Power Grid Participation and Planning Studies

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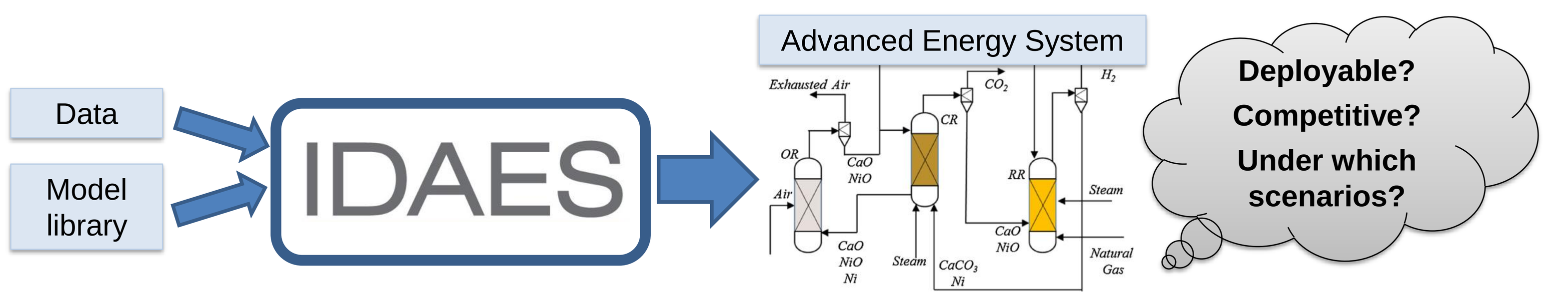
Motivation



Power systems do not exist in isolation. Plant participation, and hence revenue, comes through interaction of the plant with the balance of the electric grid through the various energy and service markets. By modeling these systems we can better understand and quantify both the benefits from **changing existing plant operating modes** and the characteristics needed to develop **new advanced energy generation technologies** that can be **competitive**.

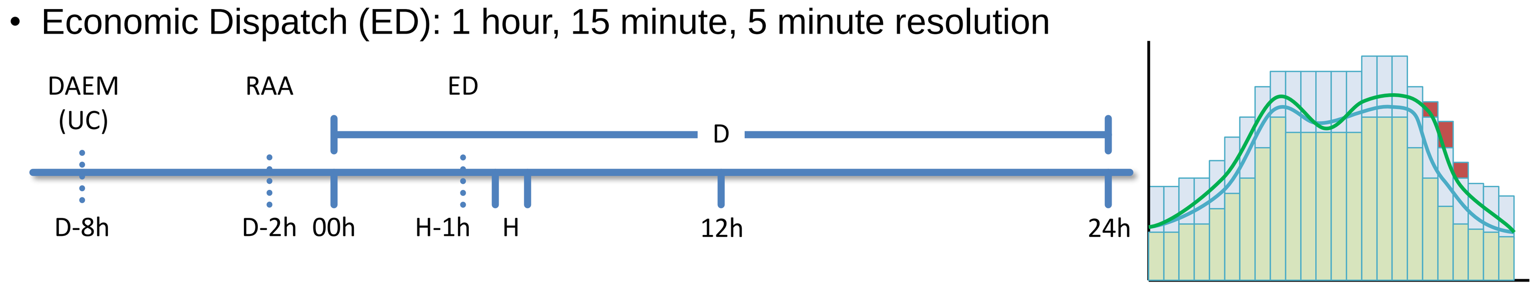
Key case studies:

- Quantify the benefit of existing plants operating in a more dynamic mode.
- Quantify the likely deployment and competitiveness of the coal plant of the future.

Modeling Strategies

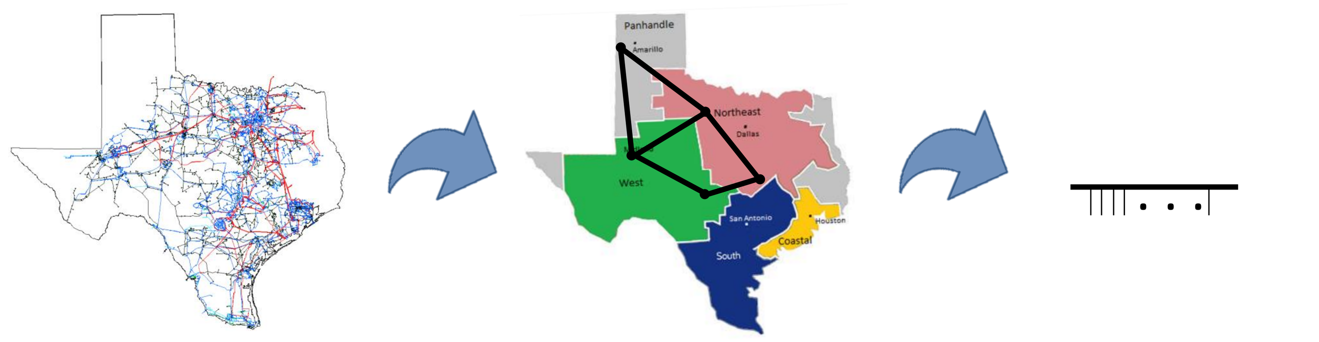
Operational Models

- Markets (optimization models) with various resolution and planning horizons
  - Unit Commitment / Day-ahead Energy Market (UC/DAEM): 24-48 hours @ hourly resolution
  - Reserve Adequacy / Contingency Analysis (RAA/CA): 24-48 hours @ hourly resolution
  - Economic Dispatch (ED): 1 hour, 15 minute, 5 minute resolution



Transmission Models

- Transmission systems can have in excess of 10,000 buses and branches
- Aggregation / network reduction can balance fidelity with computational demand



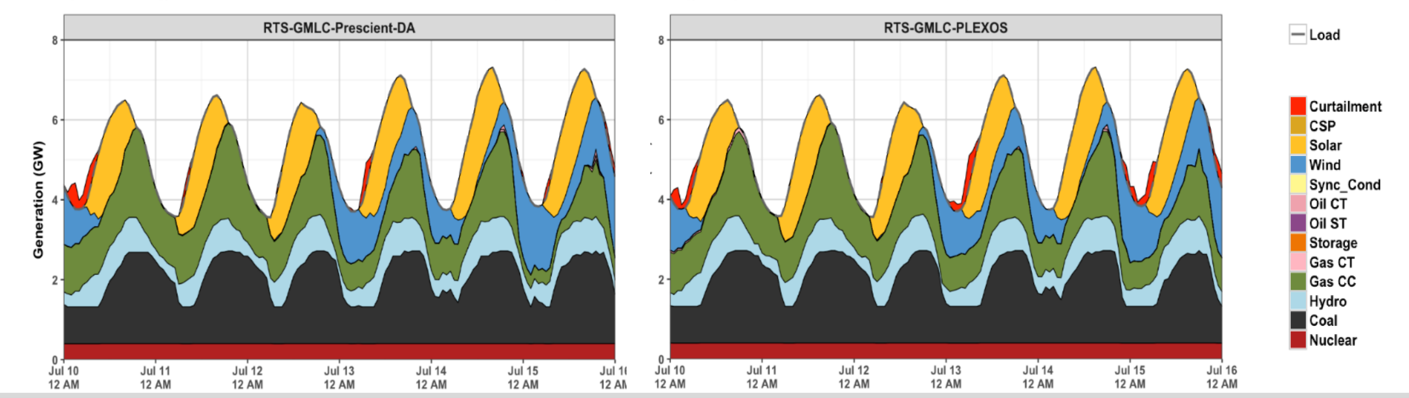
Planning Models

- Multi-period, multi-scale problem
  - Temporal: planning horizon is 30-50 years with sub-hourly operational decisions
  - Spatial: thousands of potential locations to site plants
- Sampling to reduce temporal complexity: d *representative days* per year
- Aggregation to reduce spatial complexity:
  - Site generators at the *regional* level
  - *Cluster* generators into *representative units*

Algorithmic and Analysis Capabilities

Production Cost Modeling software

- Prescient: an open, Python-based PCM package built on Pyomo and PySP
  - Simulates grid operations (energy markets) at an hourly time scale
  - Validated against commercial PCM packages (PLEXOS, PSA)
  - 12 hours to simulate a year of operations (RTS-GMLC test case, commodity desktop
  - Under development: full ancillary service stack based on MISO, CAISO, and ISO-NE, day ahead pricing and market settlement (including uplift calculation), and a 5-minute real time market



Market Participation Modeling

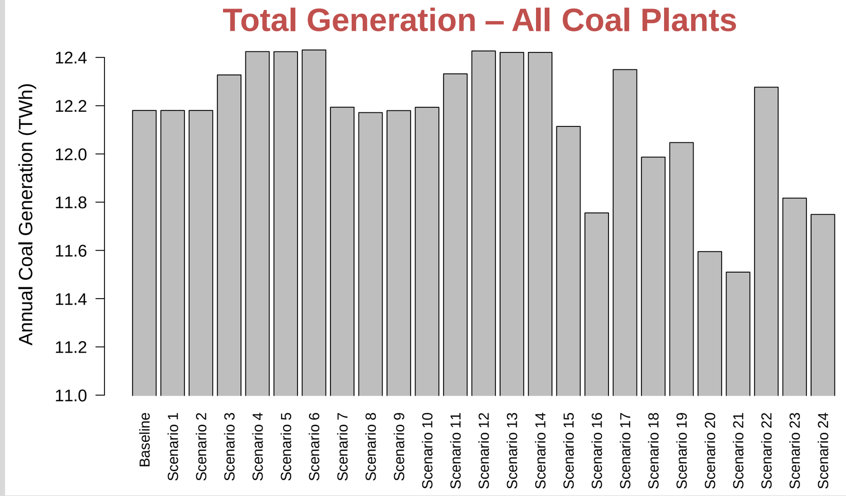
Scoping study: flexible operation of existing plants

- General assumptions that coal plants aren't flexible enough for modern markets
- If we could make them more flexible, would they be able to participate more frequently? At higher levels? With increased revenues?
- We tested this assumption using the RTS-GMLC synthetic power grid
  - 16 coal plants, 19% of system capacity
  - Also gas, oil, nuclear, PV, CSP, wind, and hydro
  - Representative of a modern power system in many parts of the US
- For all coal plants in the system, we varied the following parameters, both independently and in combination according to Table 1:
  - Minimum up time
  - Minimum down time
  - Ramp rate
  - Minimum power level
- We also compared deterministic and stochastic runs
  - For stochastic runs, the day-head unit commitment chooses the optimal solution across a set of possible realizations for variable generation (in this case, wind)

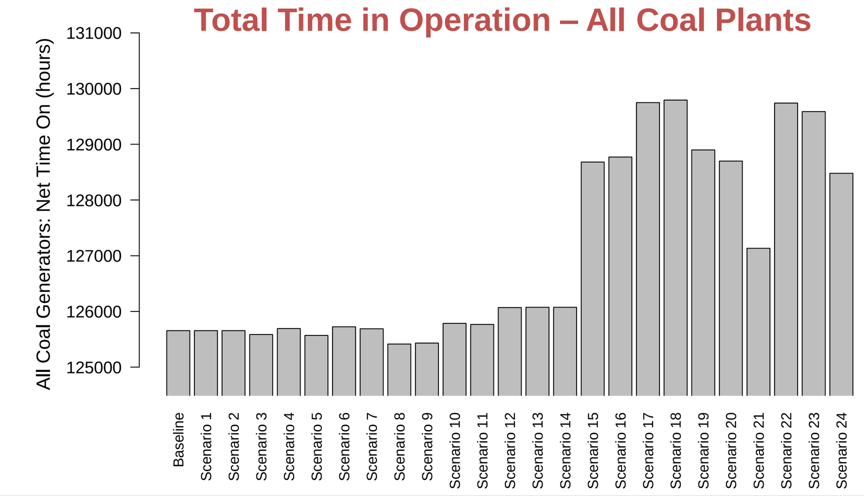
Scenario	Minimum Down Time (hours)	Minimum Up Time (hours)	Ramp Rate (MW/min)	Minimum Power Level
1			2 -> 3	
2			2,3 -> 4	
3	48 -> 24			
4	48 -> 12			
5	48 -> 12; 8-> 4			
6	48 -> 6; 8 -> 4			
7		24 -> 12		
8		24 -> 6		
9		24 -> 6; 8 -> 4		
10		24 -> 6; 8 -> 2		
11	48 -> 24	24 -> 12		
12	48 -> 12	24 -> 6		
13	48 -> 12; 8-> 4	24 -> 6; 8 -> 4		
14	48 -> 12; 8-> 4	24 -> 6; 8 -> 4	2,3 -> 4	
15				Reduce by 10%
16				Reduce by 20%
17	48 -> 12; 8-> 4	24 -> 6; 8 -> 4	2,3 -> 4	Reduce by 10%
18	48 -> 12; 8-> 4	24 -> 6; 8 -> 4	2,3 -> 4	Reduce by 20%
19				35% of Pmax
20				30% of Pmax
21				25% of Pmax
22	48 -> 12; 8-> 4	24 -> 6; 8 -> 4	2,3 -> 4	35% of Pmax
23	48 -> 12; 8-> 4	24 -> 6; 8 -> 4	2,3 -> 4	30% of Pmax
24	48 -> 12; 8-> 4	24 -> 6; 8 -> 4	2,3 -> 4	25% of Pmax

Table 1: Parameter sweep for market studies. Highlighted rows were also evaluated stochastically, using multiple scenarios for wind forecasts

Total Generation – All Coal Plants



Total Time in Operation – All Coal Plants



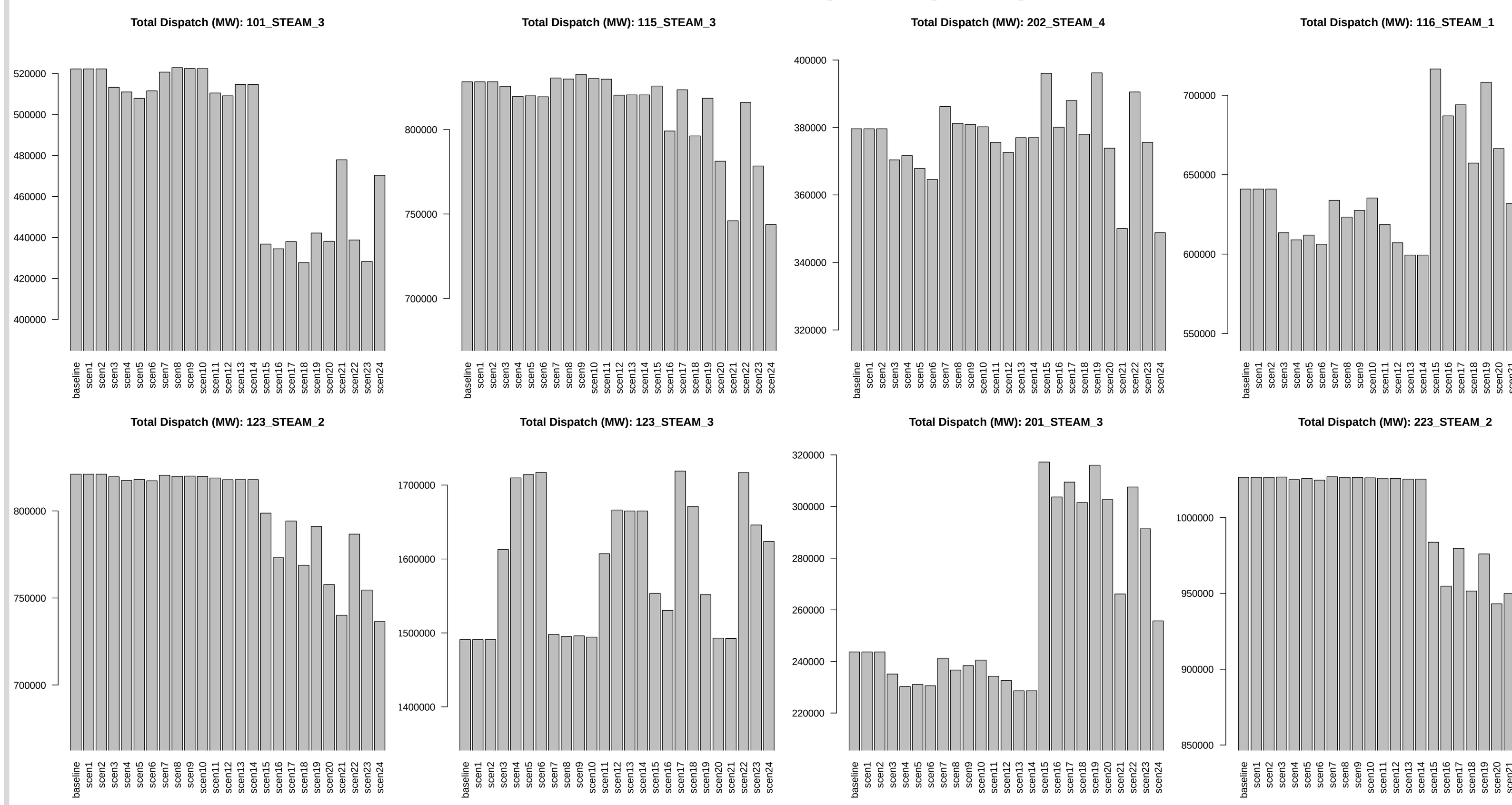
Individual Plant Behavior

- Coal generators in RTS-GMLC differ in their plant characteristics
- Plant response to changing operating parameters depends on the specific plant
- Most plants are fairly robust to changes in minimum up/down times and ramp rate
- Highest sensitivity to minimum power level

Generator ID	PMax MW	PMin MW	Min Down Time Hr	Min Up Time Hr	Ramp Rate MW/Min
101_STEAM_3	76	30	4	8	2
101_STEAM_4	76	30	4	8	2
102_STEAM_3	76	30	4	8	2
102_STEAM_4	76	30	4	8	2
115_STEAM_3	155	62	8	8	3
116_STEAM_1	155	62	8	8	3
123_STEAM_2	155	62	8	8	3
123_STEAM_3	350	140	48	24	4
201_STEAM_3	76	30	4	8	2
202_STEAM_3	76	30	4	8	2
202_STEAM_4	76	30	4	8	2
216_STEAM_1	155	62	8	8	3
223_STEAM_1	155	62	8	8	3
223_STEAM_2	155	62	8	8	3
223_STEAM_3	350	140	48	24	4
316_STEAM_1	155	62	8	8	3

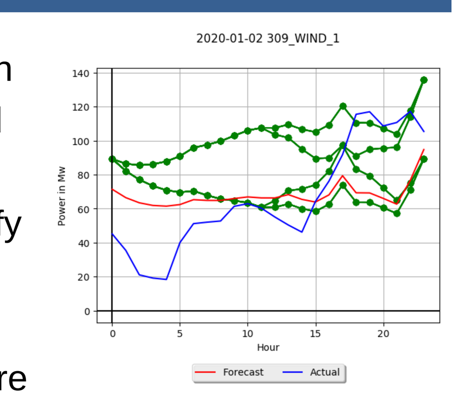
Table 2: Baseline operating parameters for coal generating units in RTS-GMLC

Total Annual Dispatch (MWh)

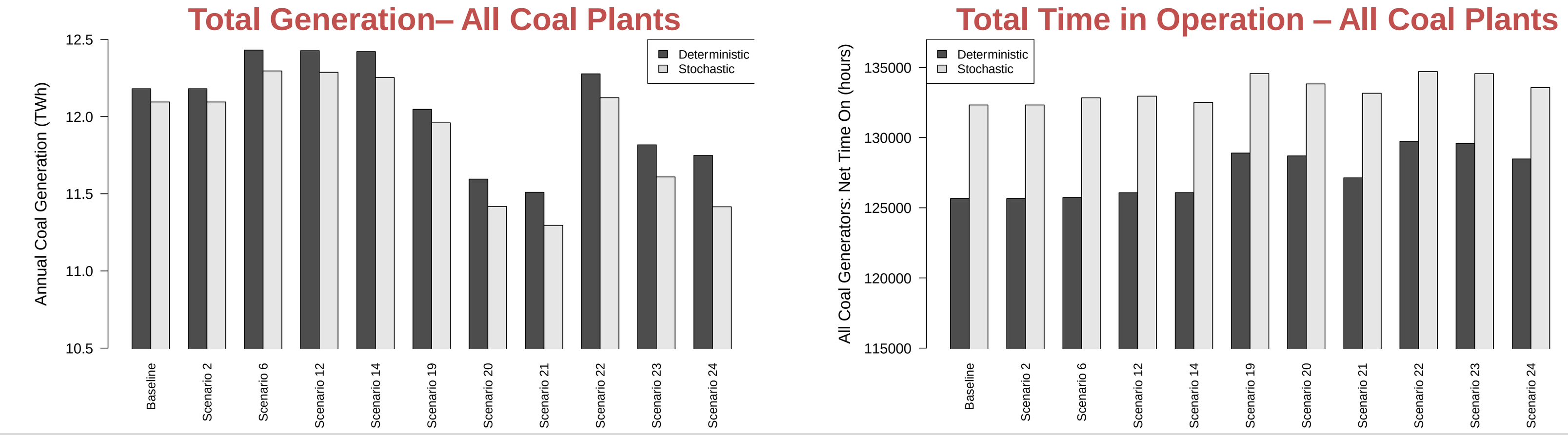


Deterministic vs. Stochastic

- For these stochastic runs, we created scenarios for wind generation that represent the range of uncertainty expected in day-ahead wind power forecasts
- Resulting commitment decisions should be flexible enough to satisfy each scenario, which can be difficult with high uncertainty
- Stochastic planning results in less overall generation from coal plants, but the units are committed more frequently, resulting in more operating time over the course of a year



Total Generation– All Coal Plants | **Total Time in Operation – All Coal Plants**



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