Statistical Learning Applied to Climate-Water-Energy Impacts Scenarios

Mort Webster (PSU), Duc Nguyen (Ascend Analytics), Jesse Bukenberger (EPRI),
Jonathan Celaya (PSU), Renee Obringer (PSU), Karen Fisher-Vanden (PSU)

Principal Investigators Meeting
Earth and Environmental Systems Modeling (EESM) Program
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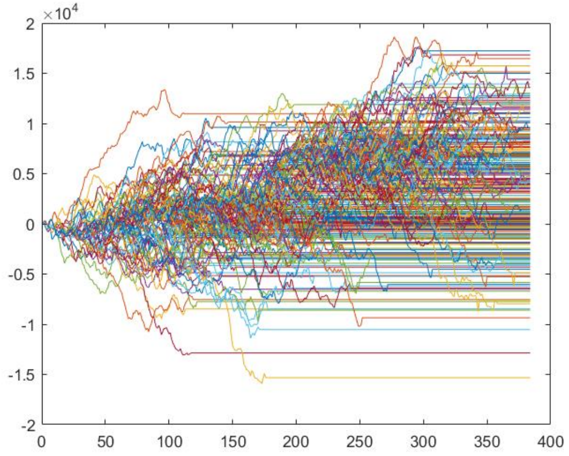
Managing Uncertainty: Scenarios

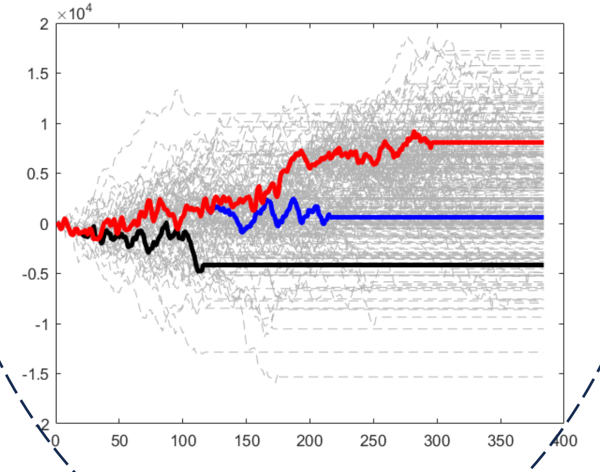
Scenario Generation

Scenario Reduction

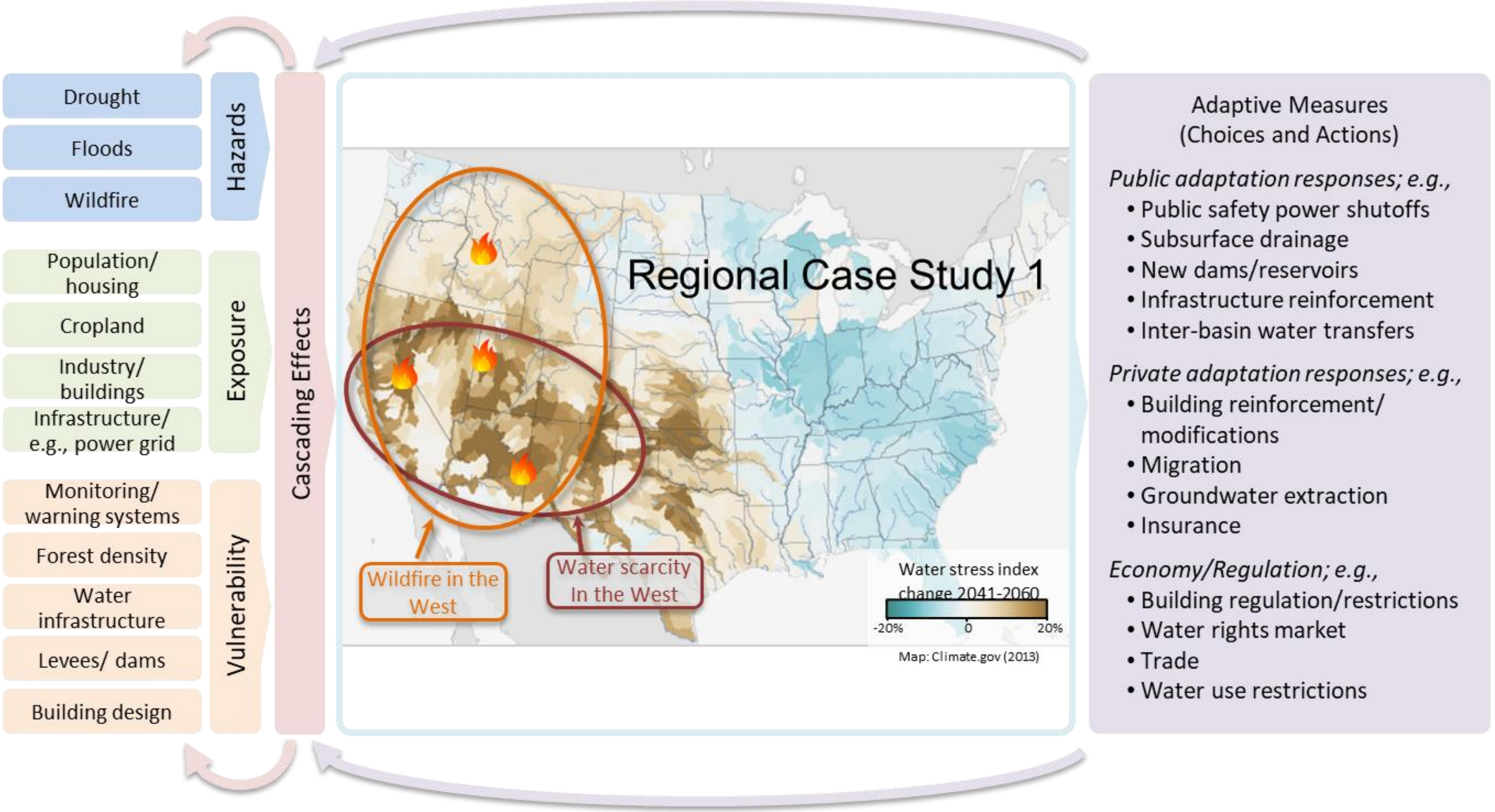
Risk Assessment: Simulation

Risk Management: Optimization





PCHES-ADAPT: visual project overview (Western US Case Study)



We seek to understand the **multisector dynamics (MSD) influences** on cascading risks associated with **hydrological stress** and **wildfire** in the U.S. West

How do **human and institutional responses** to drought and wildfire to heighten or mitigate risk to the MSD system?

To what extent can **adaptive and resilient strategies** mitigate these risks?

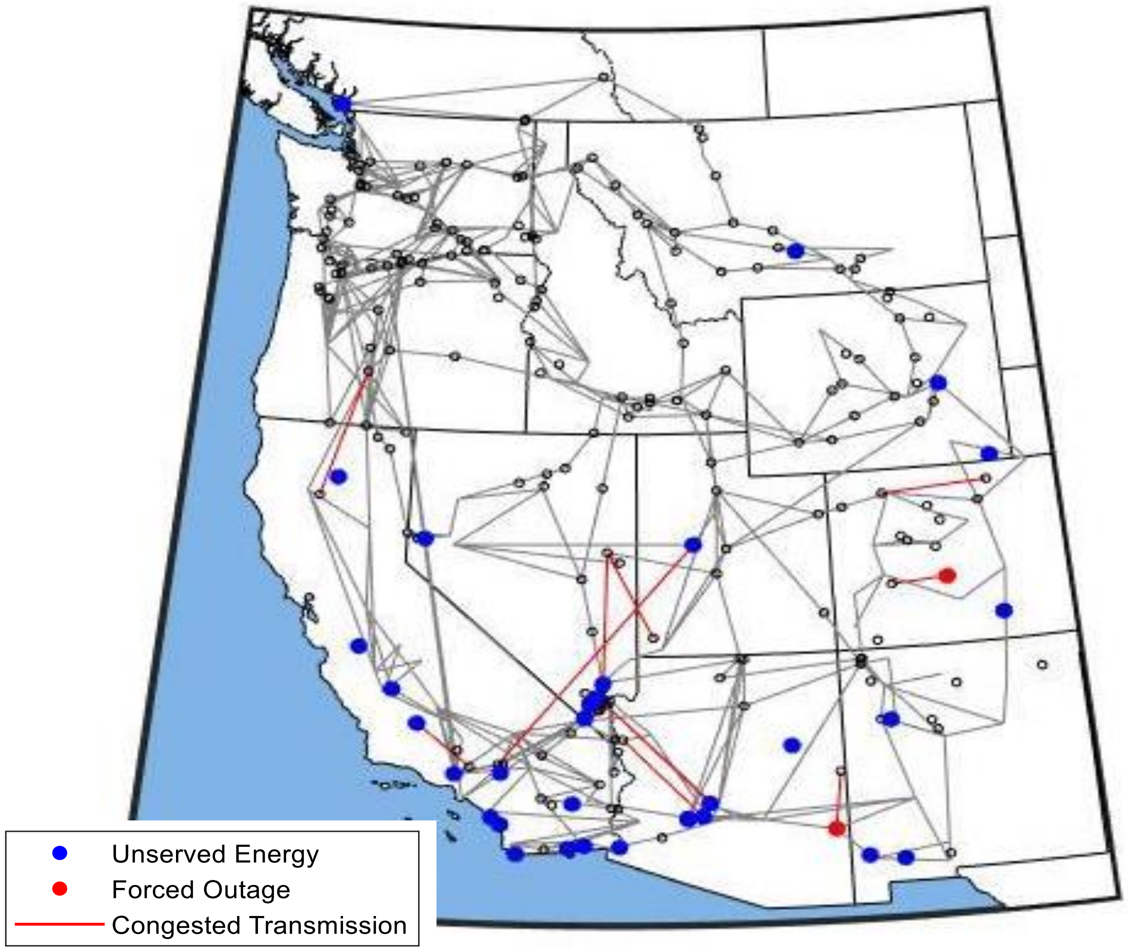
PennState · TEXAS · University of New Hampshire · Stanford University · Boston University · Cornell University · Illinois · Columbia · Purdue University · Dartmouth

Hydrology-Power-Economy Impact Example

Example:

- Future climate forcing
  - ➢ Higher surface water temperatures
- Higher water temperatures
  - ➢ Forced power plant outage
- Power rerouted
  - ➢ Transmission congestion
- Unmet electricity demand
  - ➢ Distant from the forced outages

Impacts, teleconnections for one future scenario



Hydrology-Power-Economy Impact Scenarios

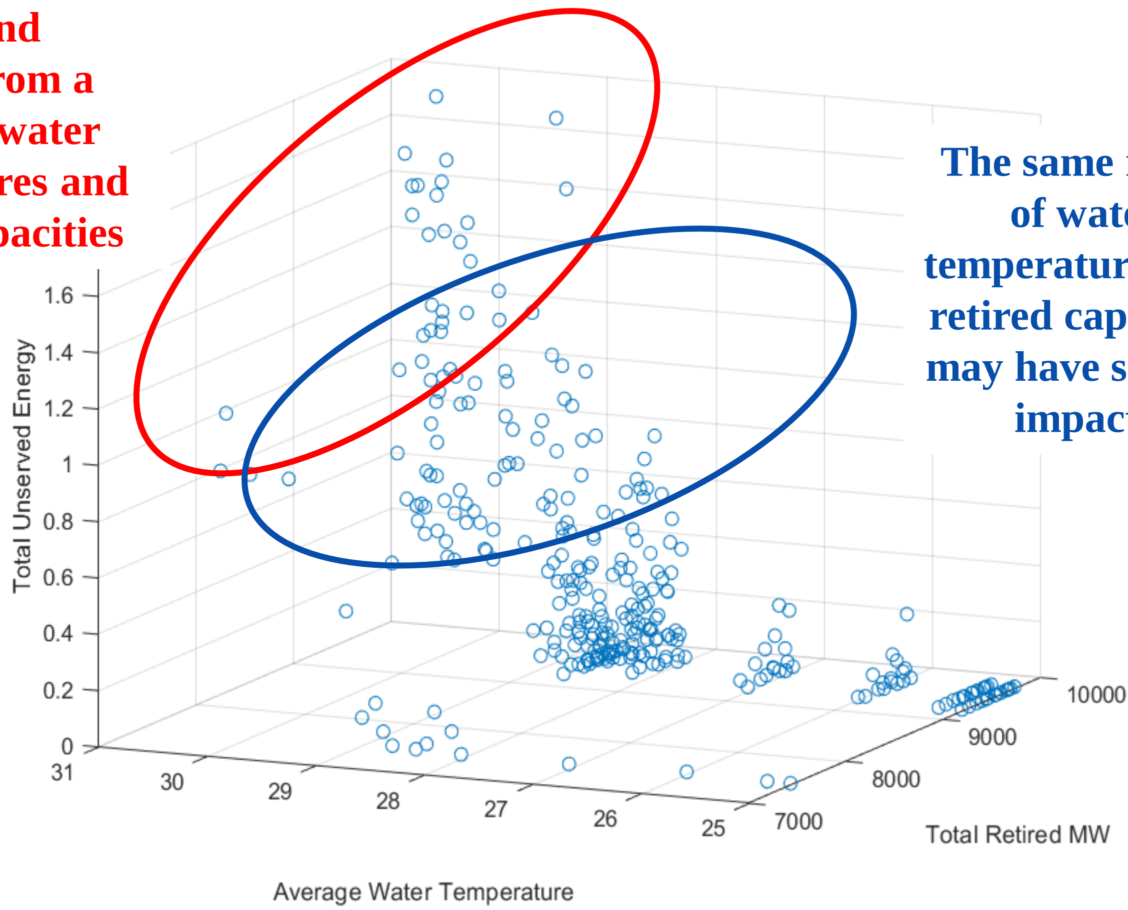
Infrastructure Resilience Planning:
- System operators must plan now:
    - Where to produce power
    - Where to add transmission lines

Uncertainty:
- Alternative futures must be planned for
- We can create many scenarios

Motivating Questions:
- How can I organize the many possible futures?
- Do I need to simulate every scenario?
- Do planners need to consider every scenario?

324 scenarios of future climate, hydrology, and changes to power grid

Greatest unserved demand results from a range of water temperatures and retired capacities



The same range of water temperatures and retired capacities may have smaller impacts

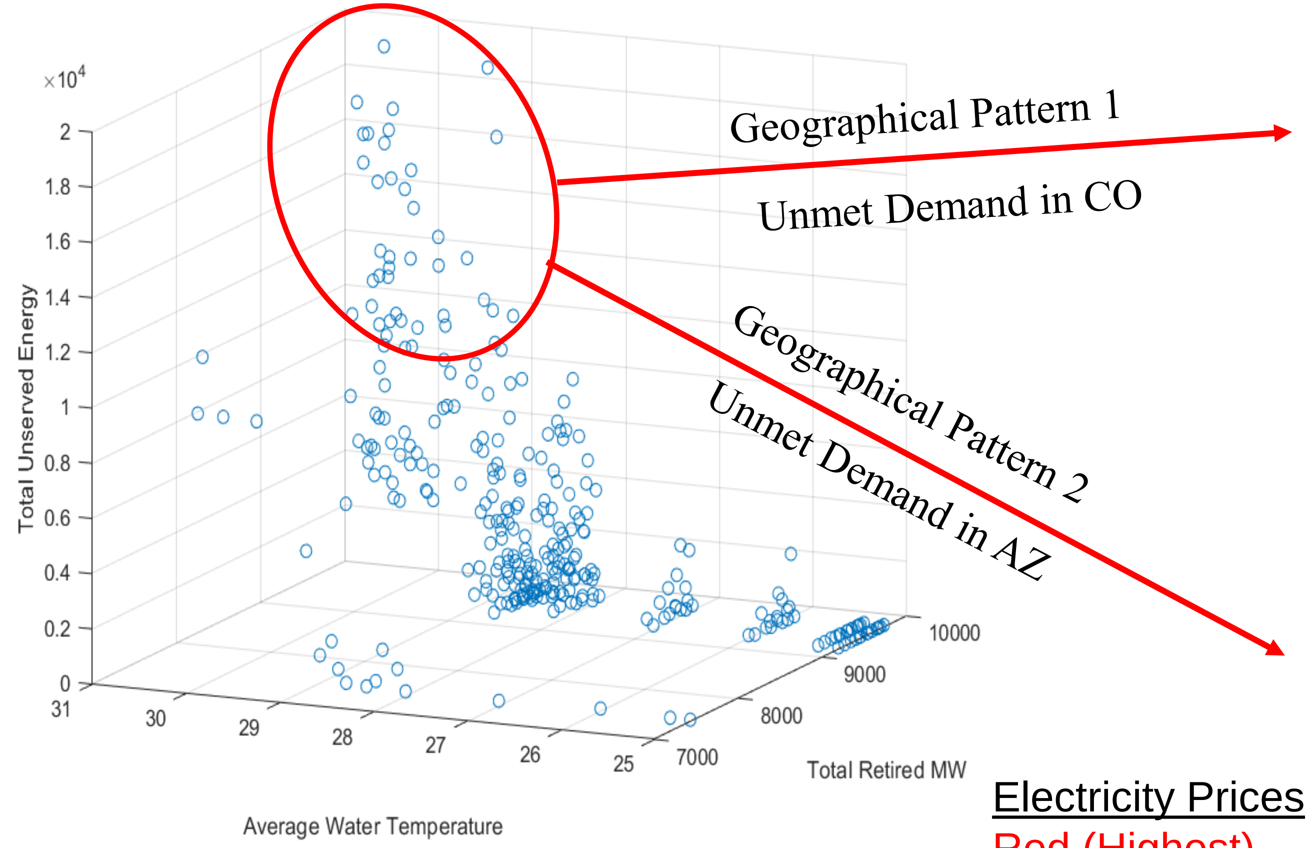
Step 1: Detect Common Patterns in Outcomes

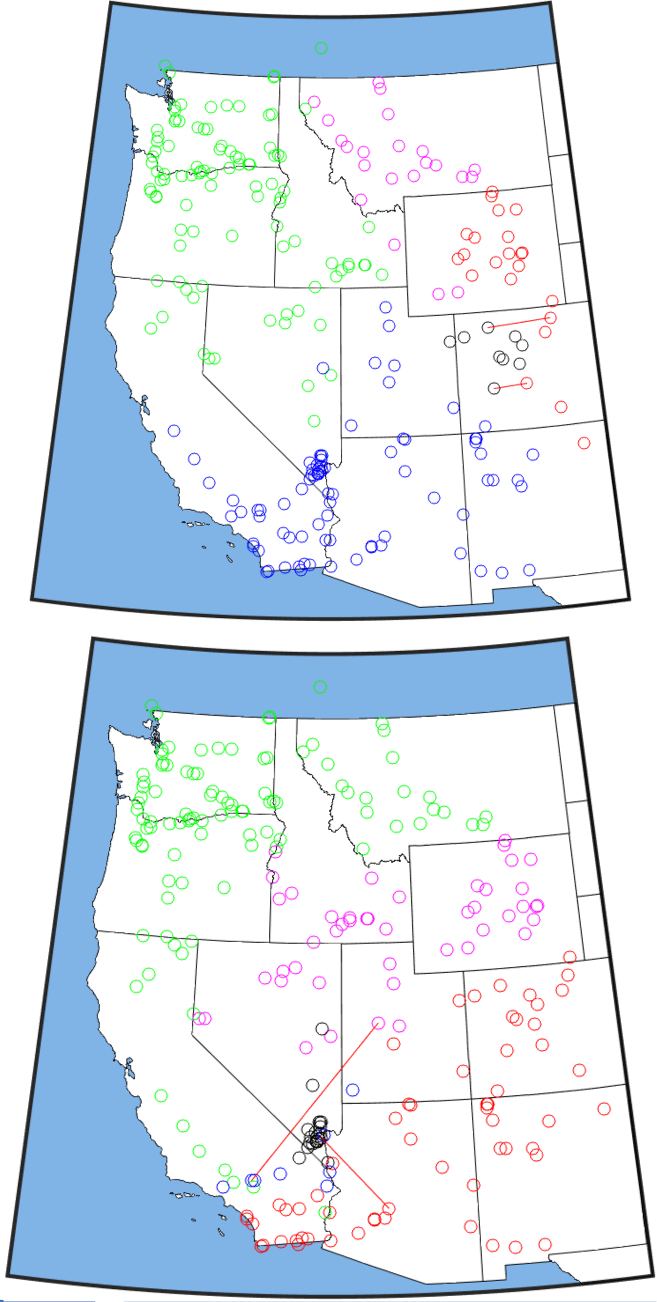
Apply *K*-means clustering to:

- Electricity Prices
- Transmission Congestion

Finding:

- Many scenarios of failure
- But only four distinct geographic patterns





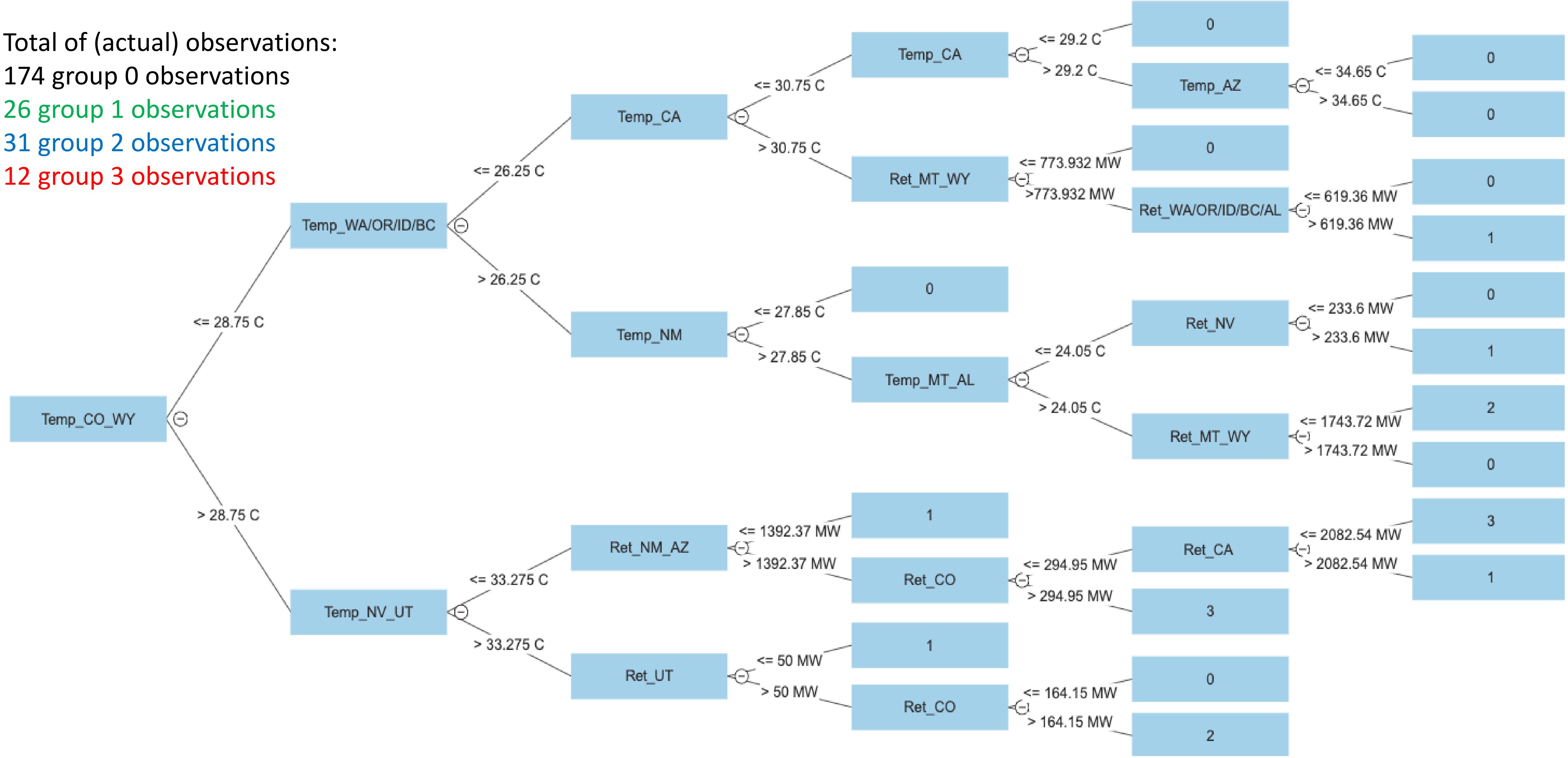
Electricity Prices
Red (Highest)
Pink
Green
Blue
Black (Lowest)

Step 2: Apply Statistical Models for Prediction

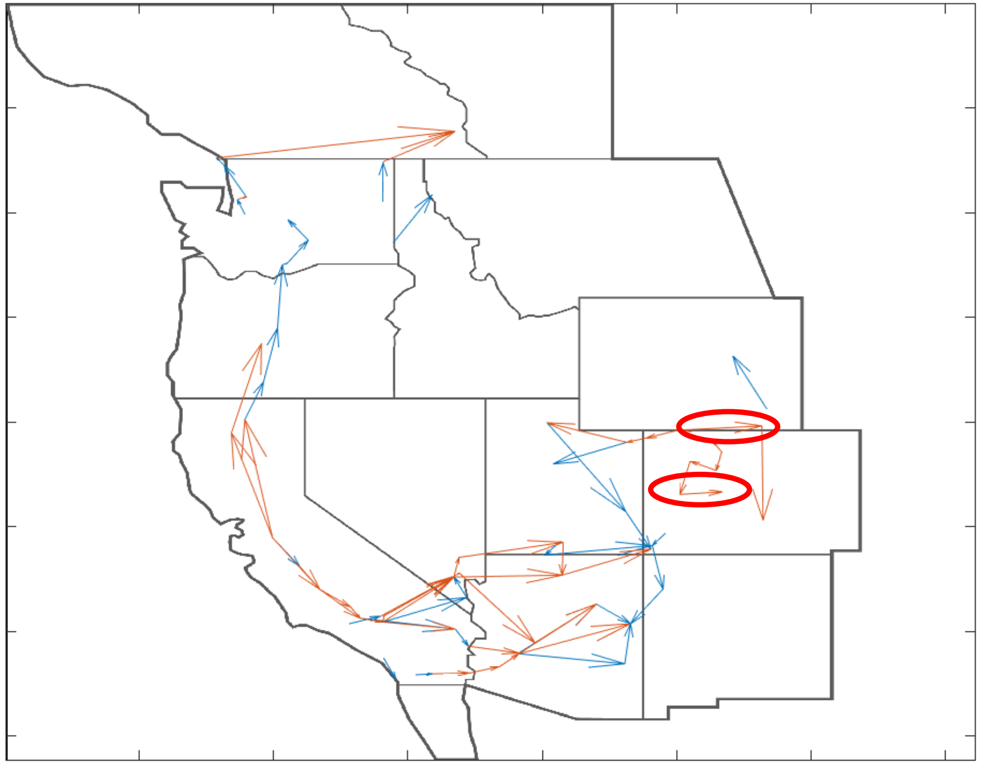
- **Next Question:**
  - How can I know which group a scenario's outcomes will belong to ***without*** simulating it?
- **Method:** Classification Tree
  - Partitions data set (all scenarios) by predictor data to differentiate groups (i.e., partition into 2 groups by one variable, then partition again based on another variable, etc.).
  - Because of randomness, ambiguity, no one tree will be a perfect predictor
- **Better Method:** Random Forest
  - Independently fit MANY classification trees
  - Use the weighted average of all trees to predict group from a scenario
- **Representative Tree**
  - Cannot visualize a random forest: good predictor but "black box"
  - Find a single tree that is minimum distance from all trees in random forest

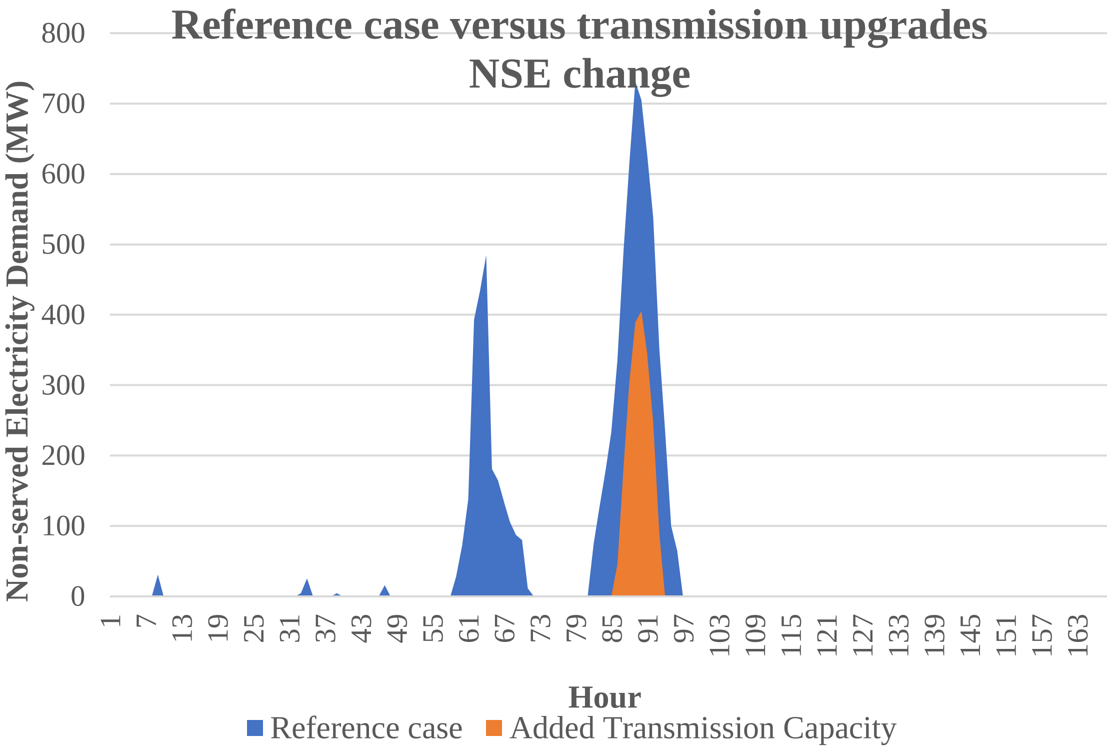
Example Classification Tree for 324 Scenarios

Total of (actual) observations:
174 group 0 observations
26 group 1 observations
31 group 2 observations
12 group 3 observations



Step 3: Test whether the Clusters are Useful for Adaptation





Example:

- Select one scenario from Group *N*
- Double transmission capacity for congested lines -> reduction in unmet electricity demand
- Test the same change for other scenarios in Group *N*
- Verify that the unmet energy is also reduced in these scenarios (yes, it is!).

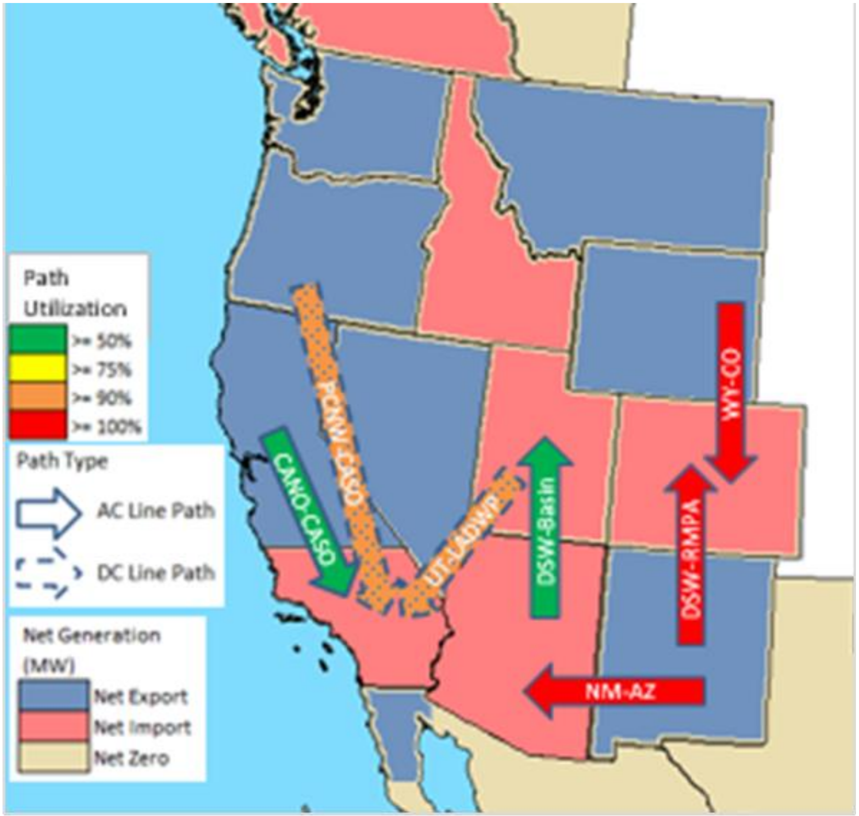
Quick Summary

Starting point:

- Unlimited number of high-resolution scenarios
- Easy to create scenarios
- Hard to simulate all of them in model
- Even harder to know what to do with the results afterwards

1. **How do I organize large set of scenarios?**
    - Cluster into groups with similar ***outcome*** patterns
2. **How can I predict which group a new scenario will belong to?**
    - Statistical learning tools (Random Forest)
3. **What to provide to infrastructure planners?**
    - Representative scenarios from each impact pattern group

Where will future transmission lines be?



Questions?

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