Multiscale Optimization of Integrated Energy Systems that Co-Produce Electricity and Hydrogen Using Market Surrogates

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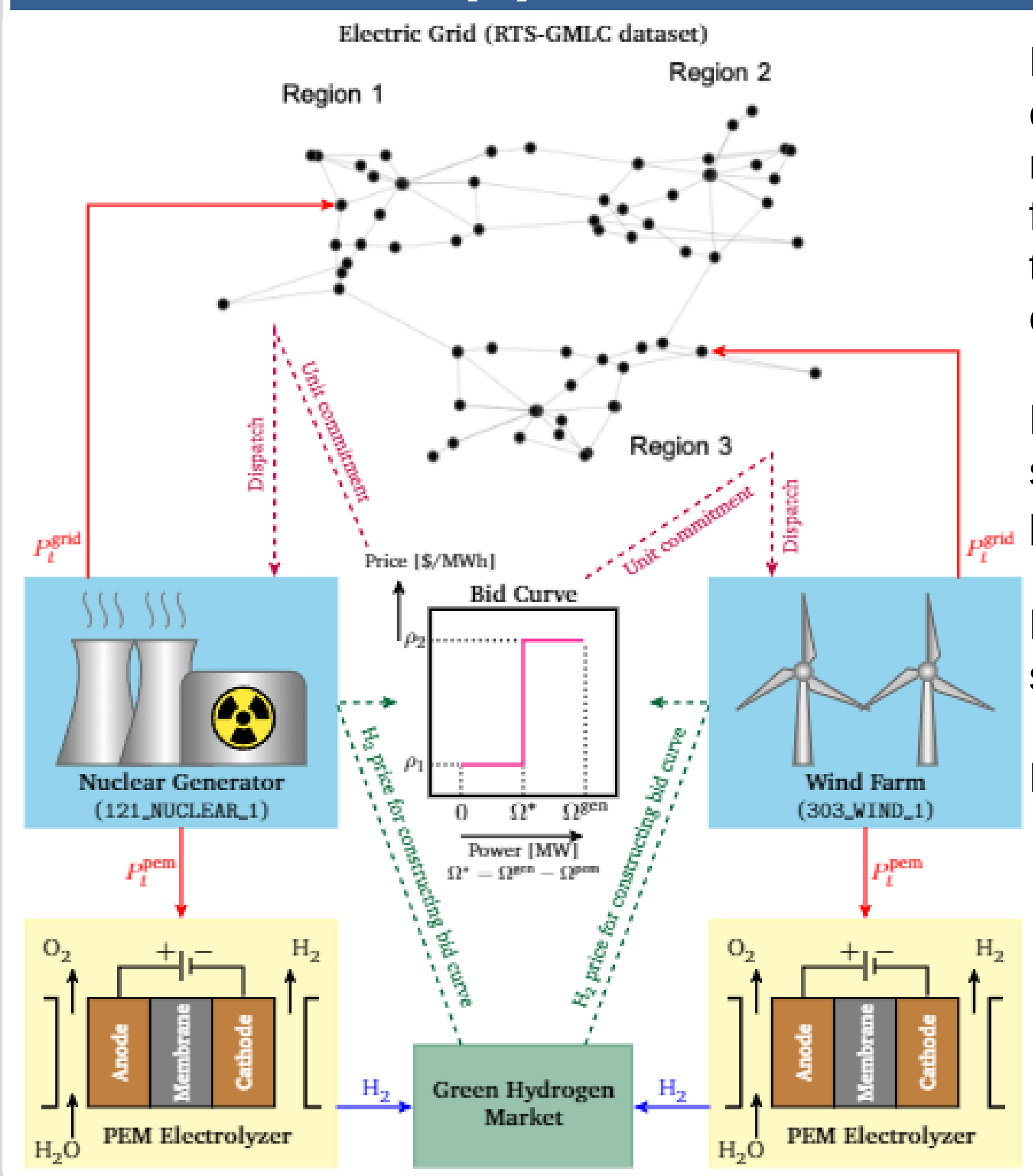
IDAES Institute for the Design of Advanced Energy Systems

DISPATCHES Design Integration and Synthesis Platform to Advance Tightly Coupled Hybrid Energy Systems

(1) Motivation

State-of-the-art of handling challenges of **integrated energy systems (IES)** is to co-optimize the design and operation of IES. The ubiquitous **price-taker approximation** ignores the interactions between the IES and market and may mislead the IES decision-making process. This work goes beyond price-taker by explicitly modeling **IES market interactions** using **neural network surrogate models**.

(2) Problem Statement



How to optimally retrofit an energy system (e.g., baseload nuclear power plant and wind farms) with a PEM electrolyzer to co-produce hydrogen and electricity?

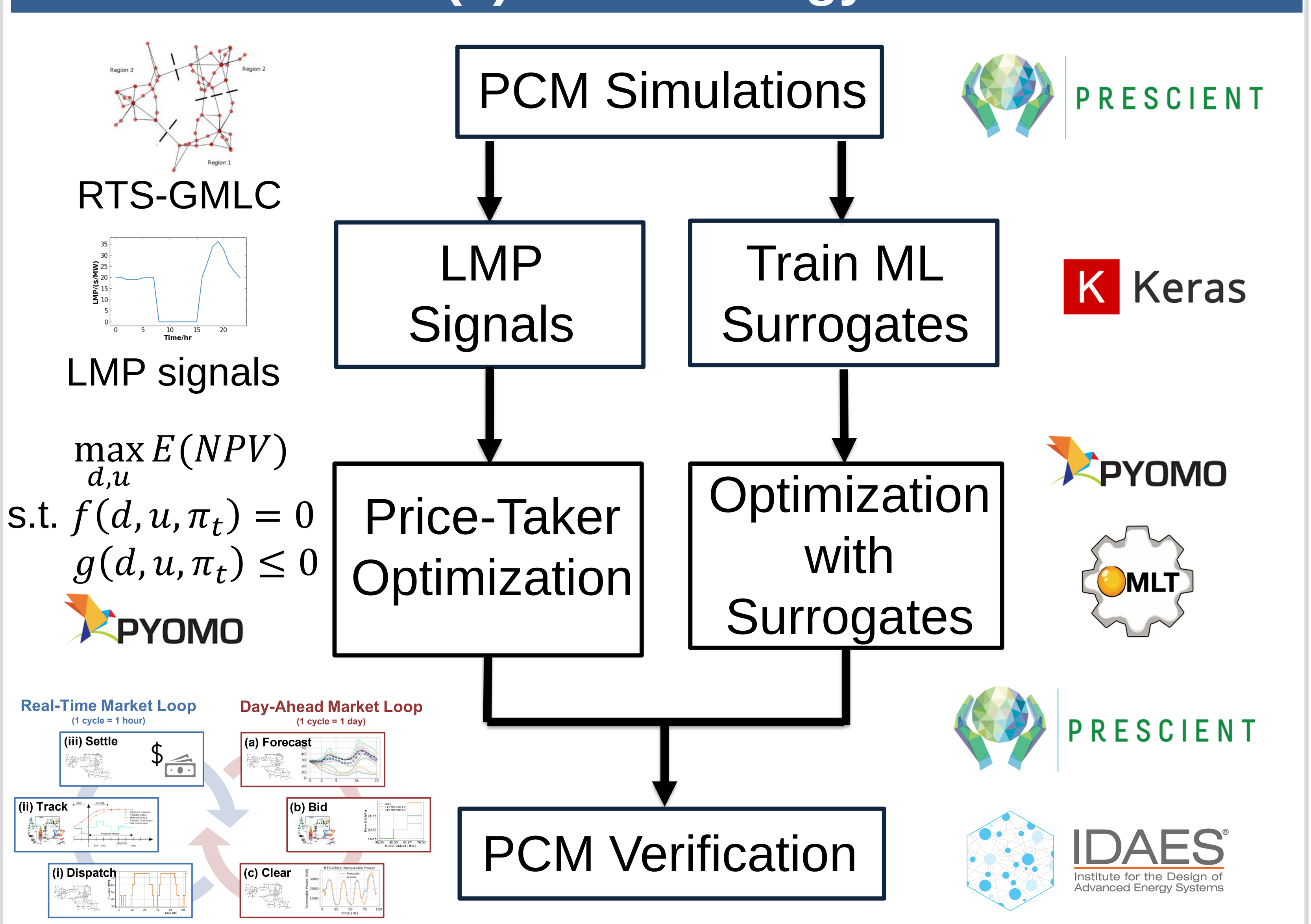
Nuclear energy (NE) case study: 400 MW nuclear power plant.

Renewable energy (RE) case study: 847 MW wind farm.

RTS-GMLC contains:

- 73 buses
- 74 thermal generators
- 20 hydro generators
- 25 photovoltaic farms
- 31 rooftop photovoltaic
- 1 nuclear generator
- 4 wind farms

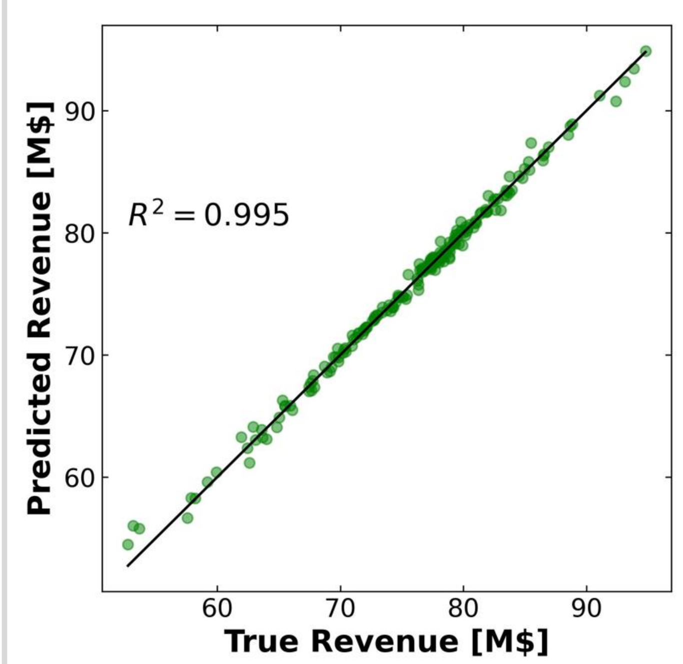
(3) Methodology



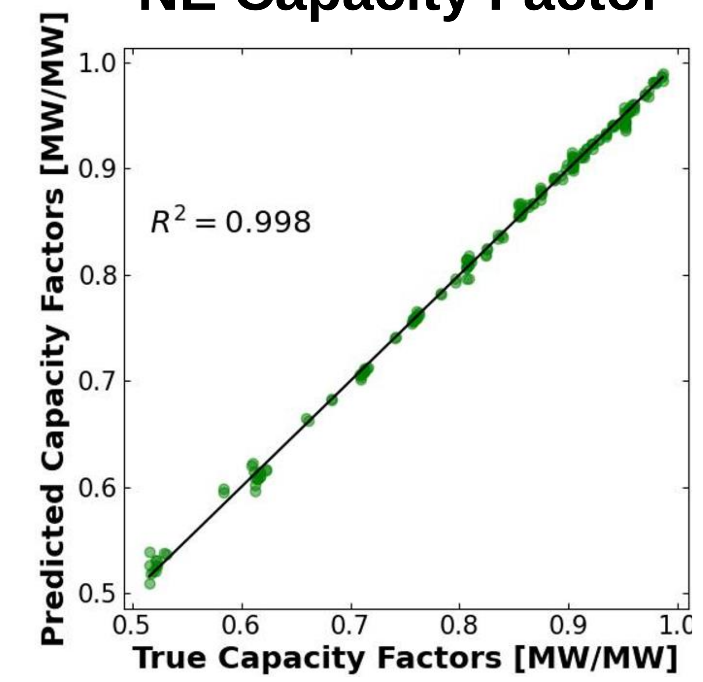
$$\max_{d,u} E(NPV)$$
$$\text{s.t. } f(d,u,\pi_t) = 0$$
$$g(d,u,\pi_t) \le 0$$

(4) Surrogate Models Are Accurate

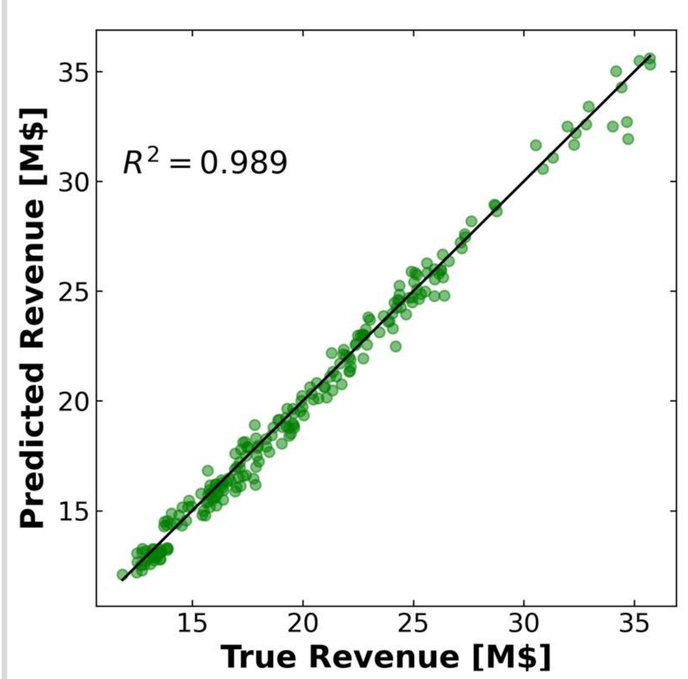
NE Revenue



NE Capacity Factor



RE Revenue



Keras v2.9.1

RE Dispatch Frequency

Number of Clusters	20
Mean R^2	0.9935
Max R^2	0.9983
Min R^2	0.9774
Standard Deviation	0.0066

(5) IES Optimization with Market Surrogates

$$\max \quad NPV$$

$$\text{s.t.} \quad EREV = f^{\text{erev}}\left(\Omega^{\text{pem}}, BID, \beta^{\text{res}}, \beta^{\text{shortfall}}\right) \rightarrow \text{Surrogate constraints}$$

$$F_s = f_s^{\text{disp}}\left(\Omega^{\text{pem}}, BID, \beta^{\text{res}}, \beta^{\text{shortfall}}\right), \quad \forall s \in \mathcal{S}$$

$$P_{\text{total}}^{\text{gen}} = \mu \cdot \Omega^{\text{gen}} \cdot \sum_{s\in\mathcal{S}} F_s \cdot \bar{\chi}_s^{\text{gen}} \rightarrow \text{Generation capacity factor}$$

$$P_{\text{total}}^{\text{grid}} = \mu \cdot \Omega^{\text{gen}} \cdot \sum_{s\in\mathcal{S}} F_s \cdot \bar{\chi}_s^{\text{grid}} \rightarrow \text{Dispatch capacity factor}$$

$$P_{\text{total}}^{\text{pem}} = \mu \cdot \Omega^{\text{gen}} \cdot \sum_{s\in\mathcal{S}} F_s \cdot \bar{\chi}_s^{\text{pem}} \rightarrow \text{PEM capacity factor}$$

$$HREV = \psi^{\text{pem}} \cdot P_{\text{total}}^{\text{pem}} \cdot \rho^{H_2} \rightarrow \text{Hydrogen revenue}$$

$$FOM = \phi_1^{\text{gen}} \cdot \Omega^{\text{gen}} + \phi_1^{\text{pem}} \cdot \Omega^{\text{pem}} \rightarrow \text{OM costs}$$

$$VOM = \phi_2^{\text{gen}} \cdot P_{\text{total}}^{\text{gen}} + \phi_2^{\text{pem}} \cdot P_{\text{total}}^{\text{pem}} \rightarrow \text{Variable costs}$$

$$CAPEX = \gamma^{\text{pem}} \cdot \Omega^{\text{pem}} \rightarrow \text{Capital costs}$$

$$DEP = CAPEX/\lambda$$

$$TAX \ge 0$$

$$TAX \ge \tau \cdot (EREV + HREV - FOM - VOM - DEP)$$

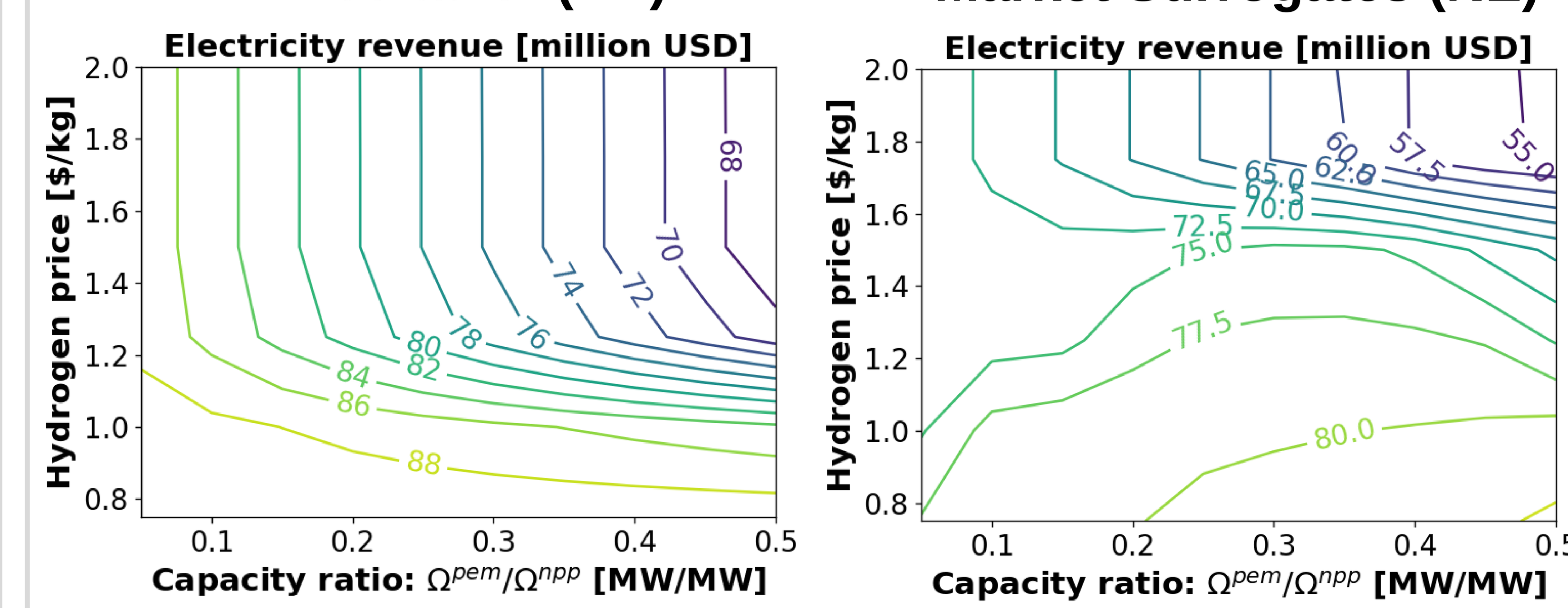
$$PROFIT = EREV + HREV - FOM - VOM - TAX$$

$$NPV = PROFIT - (1/\xi) \cdot CAPEX$$

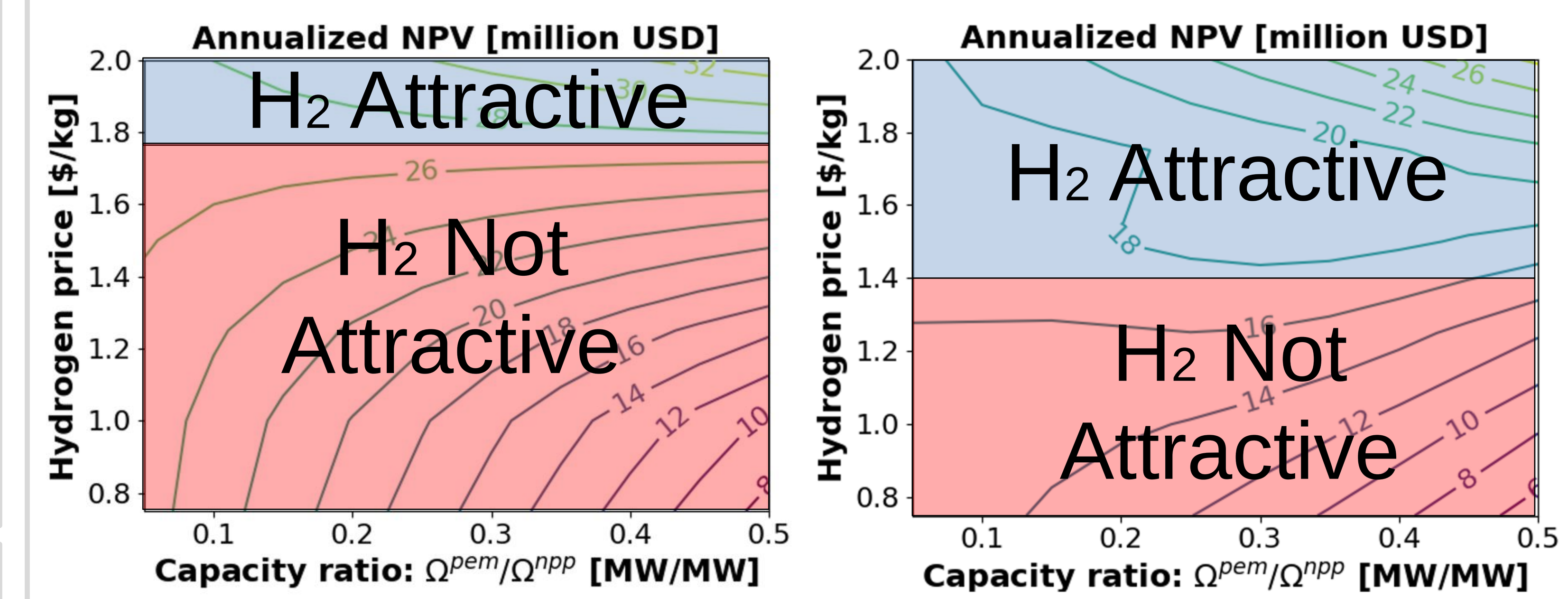
PYOMO v6.5.0

IPOPT v3.13.2

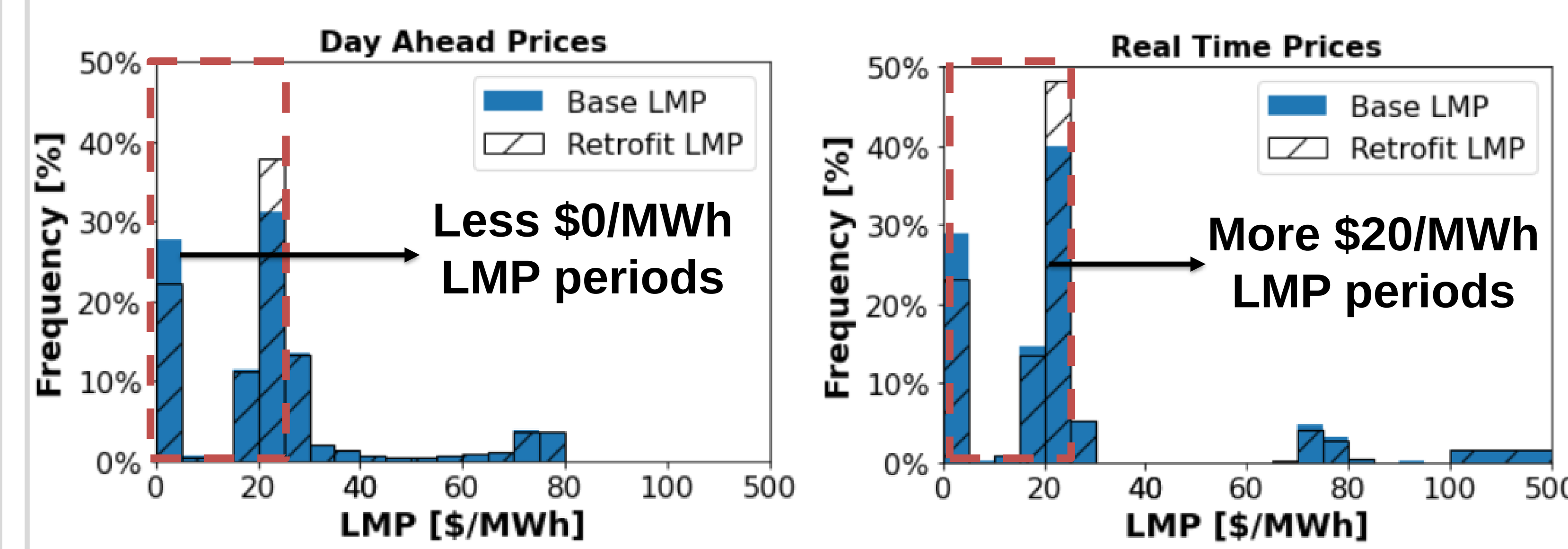
(6) Discussion and Conclusions



Price-taker overestimates the electricity revenue.
The electricity revenue may not always decrease with the increasing size of PEM.



Price-taker overestimates the hydrogen break even price.
The hydrogen co-production is attractive with a lower hydrogen selling price.



*In both RE and NE case, the IES retrofit **increases market prices**.*

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