Generation Expansion Planning Studies

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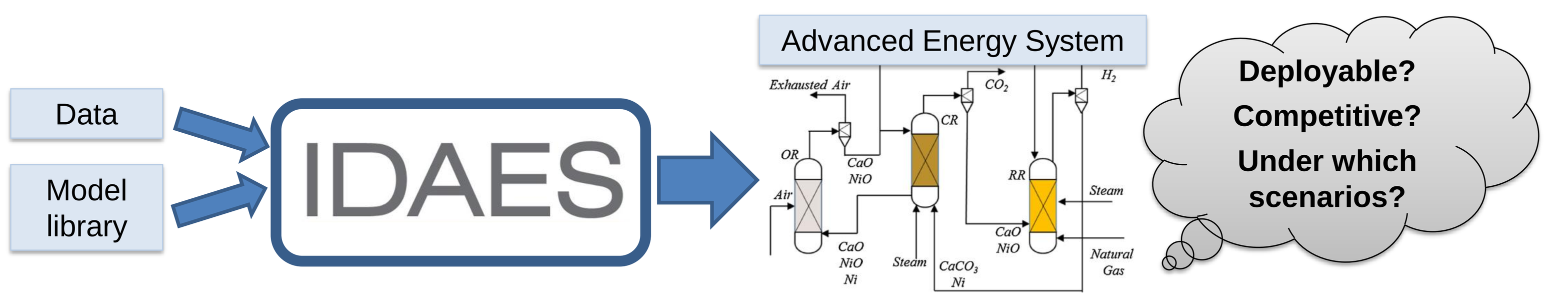
Motivation



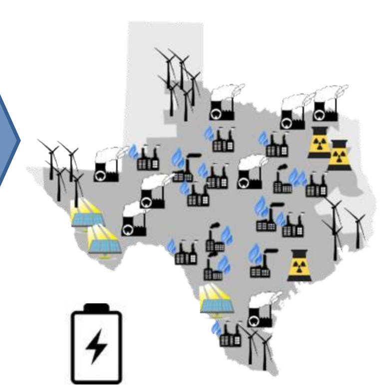
The major **goal** of this project is to help understanding the characteristics needed to develop **new advanced energy generation technologies** that can be **competitive** in the anticipated future market considering all sources of competition.

Problem statement

INPUT

- Energy source (coal, natural gas, nuclear, solar, wind*);
- **Generation** and **storage** technologies;
- Location;
- Nameplate capacity;
- Age and expected lifetime
- Emissions
- Operating and investment costs
- **Operating data**
- Renewable generation profile.
- Load demand

Minimize the **expected net present cost**.

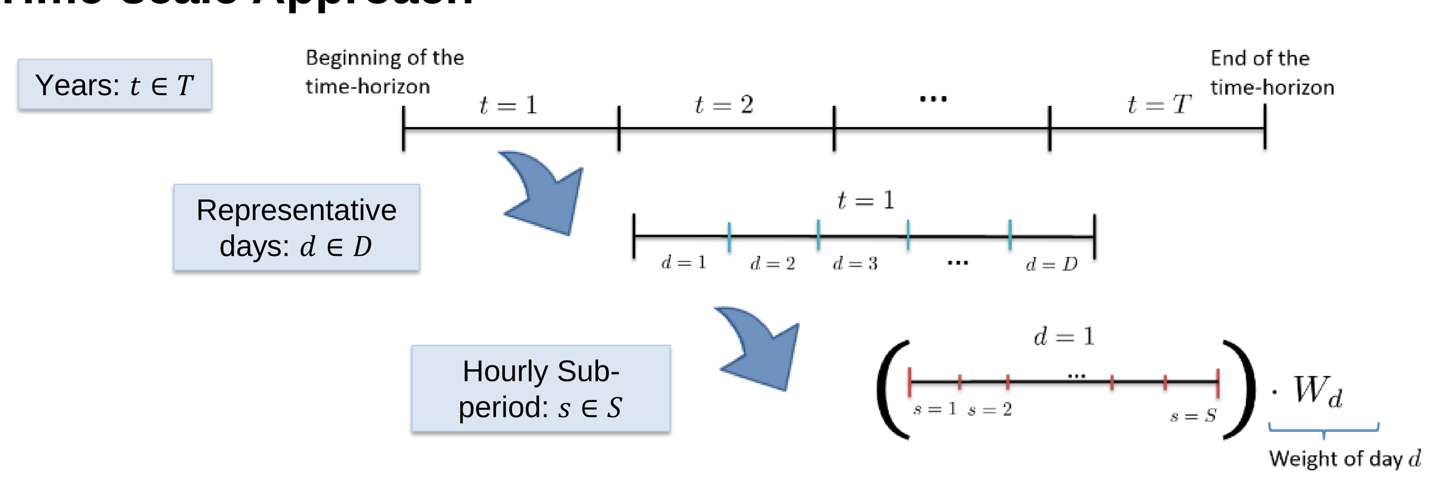


OUTPUT

- **Location**, **year**, **type** and **number** of **generators** and **storage units** to install;
- When to **retire** them;
- Whether or not to **extend** their lifetime;
- Approximate power flow between locations;
- Approximate operating schedule

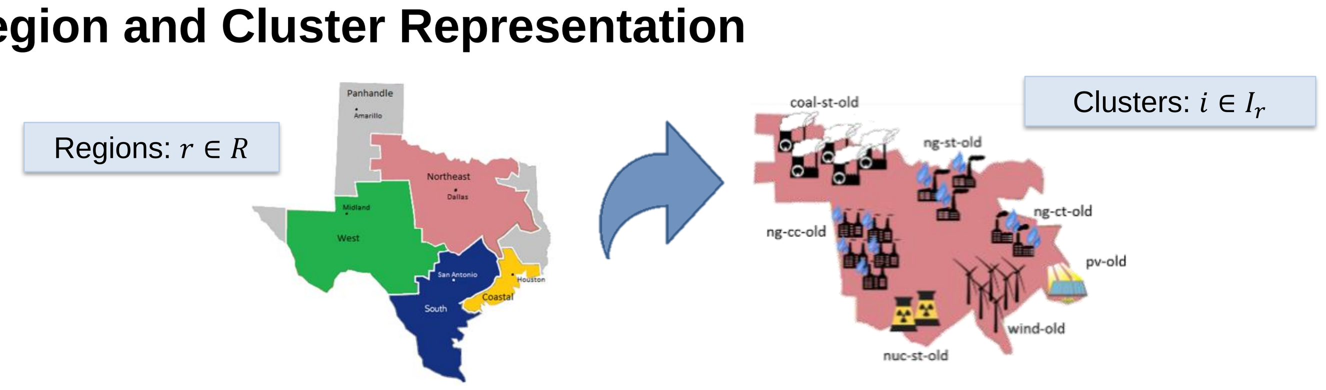
Modeling strategies to tackle multi-scale nature

Time-scale Approach



Sampling to reduce temporal complexity: ***d*** **representative days per year**

Region and Cluster Representation

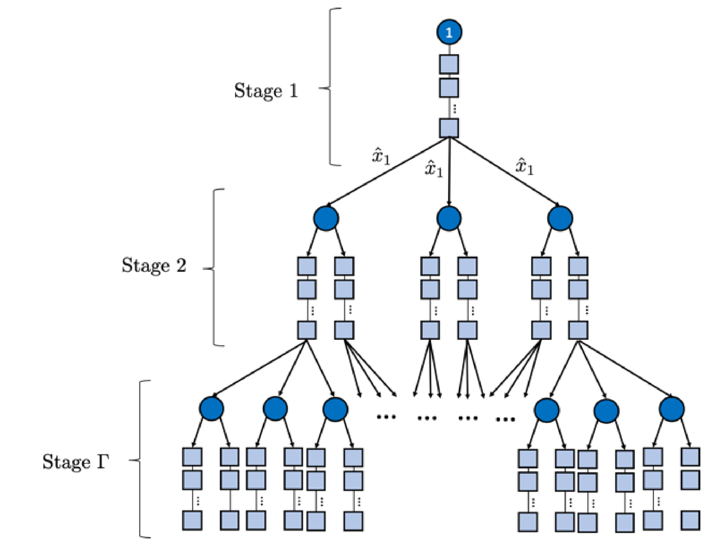


Aggregation to reduce spatial complexity:

- Reduced network at the ***regional*** level
- ***Cluster*** generators into ***representative units***
- Decision regarding generators and storage devices (e.g., install/retire, start-up/shut-down) are modeled as **integer variables.**

Multistage stochastic programming formulation

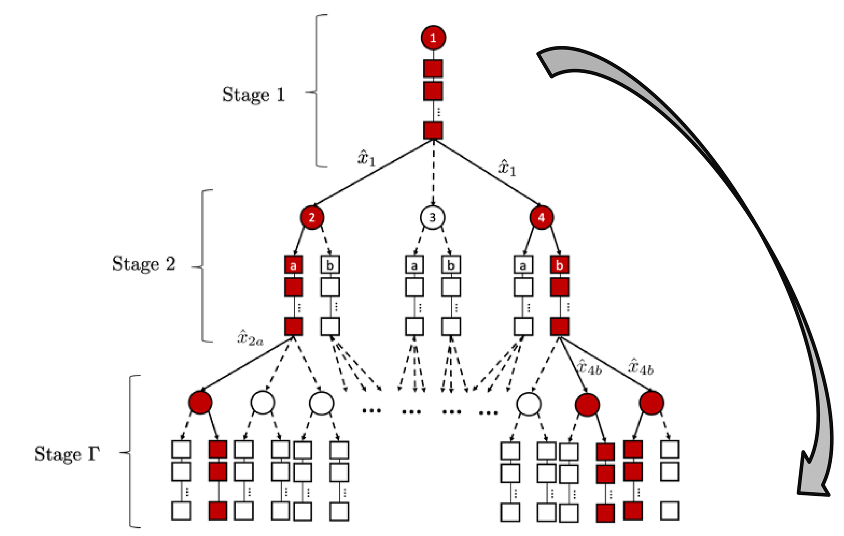
- Handles both **strategical** (e.g. fuel price uncertainty), and **operational** (e.g. different profiles of representative days) **uncertainties**.
- Number of **scenarios** grows **exponentially** with **the number of stages**.



Algorithmic Capabilities

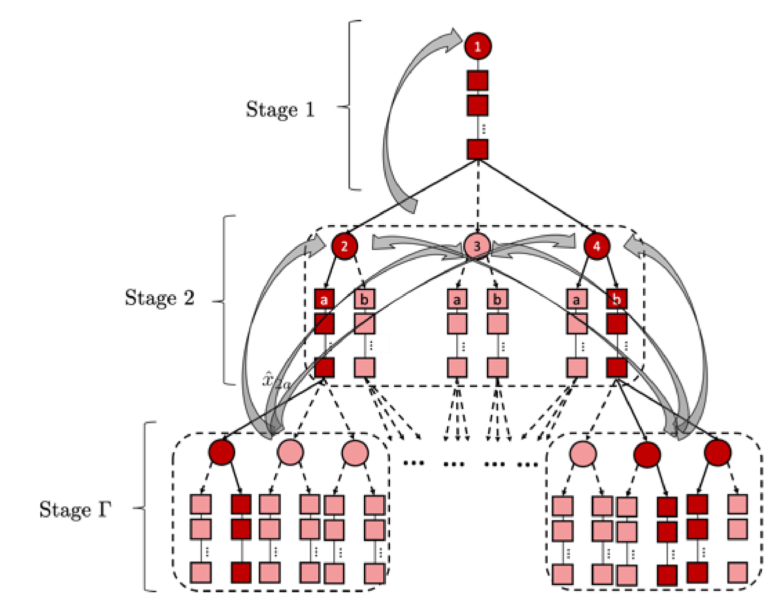
Stochastic Dual Dynamic Programming (SDDiP)

- The algorithm decomposes the problem by **nodes** in the scenario tree.
- Consists of **Forward** and **Backward** Passes.



Forward Pass

- **Scenario Sampling**
- Solve subproblems for a **subset of the scenarios.**
- Get the **Statistical Upper Bound** (for a certain **confidence level**)

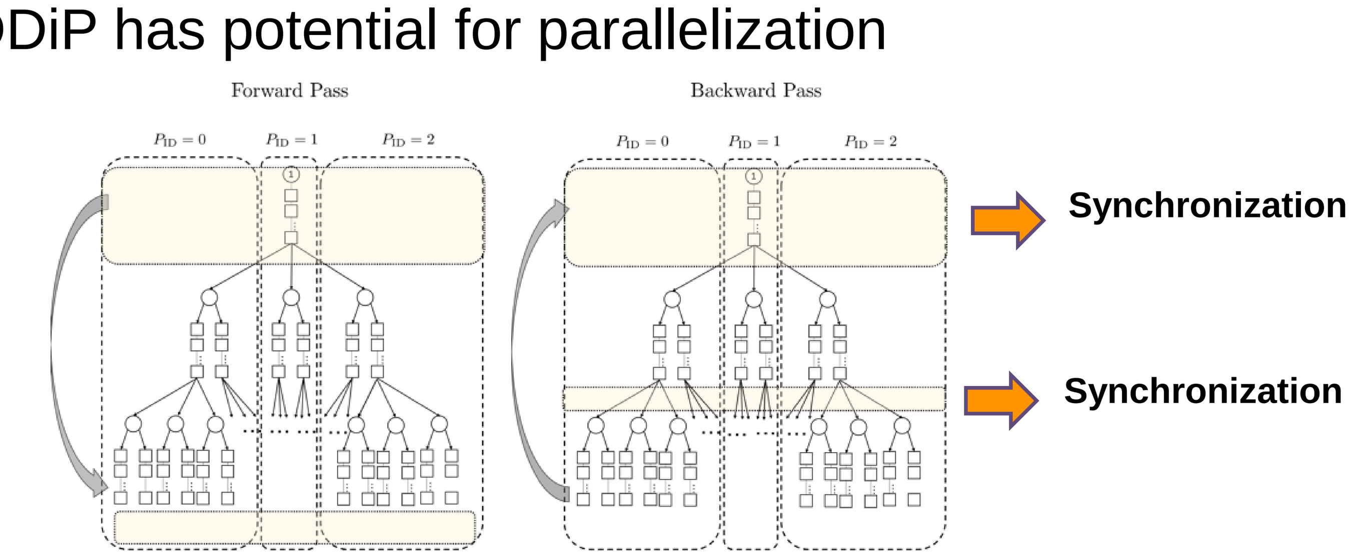


Backward Pass

- Solve for **all children nodes** of the nodes in the sampled scenarios.
- Relaxed subproblems.
- Benders cut takes the **weighted average of the coefficients for the cut** based on the conditional probability
- Solution of node 1 is the **Lower Bound**

- Assumes that the scenario tree is **stage-wise independent**.
- **Cuts can be shared** between all nodes in the same stage
- **Avoid the "curse of dimensionality".**

SDDiP has potential for parallelization



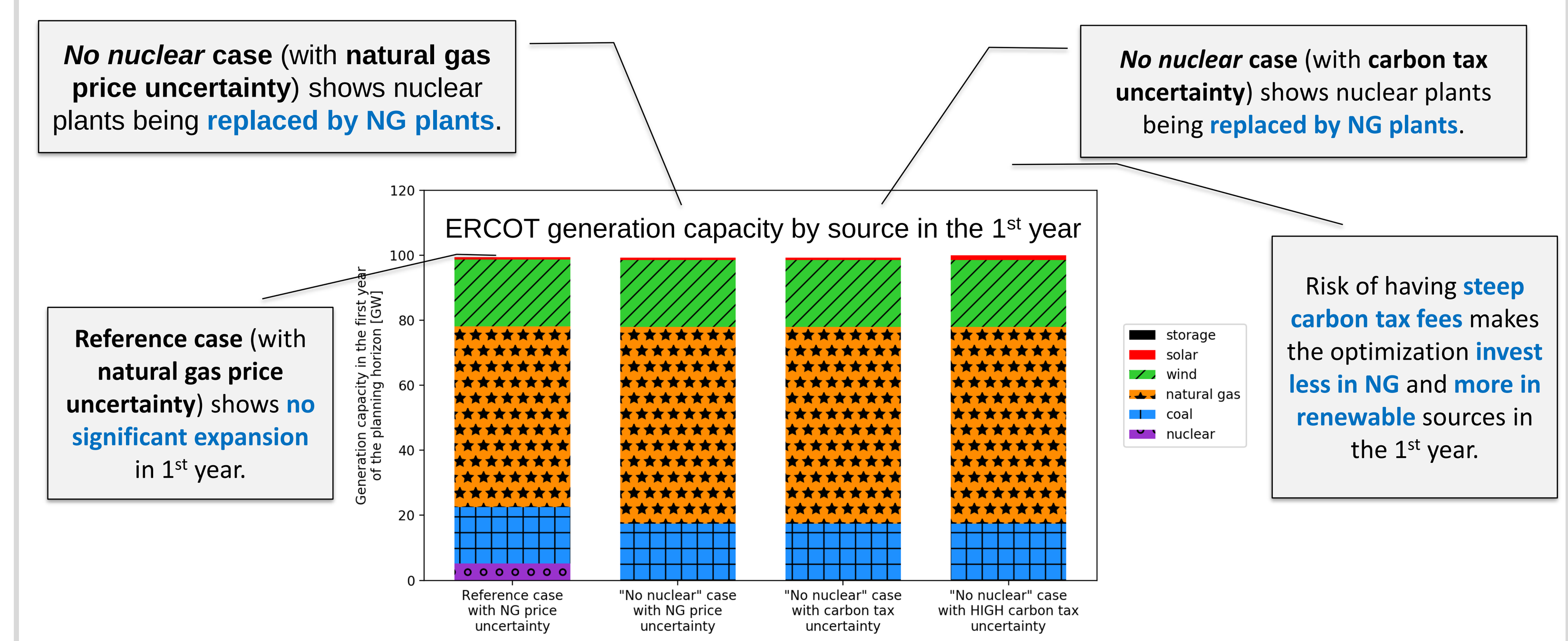
Hypothetical case study: ERCOT

Test algorithmic capabilities and performance

- **Number of scenarios** ranging from **thousands to billions**.
- **Problem size** ranging from **millions to quadrillions** variables and constraints.
- All solved in **less than 24 hours**.

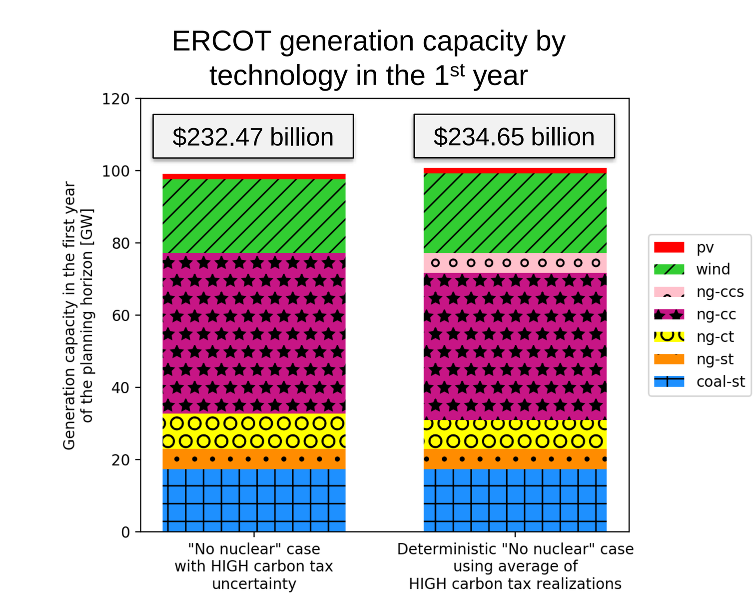
These results show how **powerful SDDiP can be** for **practical large-scale multistage stochastic programming** problems.

Here-and-now decisions vary according to the scenario tree



Value of stochastic programming

By considering carbon tax as an uncertain parameter, the **value of stochastic programming** is **$2.18 billion**, which is the **savings one can achieve in the long term**.



Remarks and Future work

- IDAES is developing cutting-edge scalable analysis approaches that enable quantification of the adoption and impact of proposed generator designs.
- Current activities focusing on increasing model fidelity:
  - Improving the **transmission representation** in the model and including the option for **transmission expansion**.
  - Developing strategies to efficiency solve **nonlinear** transmission models.
  - Adding construction **lead time** to the multistage formulation.
  - Extending parallel SDDiP to address **risk-averse** problems and **stage-wise dependent** problems.

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