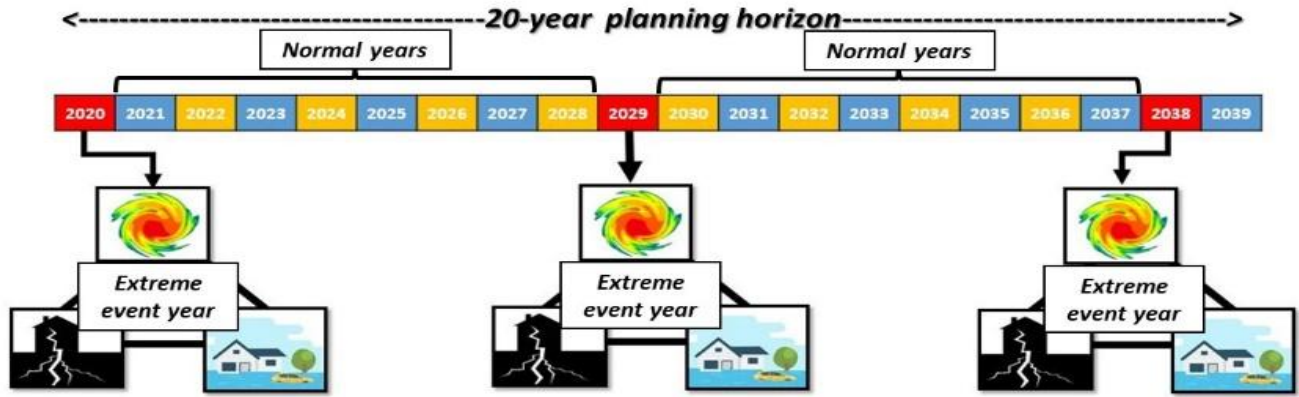


C. Phillips  
Ph.D  
Student



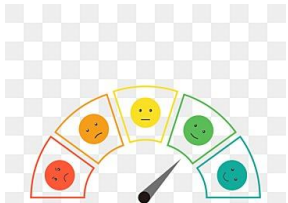
Z. Parvini  
Ph.D  
Student

# 4. Ongoing work Resilience



Resilience-based expansion planning combines extreme event years w/ normal years with user-specified ratio R/N of resilience investments to normal investments.

Dial in the resilience to normal (R/N) ratio



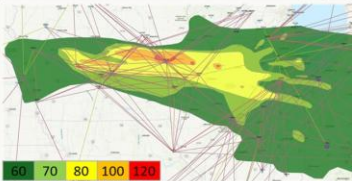
Normal conditions

Resilience (extreme events) cdt\$

## Simulating 2020 Derecho

- Five steps for simulating derecho impacts on transmission lines
1. Define 8 “weather regions” with similar windspeed/timing from derecho
  2. Create wind timeseries based on surface observations in/near weather region
  3. Calculate failure probability timeseries for each region/fragility curve
  4. Define region derate as max 20-minute failure probability
  5. Calculate derate per transmission line

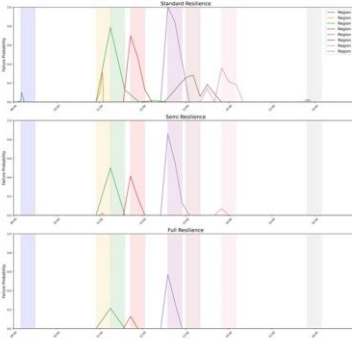
NOAA Max Estimated Wind Gust (mph)



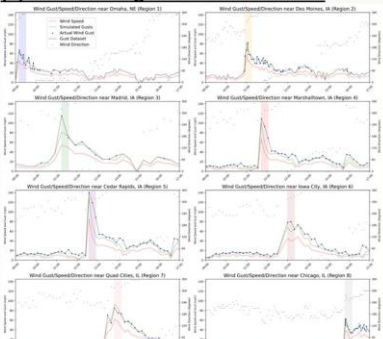
(1) Weather Regions



(3) Failure Probability Timeseries



(2) Weather Region Wind Timeseries



(4) Derate Per Region

	R1	R2	R3	R4	R5	R6	R7	R8
Standard	0.98	0.93	0.54	0.57	0.25	0.80	0.75	0.99
Semi	1	1	0.75	0.80	0.49	1	0.98	1
Full	1	1	0.89	0.96	0.72	1	1	1

(5) Derate Per Transmission Line

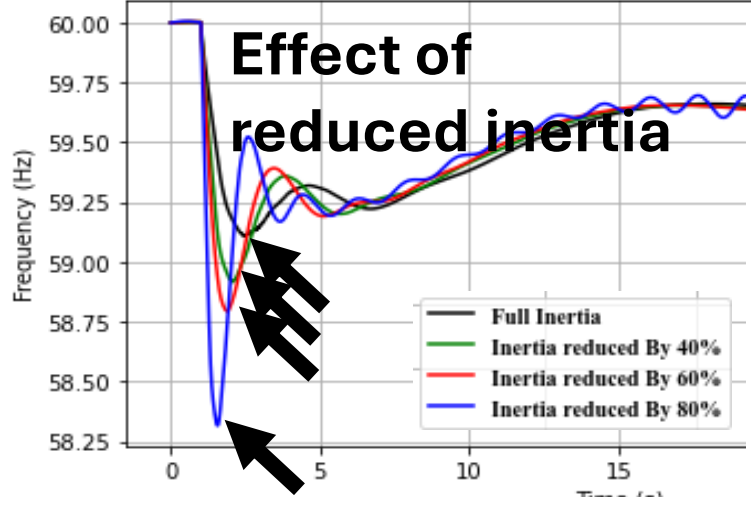
Line % in Weather Region								Derate		
Line #	R1	R2	R3	R4	R5	R6	R7	R8	Standard	Semi
396	0	19.13	0	15.26	57.01	8.60	0	0	52.38%	32.13%
390	0	27.75	0	15.56	56.69	0	0	0	51.15%	32.02%
401	0	13.23	0	14.43	56.72	15.62	0	0	52.79%	31.81%
377	0	28.25	0	15.59	56.16	0	0	0	50.80%	31.76%
378	0	0	0	11.23	56.54	32.23	0	0	53.68%	31.08%
669	0	0	0	7.40	55.28	37.31	0	0	52.11%	29.67%
n	n <sub>1</sub>	n <sub>2</sub>	n <sub>3</sub>	n <sub>4</sub>	n <sub>5</sub>	n <sub>6</sub>	n <sub>7</sub>	n <sub>8</sub>	D <sub>Standard</sub>	D <sub>Semi</sub>
									D <sub>Full</sub>	



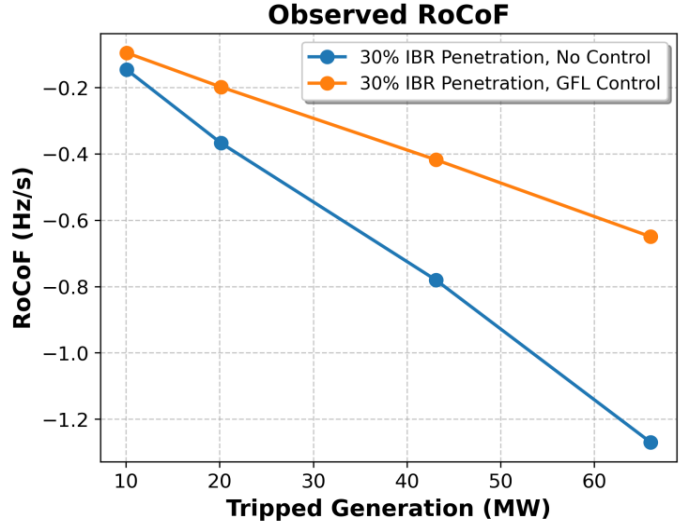
M. Elnasry,  
PhD  
Student

# 4. Ongoing work

## Additional ACEP features: Inertia



Minimum frequency dip or max ROCOF is protection against UFLS  
→ UFLS is a protection against gen tripping.  
→ Gen tripping is protection against loss of turbine life



MINIMIZE

$$[Cost\ of\ Core\ (red)] + \beta \times [Prob\{Fut\} \times (Cost\ of\ Adapting\ Core\{Fut\} + Cost\ of\ Operations\{Fut\})]$$

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

$$\Delta f = \mathbb{F}_1(\Delta P_G, H_{sys}, PFR) \leq \Delta f_{max}$$
$$RoCoF = \mathbb{F}_2(\Delta P_G, H_{sys}, PFR) \leq RoCoF_{max}$$

For high wind/solar levels, ACEP chooses from among these configurations to maintain sufficient inertia & primary frequency control at least cost.

Resource	Inertia	PFR
Synchronous Generator	Yes	Yes
Synchronous Condenser	Yes	No
BESS	Yes	Yes
Wind (MPPT)	No	No
Wind + Inertia Emulation	Yes	No
Wind + BESS	Yes	Yes
Derated Wind	Limited	Limited
Solar PV (MPPT)	No	No
Solar + BESS	Yes	Yes
Derated Solar	Limited	Limited
Load Resources (LR)	No	Yes

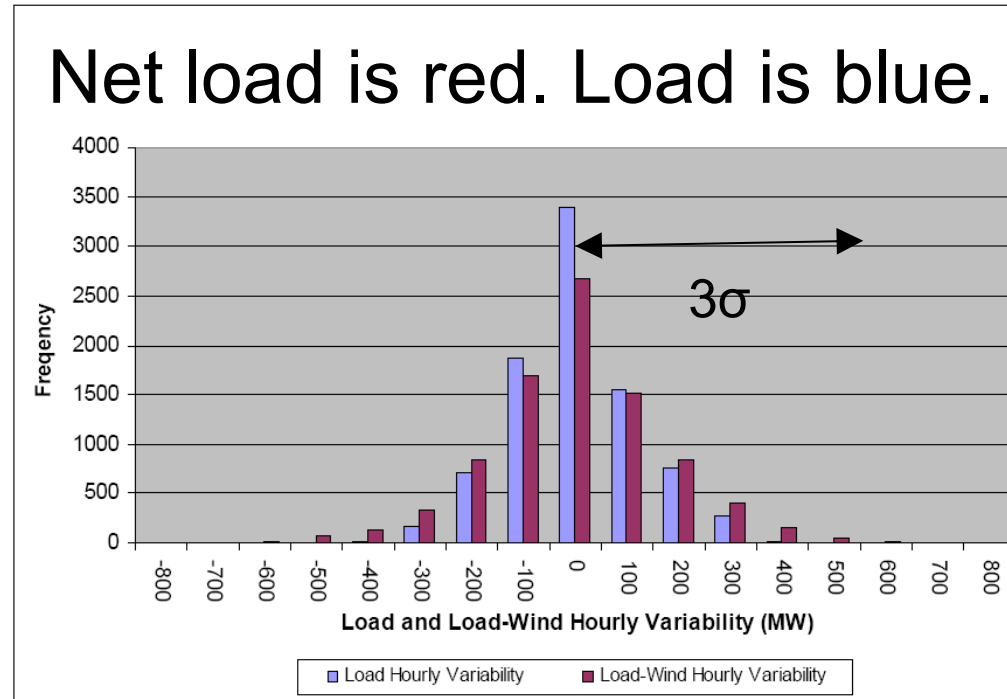
# 4. Ongoing work

## Additional ACEP features

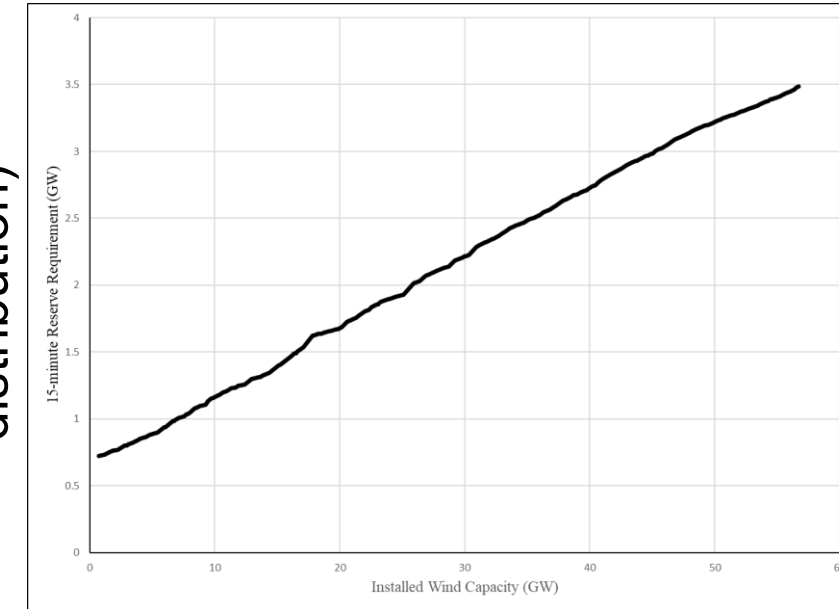


Dynamic flexibility: update regulation & ramping requirements as wind/solar grow

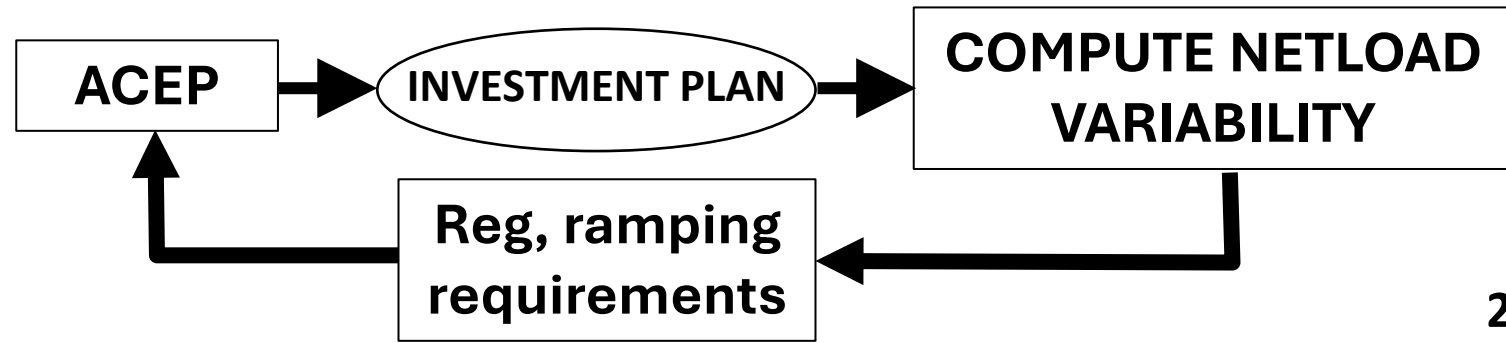
- Without wind/solar, regulation/ramping reserves depend on load variability; no change with new resources; most new resources provide reserves.
- Now, reserves are function of netload variability → depend on amount of added wind/solar.



$3\sigma$  (width of netload distribution)



GW of Wind





# 4. Ongoing work

## Additional studies: Load control



### PROBLEM:

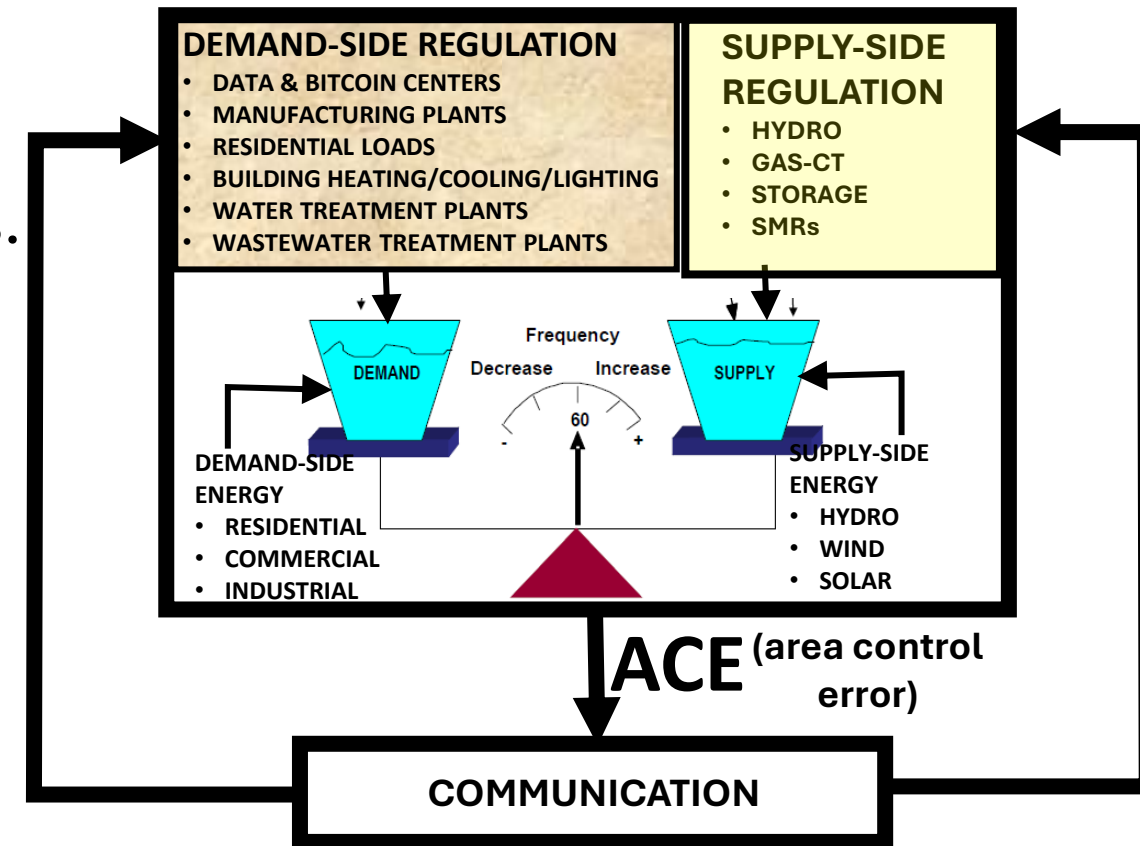
Increased wind & solar causes  
→ increased need for reserves;  
→ decreased fossil plants;  
→ decreased plants that can provide reserves.

### Reserves

- Regulation reserves
- Ramping reserves
- Short-term reserves

### Solution

Use what supply side is available (hydro, CTs, storage, Low carbon steam plants, ICE).  
Supplement with load control.

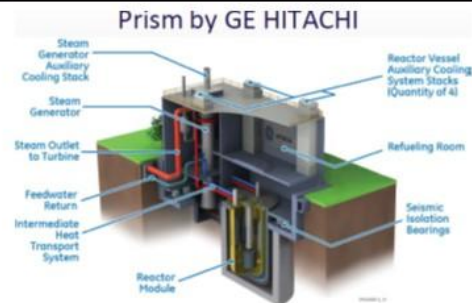
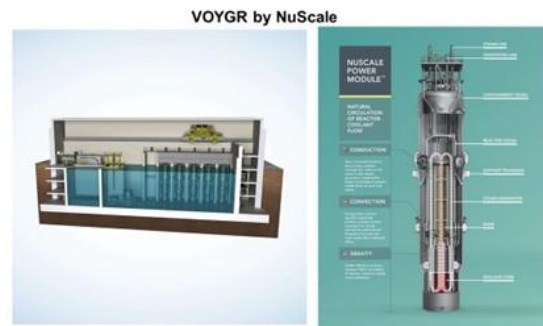


# 4. Ongoing work

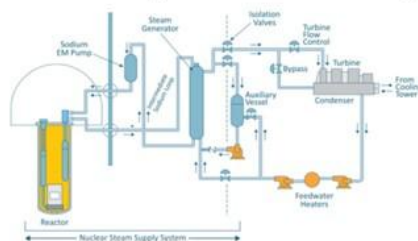
Senior Design Group 1

## Additional studies: Small nuclear reactors

Question: Given they are zero-carbon, and given their contributions to flexibility, reliability, & resilience, what is their threshold CAPX to become attractive?



Arc – 100 by ARC Clean Technology



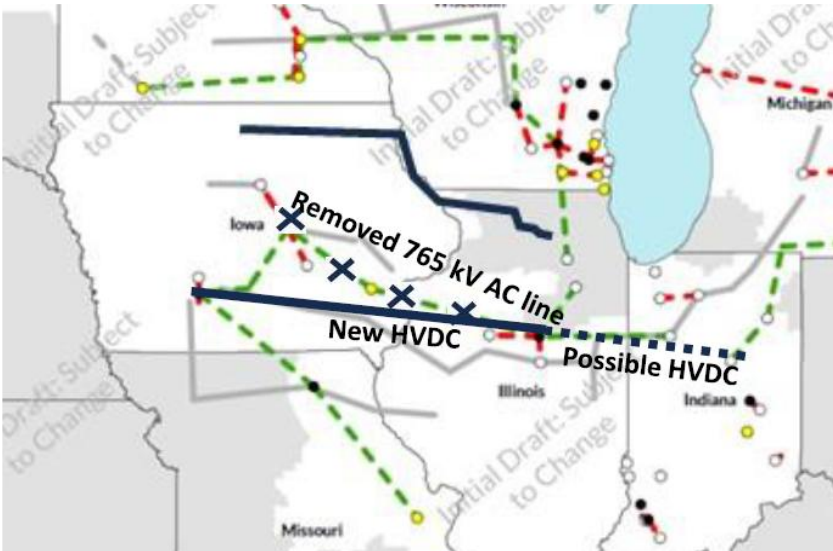
	Natrium by TerraPower [15],[16],[18]	VOYGR by NuScale [15],[16],[17],[18]	Prism by GE Hitachi [11],[12],[13],[14]	SMR-160 by Holtec International [9],[10],[19]	BWRX-300 by GE Hitachi [1],[2],[9]	ARC-100 by ARC Clean Technology [7]
Reactor Type	Sodium fast Reactor	Pressurized Water-Cooled Reactor	Sodium fast Reactor	Pressurized Water Reactor	Boiling Water Reactor	Sodium Cooled Reactor
Power Output (MWe)	345	308 (4 modules), 462 (6 modules), 924 (12 modules)	311	160	300	100
Overnight Cost (first in class)	\$4 billion	\$9 billion	\$3-4 billion	\$1 billion	\$1 billion	\$400 million
Overnight Cost (nth type)	\$1 billion	\$3.6 billion	\$1.5-2 billion	\$1 billion	\$700 million	\$400 million
Estimated Construction Period	36 months	36 months	36 months	36 months	27 months	34 months
Refueling Cycle	18 months	12-24 months	12-24 months	24 months	12-24 months	20 years
1st build benefit-to- cost Ratio	0.849937813	0.982923124	0.990779614	1.393353058	2.140124142	1.90656356
Nth build Benefit- to-cost ratio	2.325952749	1.939551286	1.680160548	1.393353058	2.62191442	1.90656356
Operational Date	2030	2029	2026	2029	2028	2030
Important Features	Thermal energy storage	Passive cooling, scalable output	Modular construction, passive cooling	Air-cooled condensers for flexible deployment in various climates	Natural circulation cooling, simple design	Passive Cooling, Cheaper Metallic Fuel
LCOE (\$/MWh)	\$50-\$60	\$64	\$58-60	\$81.50	\$35-50	\$55
Thermal Efficiency	41%	30%	37%	30%	34.50%	38%
Capital Expenditure (Billion \$ / GW)	2.9	7.79	6.43	6.25	2.33	4

# 4. Ongoing work

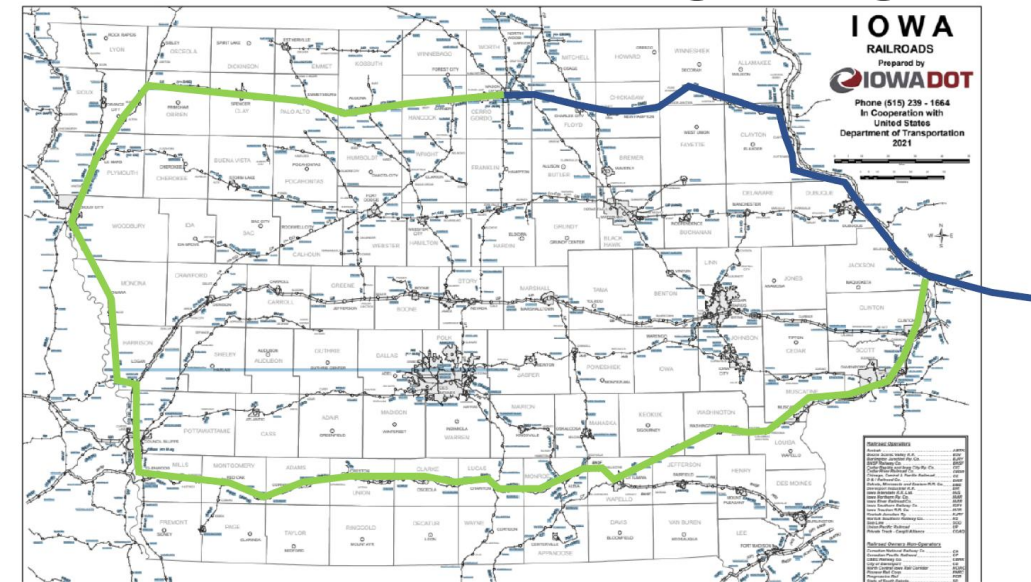
## Additional studies: HVDC

Senior Design Group 2

Explore HVDC vs 765 kV AC  
for Tranche 2.1



Study HVDC “ring design”







C. Phillips  
Ph.D  
Student



A.  
Jahanbani,  
Research  
Faculty

# 4. Ongoing work

## Additional studies: Data centers/load forecasting

### What Midwestern state is seeing the most data centers built?

AI Overview

**Iowa** is the Midwestern state currently experiencing the most data center construction. Major tech companies like Apple, Facebook, Google, and Microsoft are investing heavily in cloud campuses in Iowa, contributing to the state's data center boom. Additionally, Iowa benefits from a strategic location in the heart of the country, ample land, low energy costs, and minimal earthquake risk, making it an attractive location for data center development.



Here's a more detailed look:

**Iowa's Data Center Boom:**

Iowa has seen a significant increase in data center facilities and capacity in recent years.

**Strategic Location:**

Iowa's central location in the Midwest makes it a convenient hub for data centers, especially those serving national and international clients.

**Advantages for Data Center Development:**

Iowa offers several advantages, including ample land, affordable energy, and a stable regulatory environment.

**Major Tech Companies Investing:**

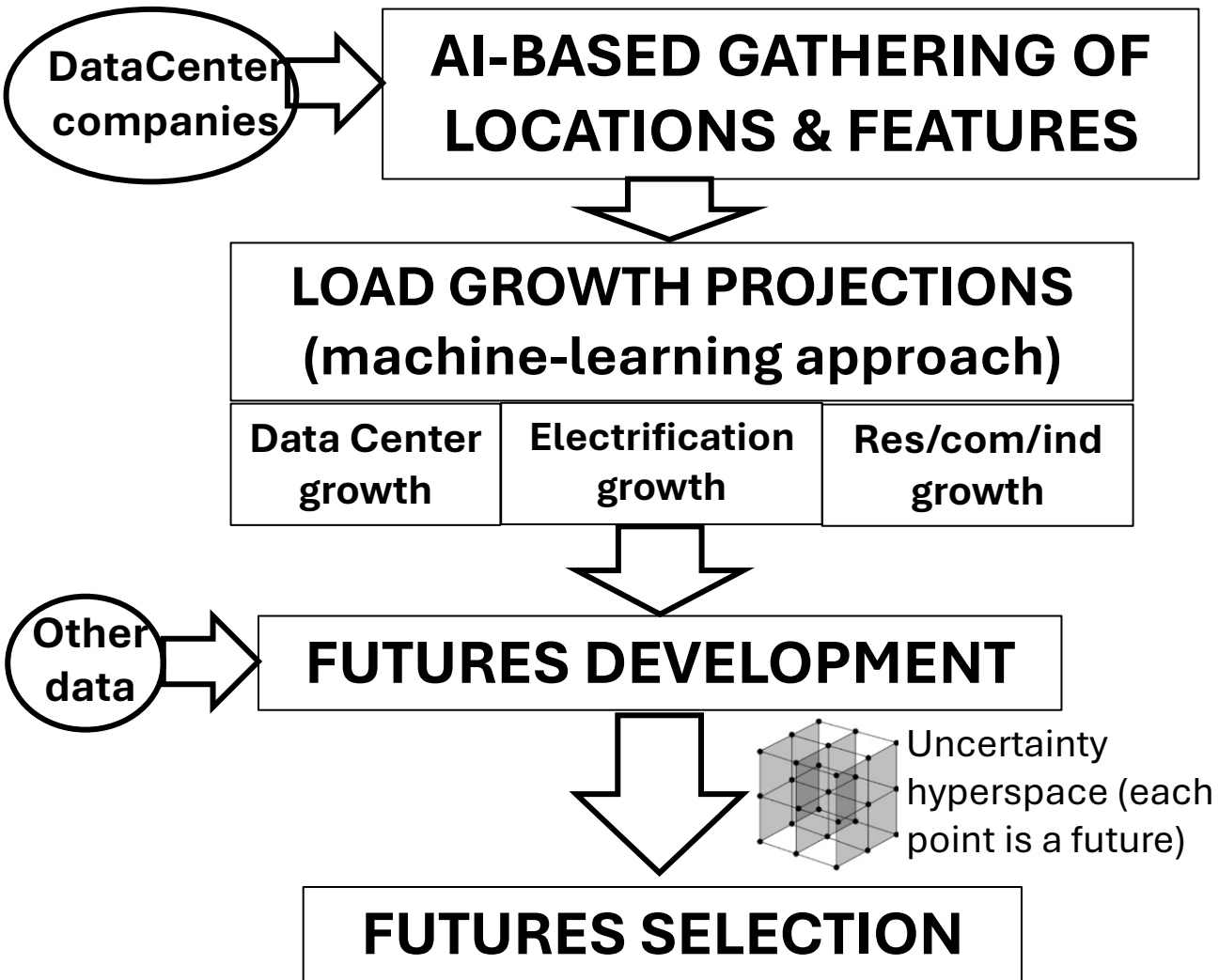
Prominent tech companies are investing heavily in Iowa, indicating the state's attractiveness for data center development.

### Where will data centers be built in Iowa?

AI Overview

Several data centers are planned or under construction in various parts of Iowa. Key locations include Cedar Rapids, Waukee (near Des Moines), Altoona (near Des Moines), West Des Moines, and Council Bluffs.

Here's a more detailed breakdown:





# 4. Ongoing work

## Robustness evaluation via folding horizon simulation

- $3^9=19,683$  futures, but ACEP uses 7
- How does final plan (core) perform when exposed to futures not used in ACEP design?
- Simulation rather than optimization  
→ fast.
- Penalties computed when plan violates a performance requirement, e.g., loss of load.

FHS performance: Total costs ( $T$ )

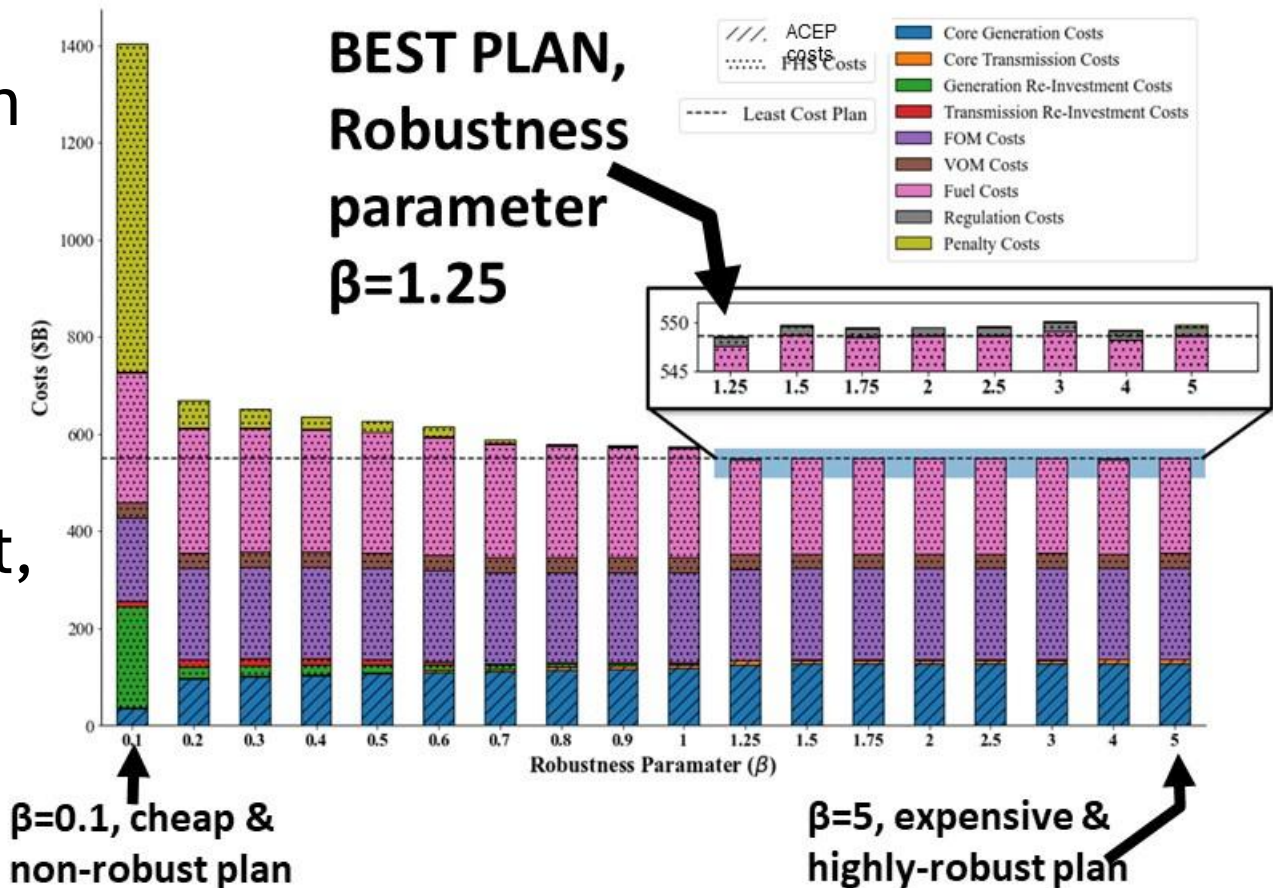
$$T = I^{ACEP} + O^{FHS} + P^{FHS} + R^{FHS}$$

$I^{ACEP}$ : Core gen/trans. Investment cost

$O^{FHS}$ : Scenario avg. FHS operational costs

$P^{FHS}$ : Scenario avg. FHS penalty cost

$R^{FHS}$ : Scenario avg. FHS re-invest costs



# Vision 1

## 5. Final Slide: Visions and survey results

Emphasize energy cost

Maintain avg annual R/C/I cost of 12, 10, 6 ¢/kwh (EIA).

# Vision 2

Emphasize CO<sub>2</sub> reduction

Cut 2038 CO<sub>2</sub> levels by 80% of 2005 levels

# Vision 3

Emphasize energy export

Produce 2 times in-state electric energy requirements.

# Vision 4

Emphasize resilience

Reduce extreme event cost of electric outages by 60%.

# Vision 5

Balanced

Seek a balanced portfolio of above 4 features.

Surveyed people of Iowa:

~2100 responses from 93/99 Iowa counties

Rank	Ag land owners	\$0-30k income	\$91-120k income	Conser-vative	Liberal	W/wrk exp in enrgy sctor
1	V1-cost	V2-CO <sub>2</sub>	V4-res	V1-cost	V2-CO <sub>2</sub>	V4-res
2	V4-res	V1-cost	V1-cost	V4-res	V4-res	V1-cost
3	V2-CO <sub>2</sub>	V4-res	V2-CO <sub>2</sub>	V3-exp	V1-cost	V2-CO <sub>2</sub>
4	V3-exp	V3-exp	V3-exp	V2-CO <sub>2</sub>	V3-exp	V3-exp

These results are “tip-of-the-iceberg” – i.e., there is much more...

- Many more categories, i.e., many more columns
- Ability to quantify not only ranking but level of support
- Ability to assess understanding of vision
- Ability to assess reasons for ranking/support

➔ Intention is to provide investment plan for reaching each of the visions, then communicate Iowan’s support for each of those visions.

**Next step: Develop plans for each of the 5 visions.**



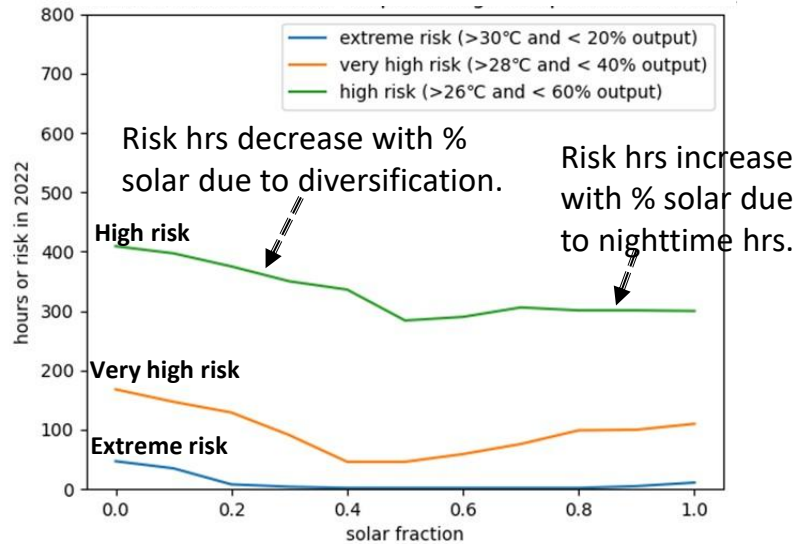
# Unused Slides

# 5. Climate Effects

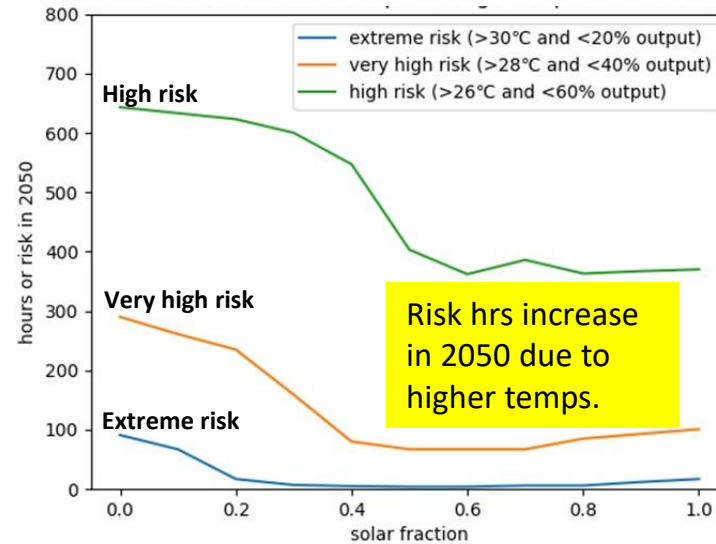
## Analysis used NREL's Sup3rCC high-resolution 2050 climate data set

See [www.nrel.gov/docs/fy23osti/85711.pdf](http://www.nrel.gov/docs/fy23osti/85711.pdf)

2022



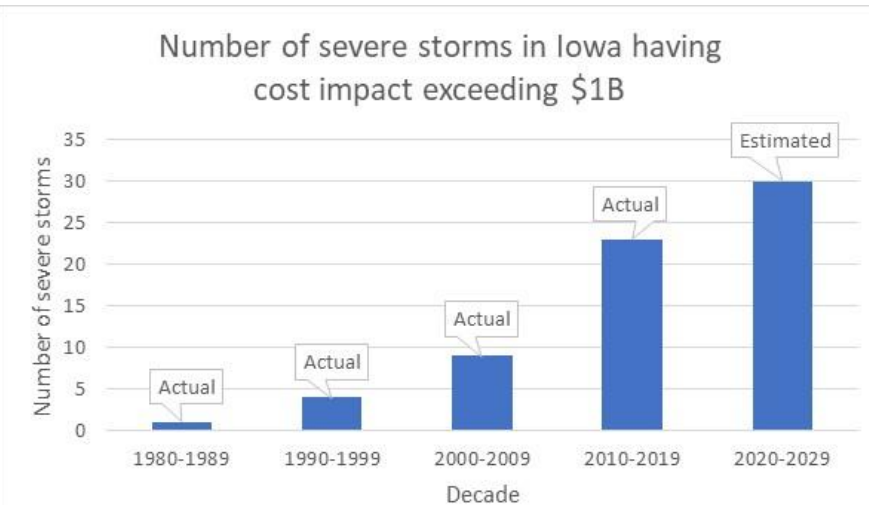
2050



High-risk conditions (high temp & low wind/solar)

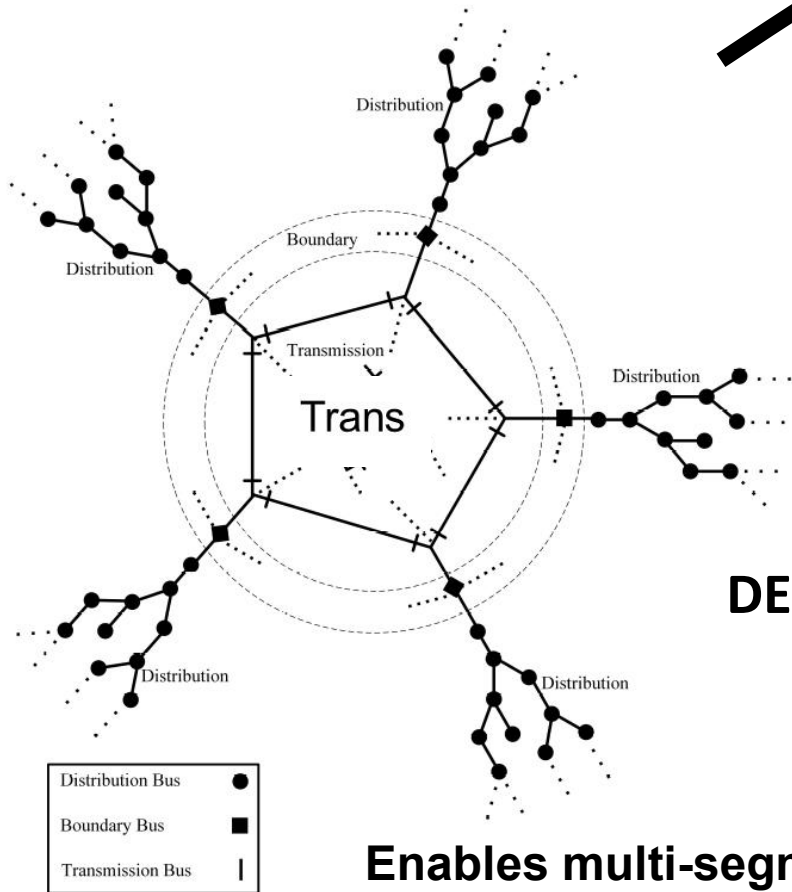
## Analysis used NOAA's Billion-dollar climate disasters

See [www.ncei.noaa.gov/access/billions/events/US/1980-2023?disasters\[\]=all-disasters](http://www.ncei.noaa.gov/access/billions/events/US/1980-2023?disasters[]=all-disasters)



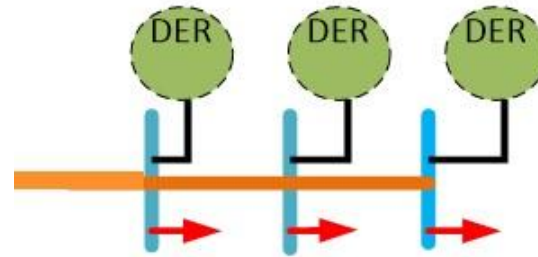
Extreme events (very high wind)

# Modeling – DER Representation

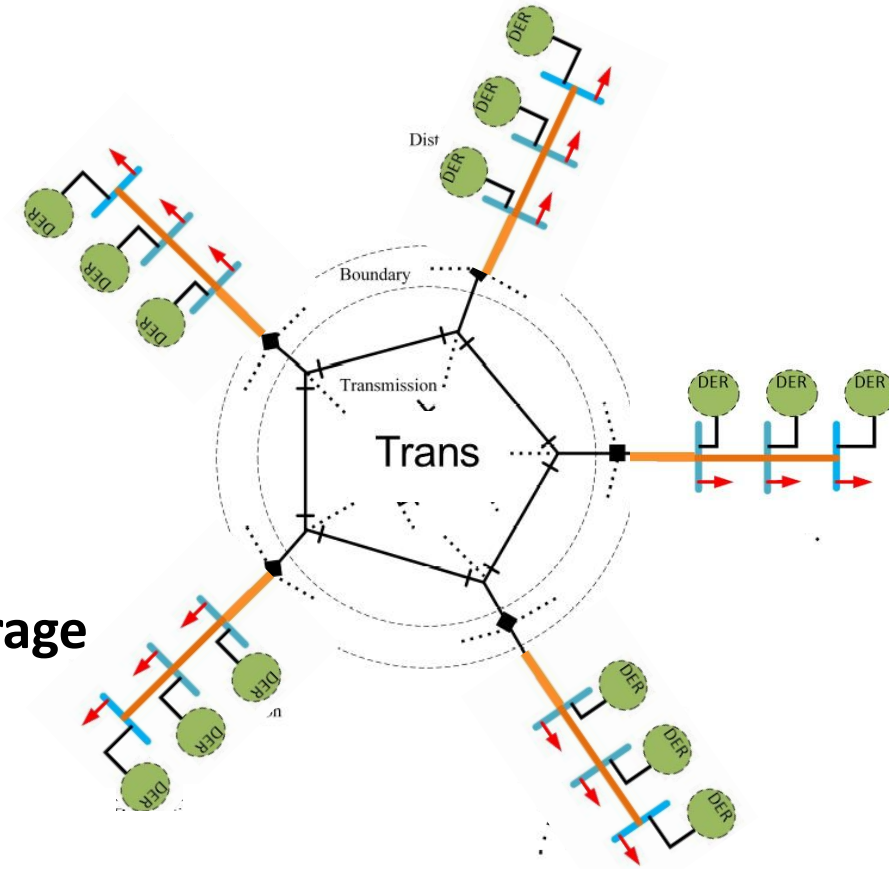


Model one N-seg feeder  
at each trans load bus.

N=3 segments



DER = EE, DR, D-PV, microT, & D-storage



Enables multi-segment loss representation & investment without increasing model size too much. Can choose N according to computation/fidelity needs.

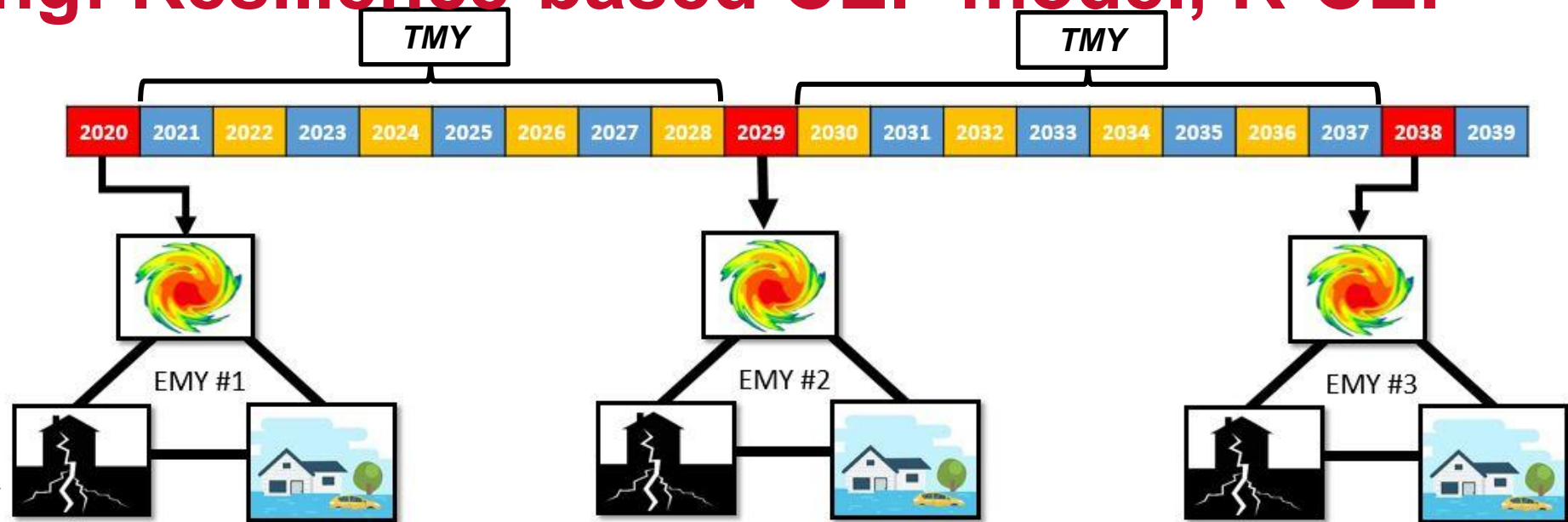


# Internal modeling: Resilience-based CEP model, R-CEP

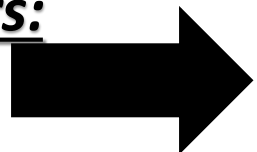
## Balance

- investments enhancing performance under “normal” conditions
- with investments enhancing performance under extreme events.

by integrating extreme event modeling within exp planning

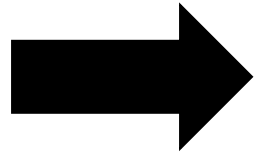
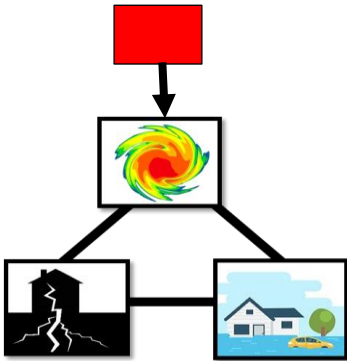


## Typical meteorological years:



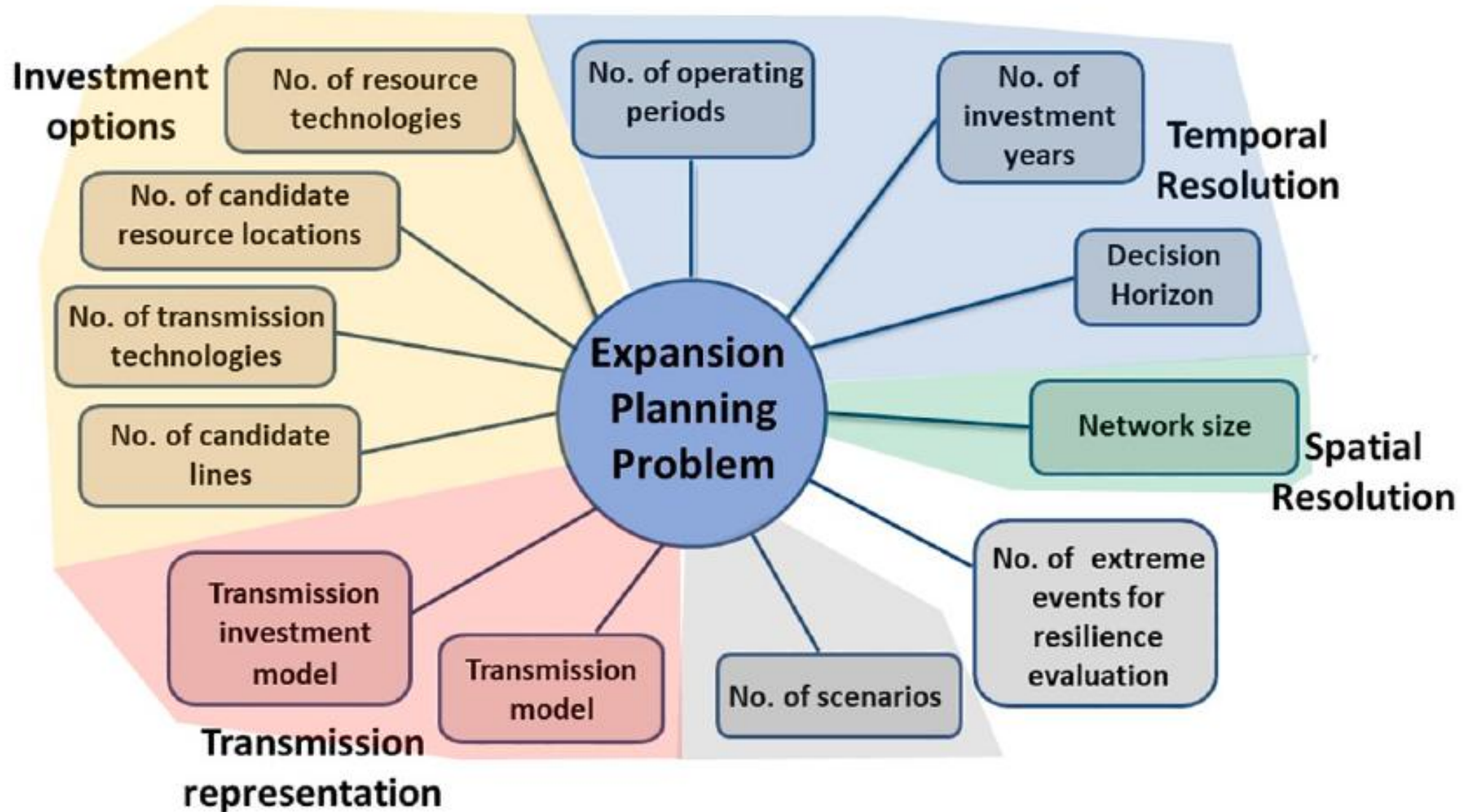
- Models normal conditions
- Uses normal ratings on components
- Investments driven by component rating & need to satisfy power demand

## Extreme meteorological years:



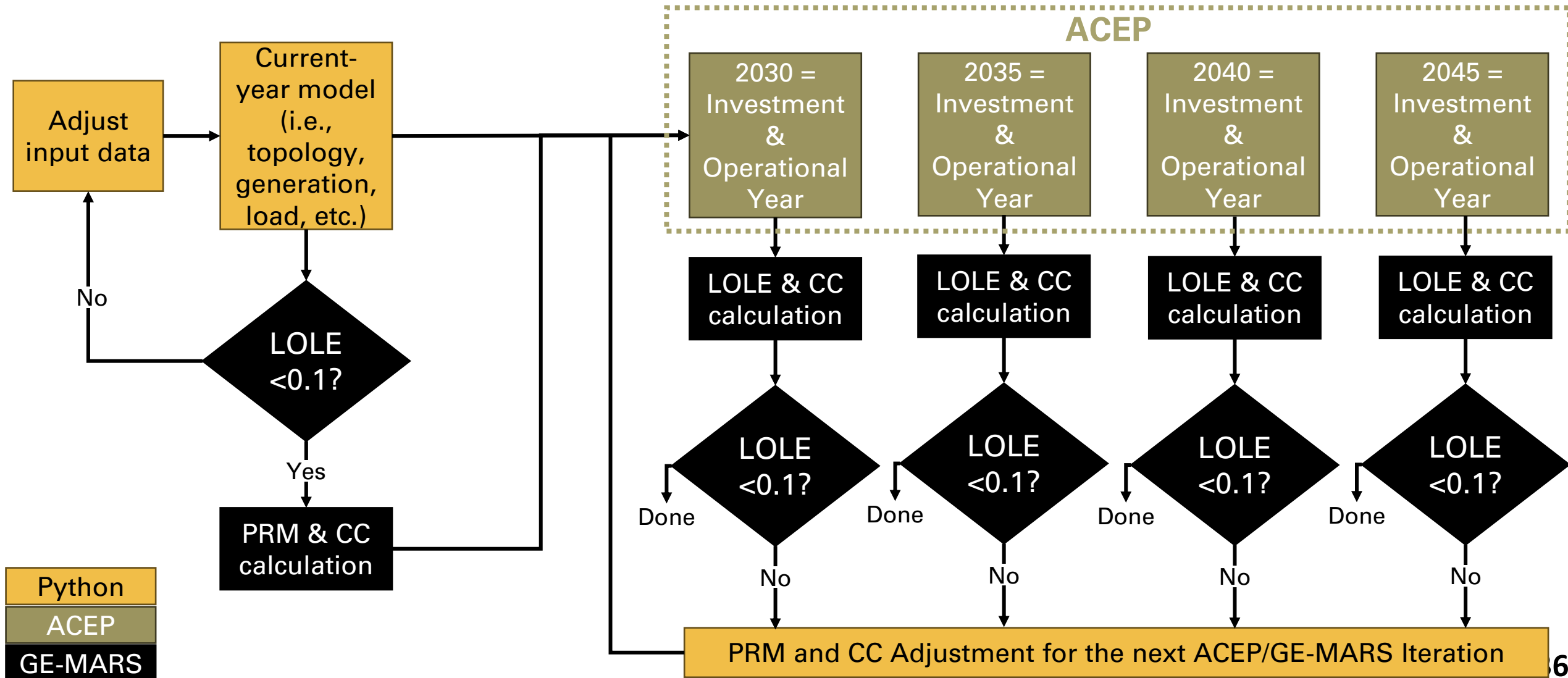
- Models extreme event scenarios:
  - Hurricanes
  - Tsunami/flooding
  - Earthquakes
  - Other: winter storms, wildfires, geomagnetic storms, etc.
- Uses **de-rated** components based on event intensity and component resilience level to identify optimal resilience investments
- Investments driven by component derating & need to satisfy power demand

# Modeling Fidelity and Computational Tractability



# Approach to include CC calculation into ACEP/GE-MARS

- Ongoing work: Implementing an iterative accreditation method in GE-MARS that dynamically updates capacity credit (CC) values over the planning horizon, using the Direct Loss of Load (D-LOL) approach proposed by MISO to reflect each resource's contribution to system reliability during periods of highest system stress.





# Approach to include CC calculation into ACEP/GE-MARS – Initial Results

Capacity credit values for wind and solar in MISO North, Central, and South were obtained using the D-LOL method in the latest iteration of the ACEP/GE-MARS tool for a reduced model of MISO with  $\beta$  set to 1.

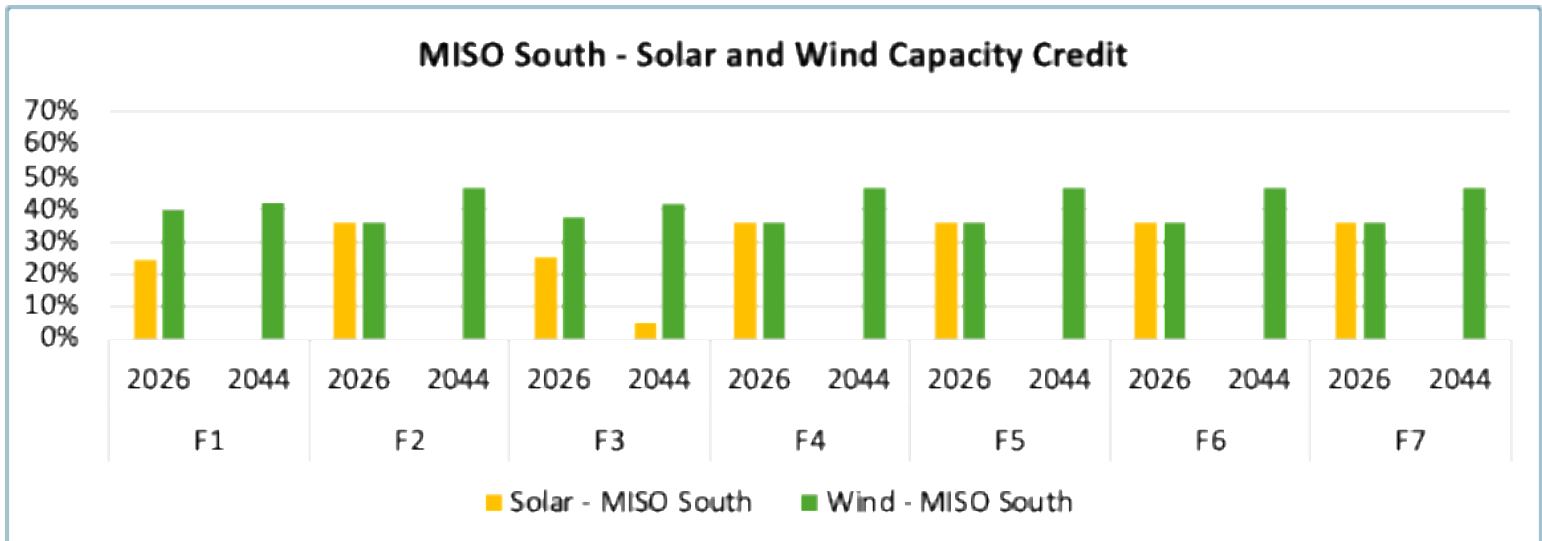
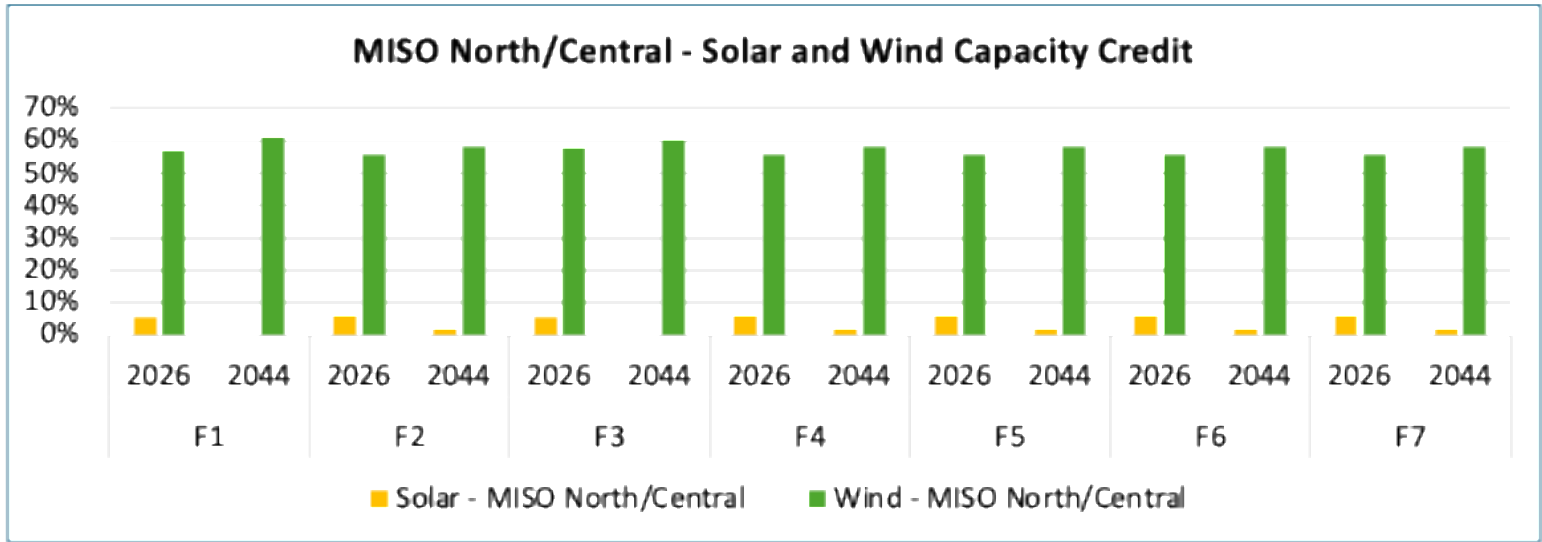
- **Wind Capacity credit:**

Capacity credit values remain relatively stable across futures and years (around 60% in MISO North/Central, and 40% in MISO South), indicating a consistently strong contribution of wind to resource adequacy in the region.

- **Solar Capacity credit:**

In 2026, solar capacity credit values tend to be higher in MISO South, generally ranging from 20–40%, compared to lower values in MISO North/Central (below 10%). This highlights the differences that exist across various geographic locations.

By 2044, solar capacity credit values reach minimal levels, approaching 0% across both MISO North/Central and MISO South in several futures, highlighting a reduction in solar's reliability contribution during critical periods under evolving system conditions.



**Initial results highlight the need for adaptive planning that considers regional differences and evolving system dynamics!**

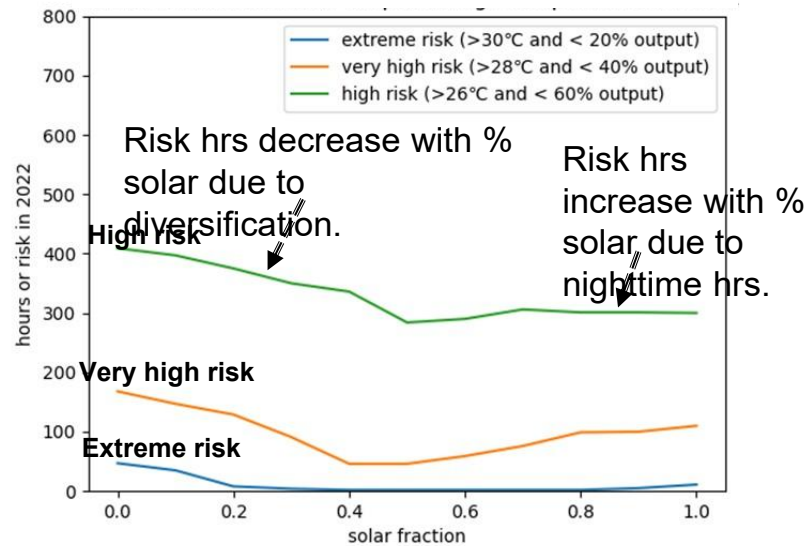
# 4b. Ongoing work – motivation for resilience

Analysis used NREL's Sup3rCC  
high-resolution 2050 climate data set

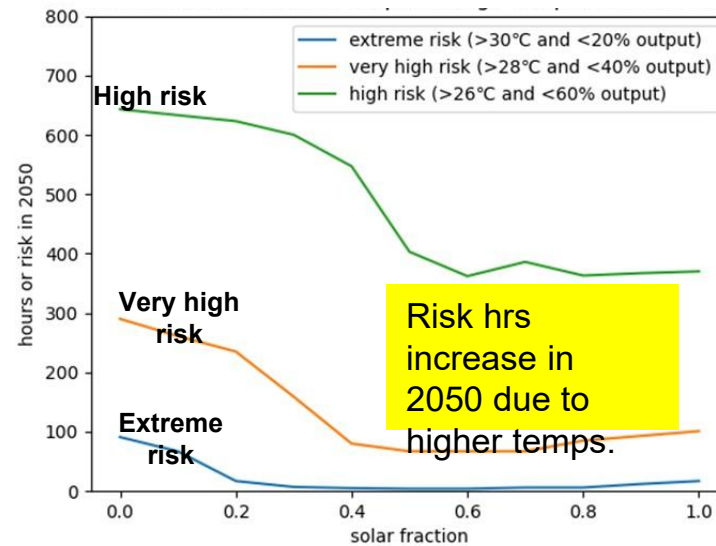
See

[www.nrel.gov/docs/fy23osti/85711.pdf](http://www.nrel.gov/docs/fy23osti/85711.pdf)

2022



2050



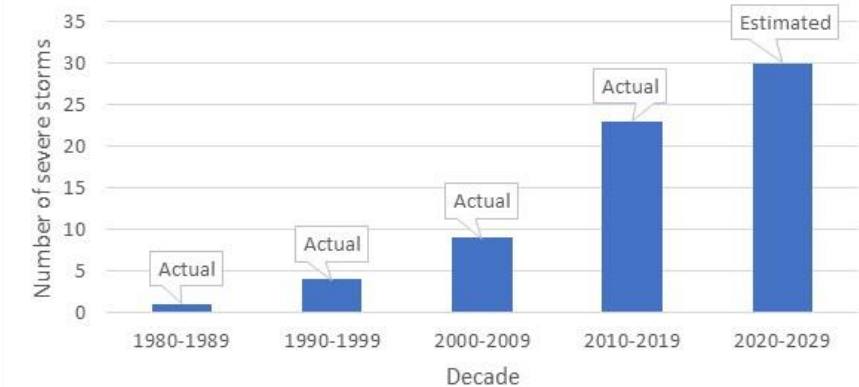
High-risk conditions (high temp & low wind/solar)

## Analysis used NOAA's Billion-dollar climate disasters

See

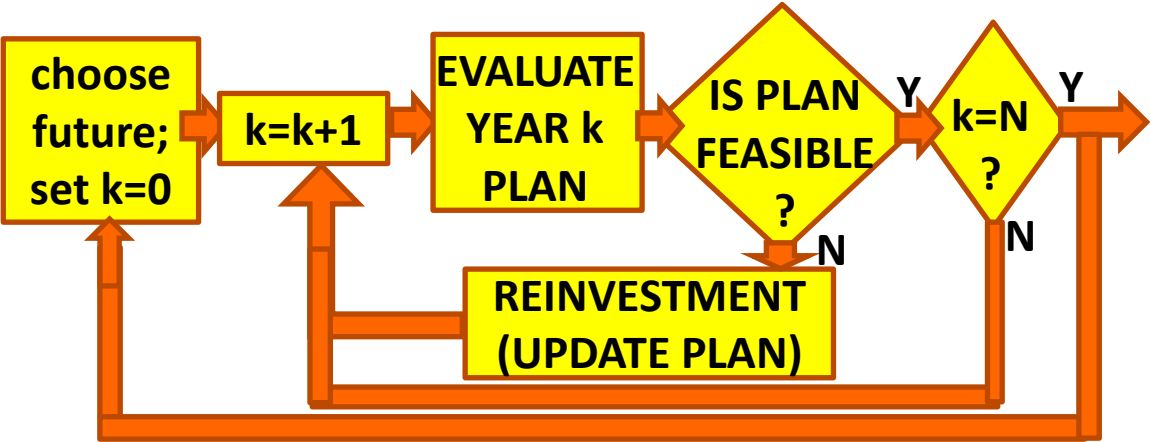
[www.ncei.noaa.gov/access/billions/events/US/1980-2023?disasters=all-disasters](http://www.ncei.noaa.gov/access/billions/events/US/1980-2023?disasters=all-disasters)

Number of severe storms in Iowa having cost impact exceeding \$1B



Extreme events (very high wind)

# 3d. Robustness: develop evaluation tool



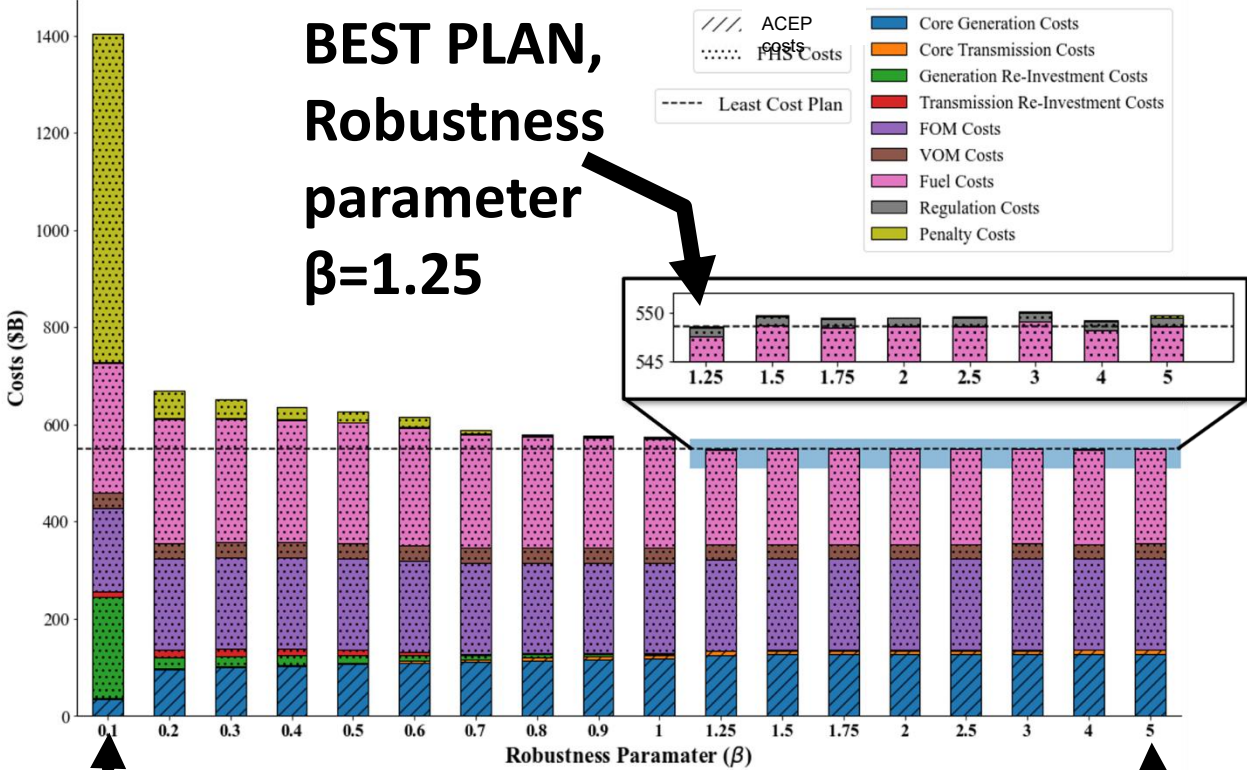
## Evaluates/Refines a plan

- Whereas plan design (ACEP) optimizes over 5-10 futures, FHS simulates over 100's of futures;
- FHS exposes plan to 1 future at a time;
- Assesses plan robustness; enables plan refinement via reinvestments;
- Time steps are 3 months (seasonal, each year).

FHS performance: Total costs ( $T$ )

$$T = I^{ACEP} + O^{FHS} + P^{FHS} + R^{FHS}$$

$I^{ACEP}$ : Core gen/trans. Investment cost  
 $O^{FHS}$ : Scenario avg. FHS operational costs  
 $P^{FHS}$ : Scenario avg. FHS penalty cost  
 $R^{FHS}$ : Scenario avg. FHS re-invest costs



**BEST PLAN,**  
**Robustness**  
**parameter**  
 **$\beta=1.25$**

$\beta=0.1$ , cheap & non-robust plan

$\beta=5$ , expensive & highly-robust plan