Beyond Price-Taker: Multiscale Optimization of Wind and Battery Integrated Energy Systems

Xinhe Chen[a], Xian Gao[a], Darice Guittet[b], Radhakrishna Tumbalam-Gooty[c,d], Bernard Knueven[b], John D. Siirola[e] and Alexander W. Dowling[a*]

[a] *Department of Chemical and Biomolecular Engineering, University of Notre Dame, Notre Dame, IN.*
[b] *National Renewable Energy Laboratory, Golden, CO 80401, United States.* [c] *National Energy Technology Laboratory (NETL), Pittsburgh, PA 15236, United States.*
[c] *NETL Support Contractor, Pittsburgh, PA 15236, United States.* [e] *Sandia National Laboratories, Albuquerque, NM 87185, United States.*

Background

Increasing Renewable Capacity and Challenges

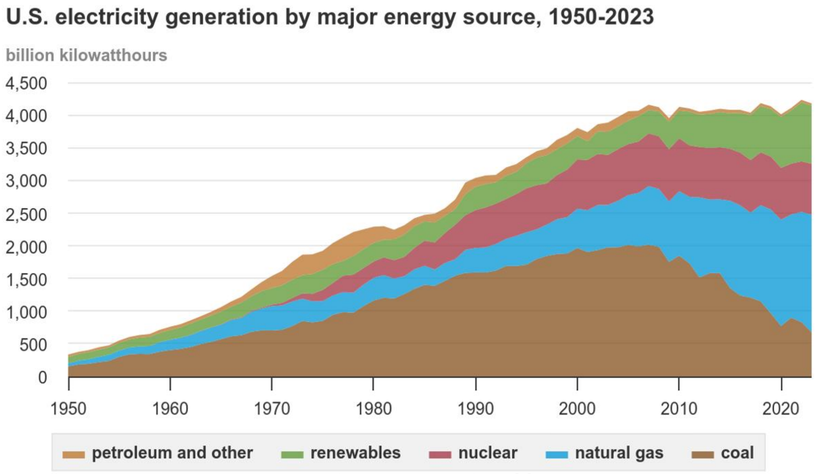


Figure source: www.eia.gov [1]

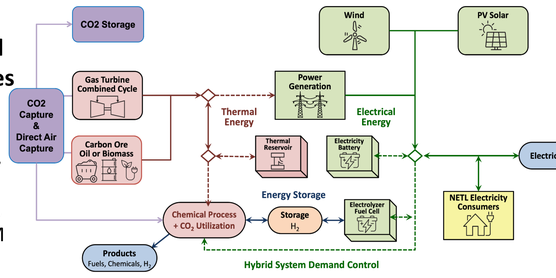
With the increasing renewable generation comes challenges:

- Intermittency and variability
- Infrastructure and grid integration
- Cost and economics

Integrated Energy Systems (IES)

Multiple inputs and technologies

Nuclear, Gas turbine, Fossil fuels, Solar, Wind, Battery, PEM



Multiple outputs and markets

Electricity, Hydrogen, Heating, Cooling, Ancillary services

Figure adapted from Douglas et. al, Joule 5, no. 1 (2021): 47-58. [2]

Reference and Disclaimer

[1] U.S. Energy Information Administration. "Homepage." Accessed [08-19-2024]. https://www.eia.gov.
[2] Arent, Douglas J., Shannon M. Bragg-Sitton, David C. Miller, Thomas J. Tarka, Jill A. Engel-Cox, Richard D. Boardman, Peter C. Balash, Mark F. Ruth, Jordan Cox, and David J. Garfield. "Multi-input, multi-output hybrid energy systems." Joule 5, no. 1 (2021): 47-58.
[3] Gao, Xian, Bernard Knueven, John D. Siirola, David C. Miller, and Alexander W. Dowling. "Multiscale simulation of integrated energy system and electricity market interactions." Applied Energy 316 (2022): 119017.
[4] Barrows, Clayton, Aaron Bloom, Ali Ehlen, Jussi Ikäheimo, Jennie Jorgenson, Dheepak Krishnamurthy, Jessica Lau et al. "The IEEE reliability test system: A proposed 2019 update." IEEE Transactions on Power Systems 35, no. 1 (2019): 119-127.

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Price-taker vs. Multiscale

Price-taker Optimization

$$\max \text{ Net Present Value}(\pi_t, p_t)$$
$$\text{s.t.} \quad \text{IES process constraints}$$

π_t: electricity price during time period t
p_t: power dispatch decision for IES during time period t

Multiscale Optimization with Time-variant Bidding

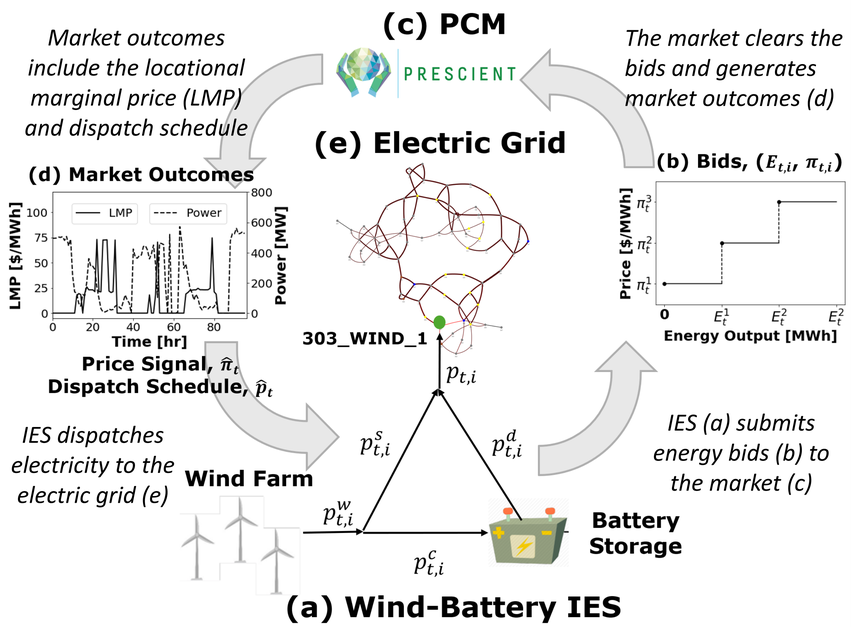


Figure adapted from Gao et. al [3], and Barrows et, al. [4]

Time-invariant (TI) bidding:

- Bids the renewable IES/generator at zero marginal cost
- Does not change with time and renewable resource availability

Time-variant (TV) bidding:

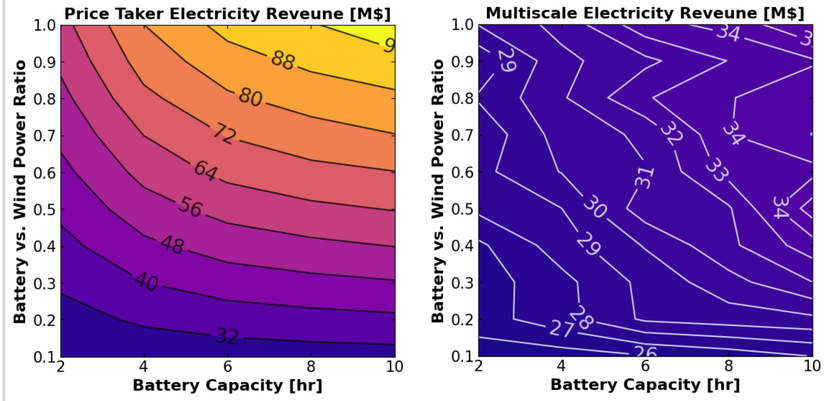
- Bids will change according to the resource availability and electricity market prices
- Forecasts constructed via machine learning or statistical methods, provide input scenarios for stochastic program

$$\max \frac{1}{I} \sum_{i \in I} \sum_{t \in T} (\pi_{t,i} p_{t,i} - c_{t,i})$$
$$\text{s.t.} \quad \text{IES process constraints}$$

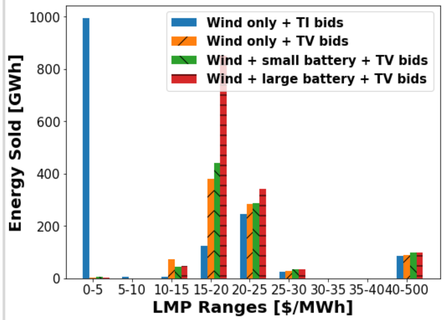
$\pi_{t,i}$: electricity price during time period t for forecast scenario i
$p_{t,i}$: power dispatch decision during time period t for forecast scenario i
$c_{t,i}$: operating cost during time period t for forecast scenario i

Results and Discussion

Price-taker Overestimates the Electricity Revenue



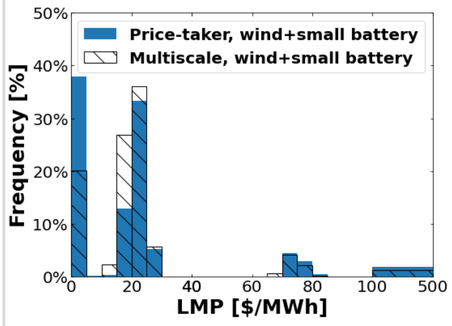
Time-variant Bids Improve IES Economics



	Wind+TI	Wind+TV
Revenue [M$]	19.03	23.57
Power sold [MWh]	1487	861

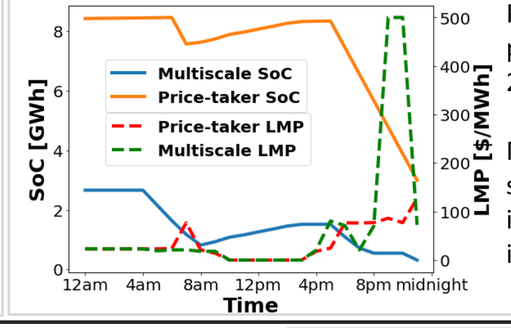
TI bids sell the most power at 0 - 5 $/MWh.
TV bids sell the most power at 15 - 25 $/MWh.

Price-taker Ignores the IES-market Interactions



IES retrofitting shifts LMPs.

Battery reduces the time periods that LMP is low (0 – 5 $/MWh) or high (100 – 500 $/MWh)



Price-taker assumes 1) perfect price forecasts, and 2) the grid is an infinite bus.

Multiscale optimization shows that IES-market interactions should not be ignored.

Contact: Xinhe Chen, xchen24@nd.edu; Alexander Dowling, adowling@nd.edu;

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