2019 FERC Technical Conference: Increasing Real-Time and Day-Ahead Market Efficiency and Enhancing Resilience through Improved Software

MARKET-BASED RESOURCE ADEQUACY ASSESSMENT FRAMEWORK UNDER HIGH WIND PENETRATIONS

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BACKGROUND

- Resource adequacy
  - The ability to provide adequate supply during peak load and stressed system conditions
  - Typically measured using long-term reliability standards (e.g. LOLE, LOLH, LOLP)
- Resource adequacy requirements
  - E.g., planning reserve margin
    : translates the reliability standards into a reserve margin

MARKET DESIGN FOR RESOURCE ADEQUACY

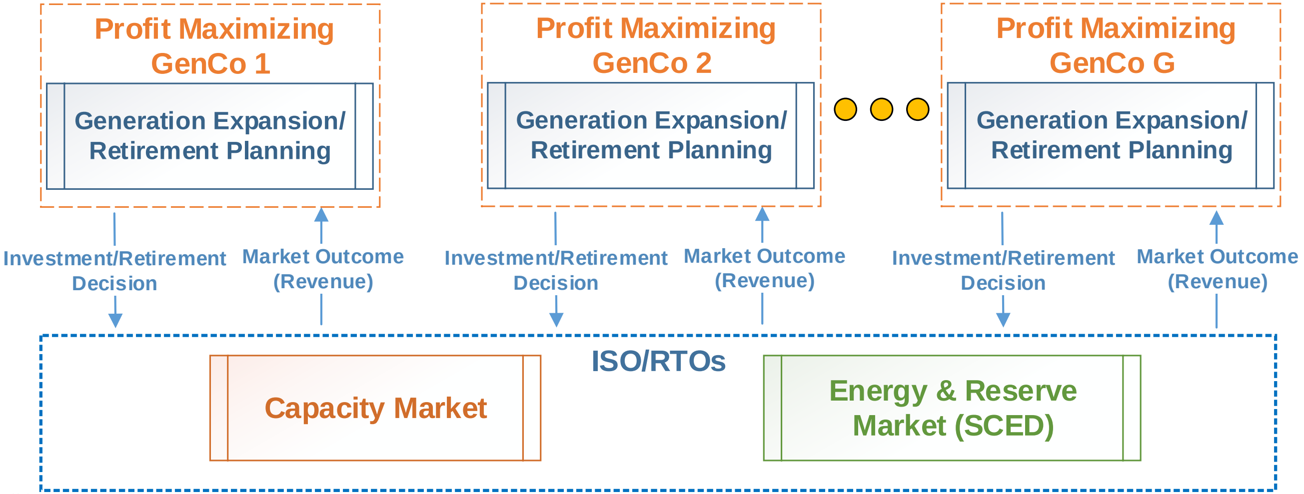
- Vertically integrated system
  - Centralized generation expansion planning
  - Integrated resource planning
- Restructured electricity markets
  - Market-based mechanisms to promote investments to meet resource adequacy requirements
- Energy-only markets (ERCOT)
- Capacity remuneration mechanisms (CRMs)
  - Capacity obligation and market (ISO-NE, MISO, NYISO, PJM)
  - Capacity obligation (CAISO, SPP)
  - Capacity payments
  - Strategic reserves

RESEARCH MOTIVATION

- Investigate resource adequacy in a competitive market environment
  - Main driver: Individual profit-maximizing generating companies (GenCos)
  - Various market designs and conditions to consider:
    - Electricity market design, in particular CRMs
    - Industry structure and level of competition
    - VRE penetration level
- Traditional centralized capacity expansion models
  - Minimizes system cost, cannot capture the decision making of individual generation GenCos
  - Limited ability to assess the effectiveness of capacity remuneration mechanisms
- Other tools needed to investigate market dynamics and resource adequacy in a competitive market environment

MULTI-AGENT RESOURCE PLANNING MODEL

- Captures strategic interactions between individual GenCos' investment decisions
- Considers revenues from capacity + energy/reserve markets
- Bi-level programming formulation



MULTI-AGENT RESOURCE PLANNING MODEL

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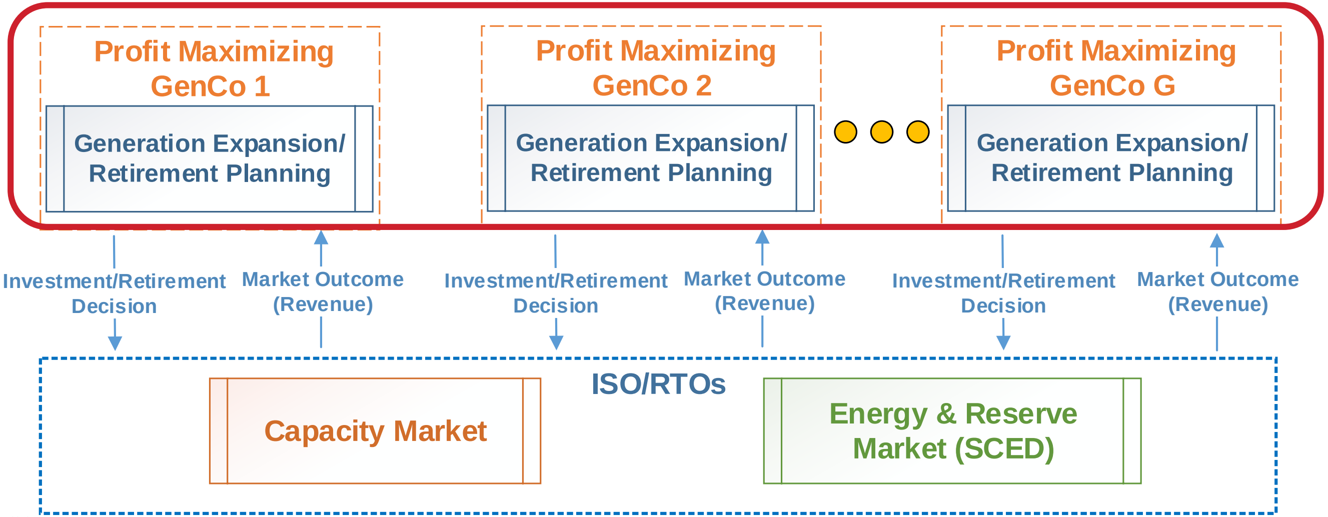
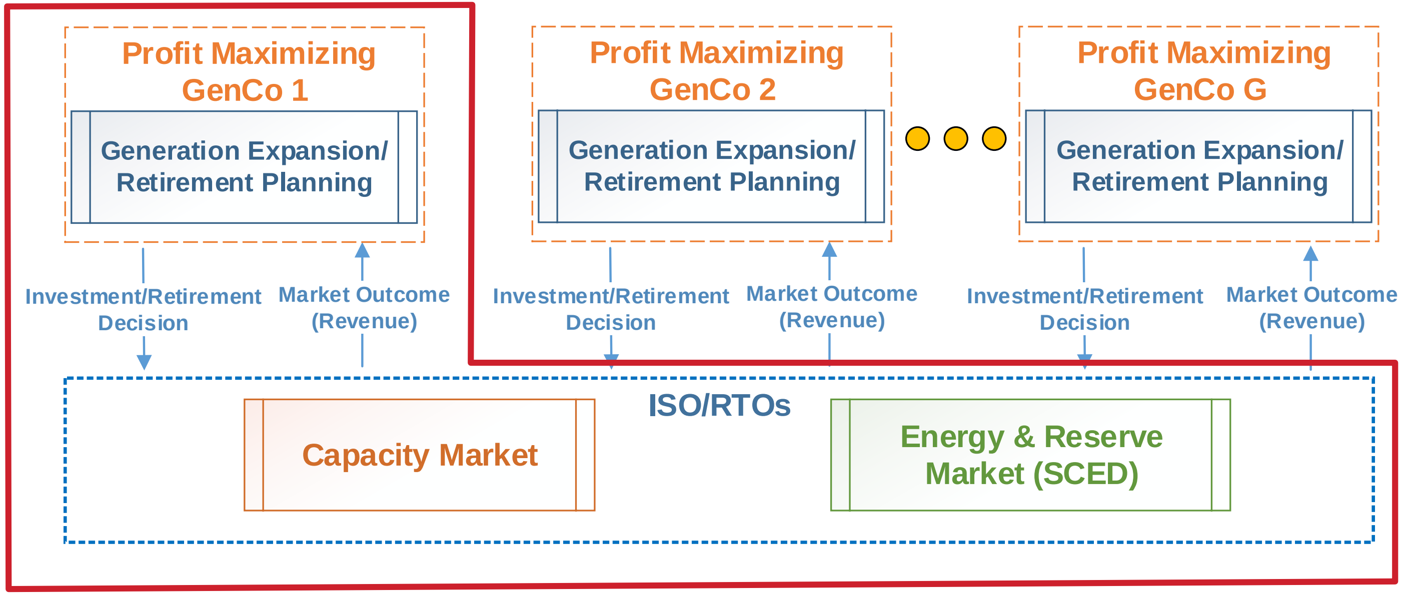
Goal: Find an equilibrium investment and retirement solution
Philosophy: Stackelberg leader-follower games
Method: Diagonalization Method



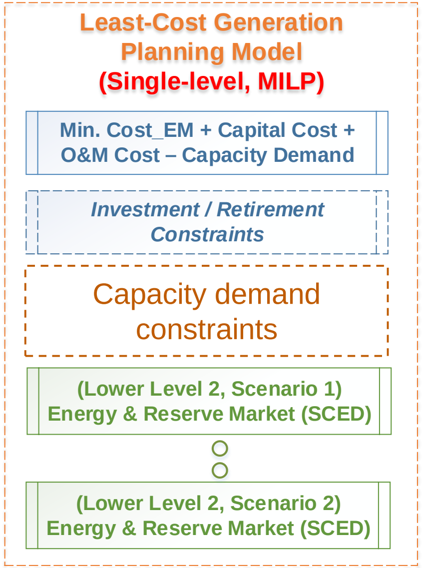
SOLUTION APPROACH

- A GenCo's decision solved individually as Stackelberg leader-follower game
- Nash Equilibrium among GenCos found with "diagonalization method"

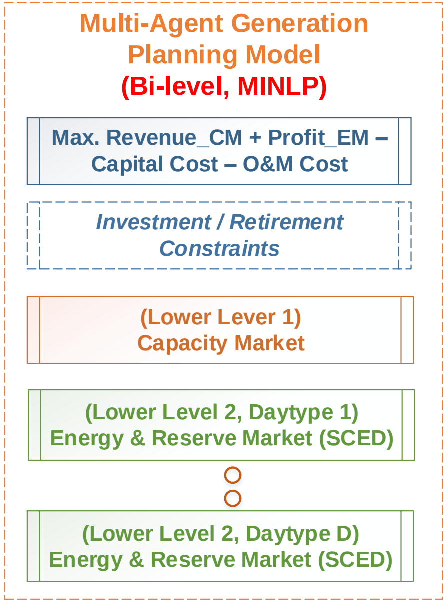


LEAST-COST MODEL FOR COMPARISON

- **Least-cost model**: finds optimal generation portfolio while minimizing system-wide costs

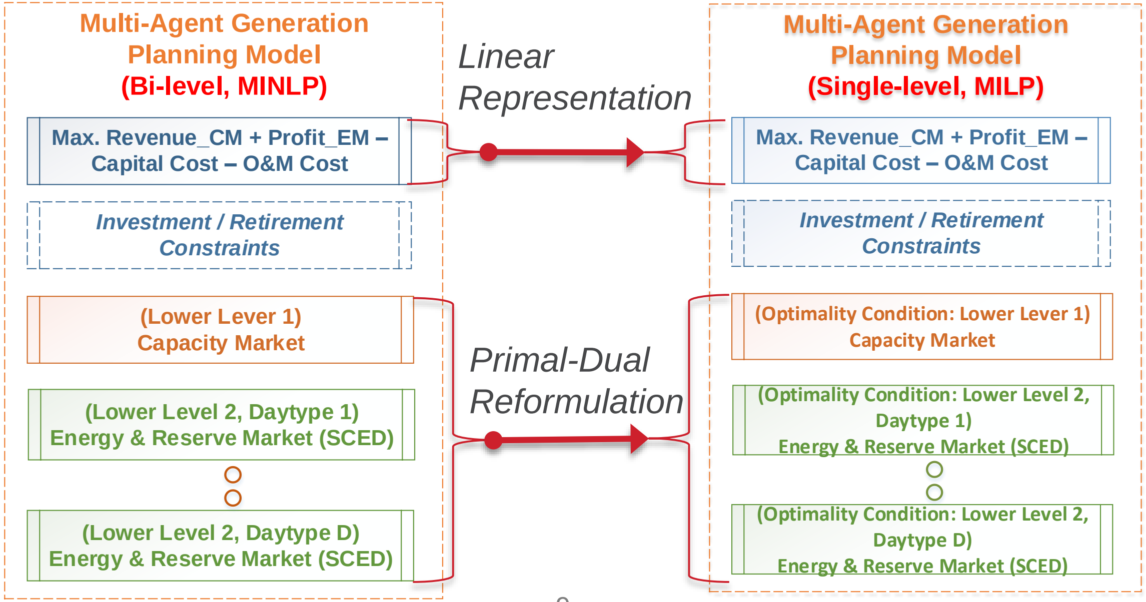


- **Individual Genco model**: finds optimal generation portfolio while maximizing own profits



INDIVIDUAL GENCO PROBLEM

- Mathematical Problem with Equilibrium Constraints (MPEC)
- MPEC re-formulated as a MILP
- Further computational performance enhancement using a decomposition method



CASE STUDY

- Simplified “ERCOT”-like system for 2030
  - Projected peak load: 86,613 MW (1.57% increase per year)
  - Simple transmission system (9 nodes, 34 lines)
  - 30 representative days (scenario reduction)
- Generation Portfolio and GenCos
  - Total system capacity: 94,916 MW (ICAP), 77,218 MW (UCAP)
  - No. of existing thermal units: 176 → 51
  - No. of existing GenCos: 23 - No. of new entrants: 8

Node	1	2	3	4	5	6	7	8	9	Total ICAP	Capacity Factor	Total UCAP
Coal	2,127	8,347	1,770	1,804	538	925	0	0	0	15,511	1.00	15,511
NGCC	8,451	11,854	6,914	1,758	498	300	3,259	0	0	33,035	1.00	33,035
NGCT	5,373	5,040	804	2,646	1,845	811	672	1,210	0	18,401	1.00	18,401
Nuclear	0	2,328	2,632	0	0	0	0	0	0	4,960	1.00	4,960
Wind	0	3,756	4,967	12,793	0	0	0	0	0	21,516	0.19	4,191
Solar	0	0	1,493	0	0	0	0	0	0	1,493	0.75	1,120
Total	15,952	31,325	18,581	19,001	2,881	2,035	3,932	1,210	0	**94,916**		**77,218**

ANALYSIS DESIGN

- Investment Options

Type	Size (MW)	Overnight cost ($/kW)	Life Cycle	Fixed O&M Cost ($/kW/Year)	Variable O&M Cost ($/MWh)	Fuel Cost ($/MMBTU)	Weighted Average Cost of Capital (%)
NGCC	400	1,026	30	10.25	3.08	4.64	5.3
NGCT	200	873	30	12.30	7.18	4.64	5.3

- VRE Penetration Levels

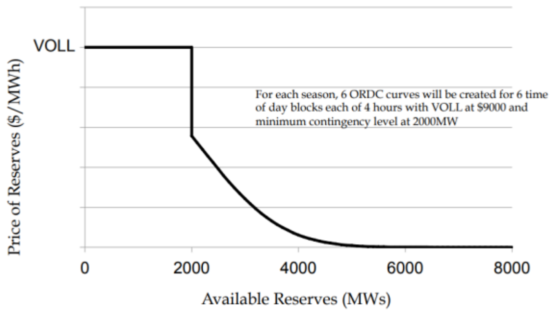
Scenario	Wind Capacity (MW)	Penetration Level (%)
Base	21,516	18.4
Modest	30,070	25.7
High	38,625	33.1

- Cost of New Entry (CONE)
  - $177.6 /MW-day
  - Capital cost, fixed O&M cost, and life cycle of NGCT unit
  - Net CONE = CONE – revenue offset from energy/reserves (30%)
- Target installed reserve margin (IRM):
  - 13.75%

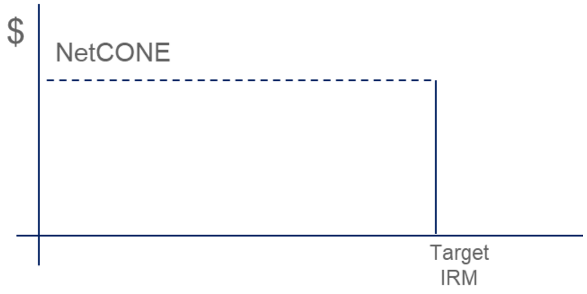
MARKET DESIGN OPTIONS

- Market design parameters

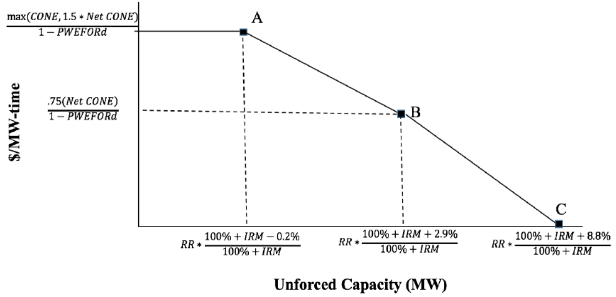
Market Design	Load Shedding Penalty	Reserve Shortage Penalty	Capacity Market Demand Curve
Energy-only (**EO**)	$9,001	ORDC ($9,000 Max)	N/A
Vertical Capacity Demand Curve (**VDC**)	$3,500	$3,500 (~4%); $2,250 (4~96%); $200 (96~100%)	Vertical (Fixed)
Sloped Capacity Demand Curve (**SDC**)	$2,100	$850(~96%); $300(96~100%)	Sloped



<ERCOT Operating Reserve Demand Curve(ORDC)*>



<MISO Capacity Market Demand Curve>

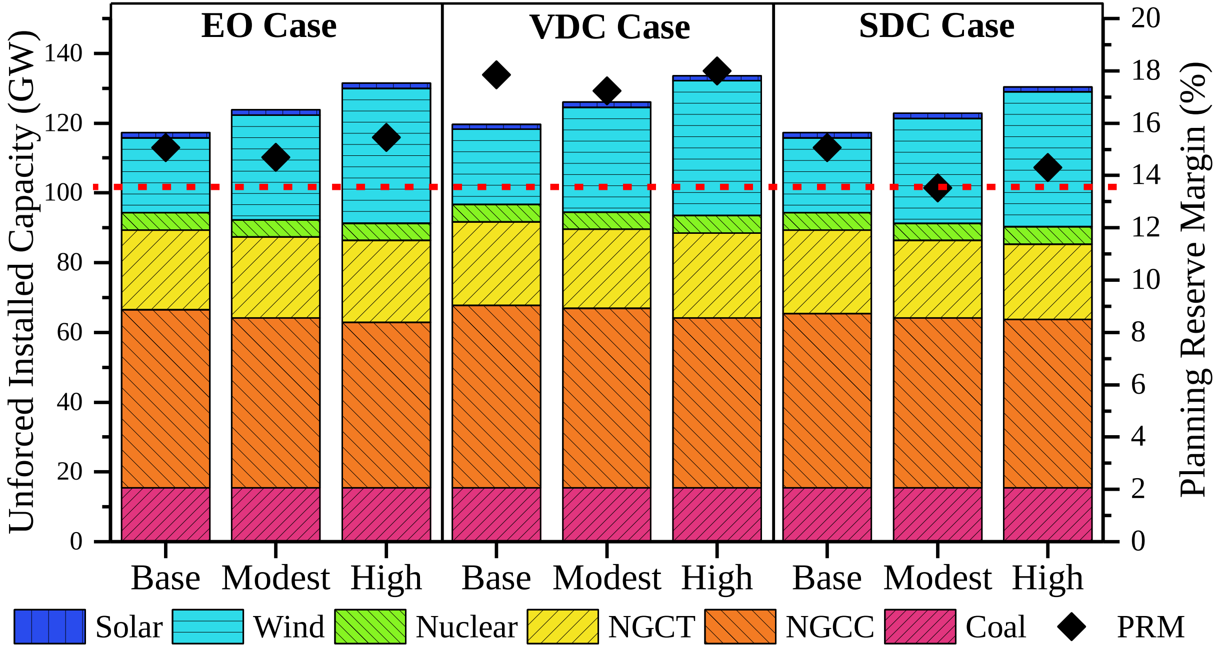


<PJM Capacity Market Demand Curve>

* R. Surendran et al., "Scarcity Pricing in ERCOT," FERC Technical Conference, June 27, 2016

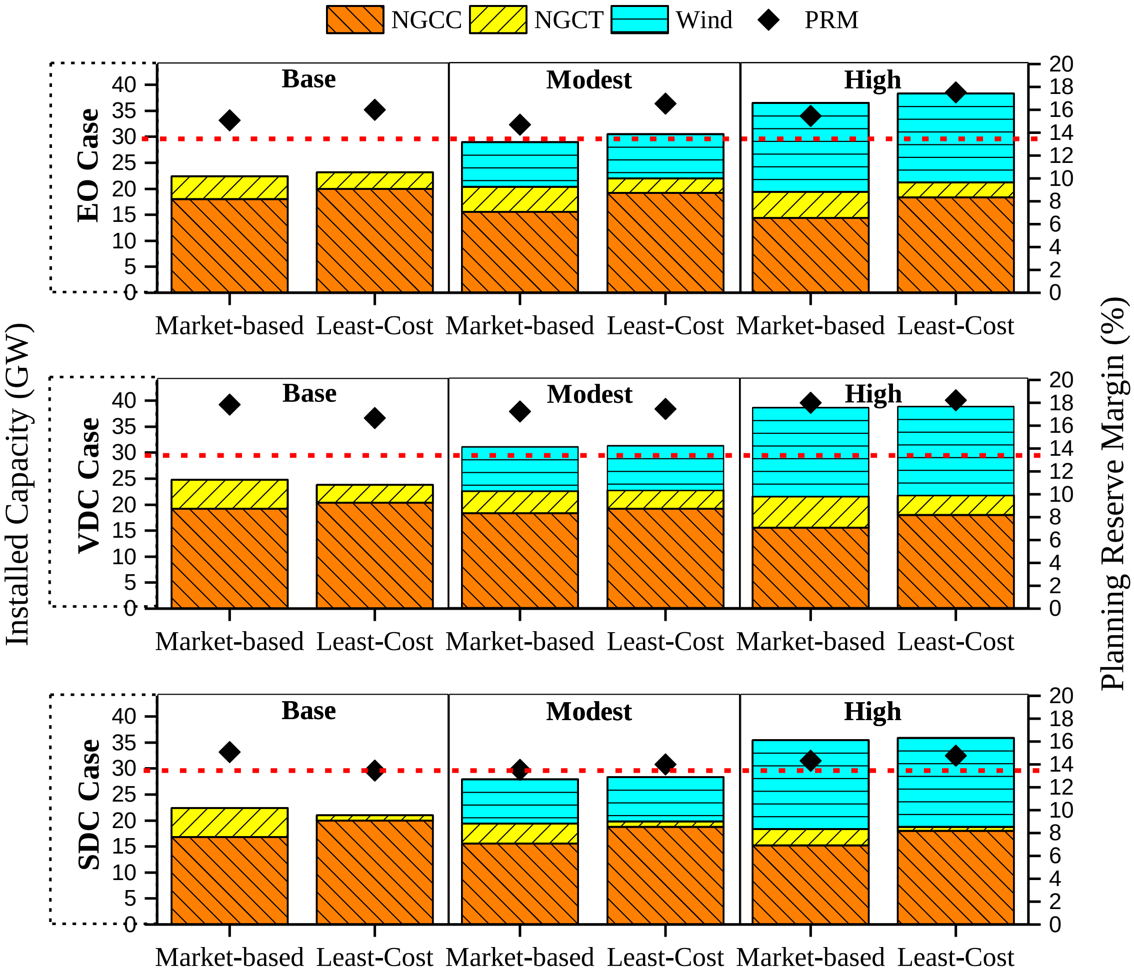
RESULTS

- Comparison of the generation portfolio in terms of ICAP and PRM from the market-based model



RESULTS

- Comparison of the additional investment capacity (ICAP) from the least-cost and the market-based model



CONCLUSIONS

- VRE influence electricity markets
  - Incentive schemes may have substantial impacts on prices
- Open questions around resource adequacy with VRE
  - Capacity markets are complex and not well understood
  - Solutions need to enable economic entry and exit
- A multi-agent model for capacity expansion
  - Considers market interactions between competing GenCos
  - Models revenues from energy, reserves, and capacity markets
- Case study results
  - Energy only design may work well
  - Capacity markets benefit from using a sloped capacity demand curve
  - Proper market signals can guide the market outcome towards a least-cost optimum, also with high VRE levels

FUTURE WORK AND EXTENSIONS

- Incorporate transmission expansion planning
- Investigate other capacity remuneration policies
- Further enhance the computational performance
- Heuristics to find an equilibrium solution

REFERENCES AND ACKNOWLEDGEMENTS

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THANK YOU