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Impact of Uncertainty from Load-based Reserves and Renewables on Dispatch Costs and Emissions

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Motivation

Previous work

- Load-based reserves are inexpensive, fast-responding and environmental-friendly
- Their capacities are highly affected by ambient conditions and load usage patterns
- Chance-constrained optimization and thermal battery model are used to model the load and renewable uncertainties in a multi-period optimal power flow problem

This work

- Qualitatively explore the impacts of renewable and load control uncertainty, cost parameters, methods for solving the problem and types of controllable loads on optimal dispatch solutions and CO_2 emissions.

Load Model

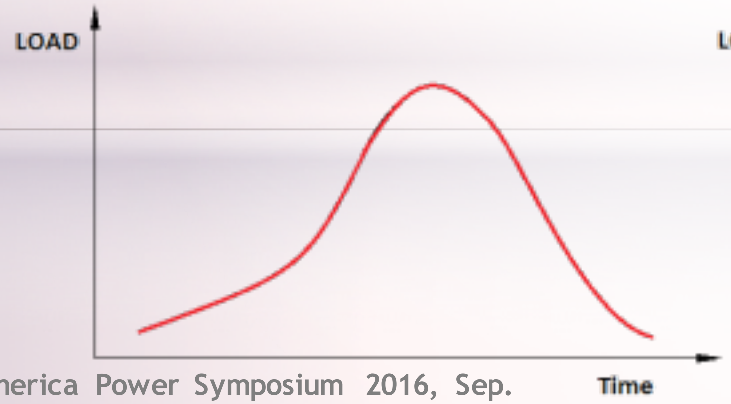
Aggregation of residential loads

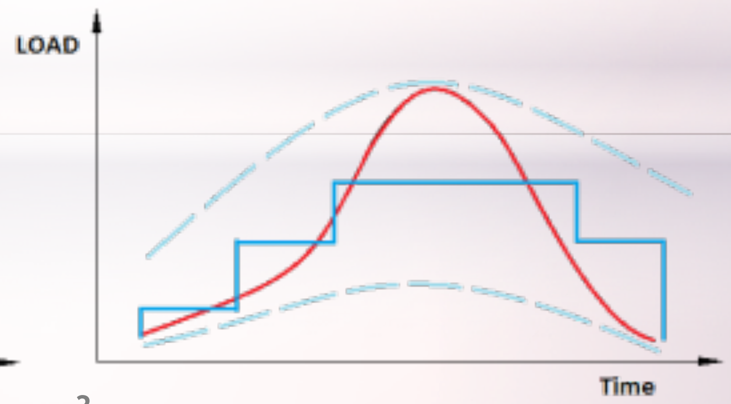
- Thermostatically controlled loads (i.e. electric heaters) with temperature setting and deadband
- On/Off signals from aggregator to individual loads (Non-disruptive control)

Thermal battery model (Mathieu, et al. 2015)

- Baseline power consumption P_T
- Aggregated power consumption (set point) $P_{C,t}$
- Real time energy state S_t
- Energy Storage: Charging/Discharging

$$S_{t+\Delta\tau} = S_t + (P_{C,t} - P_T(T_t))\Delta\tau$$
$$\underline{P}_C(T_t) \leq P_{C,t} \leq \overline{P}_C(T_t)$$
$$\underline{S}(T_t) \leq S_t \leq \overline{S}(T_t)$$





Problem Formulation

Optimization for day-ahead planning

- Objective: To determine the optimal dispatch with uncertain load control and renewable resources by co-optimizing reserves and energy.
- Uncertainties: wind power production and outdoor temperature

Design variables

- Generation schedule and load set points
- Generation and load reserve capacity
- Percent contribution of each reserve provider

Constraints

- Deterministic/Probabilistic
- Generation limits/Load limits/Line limits/Reserve limits

Solving methodologies

- Probabilistic robust method (Margellos, et al. 2014)
- Analytical reformulation (Bienstock, et al. 2014)

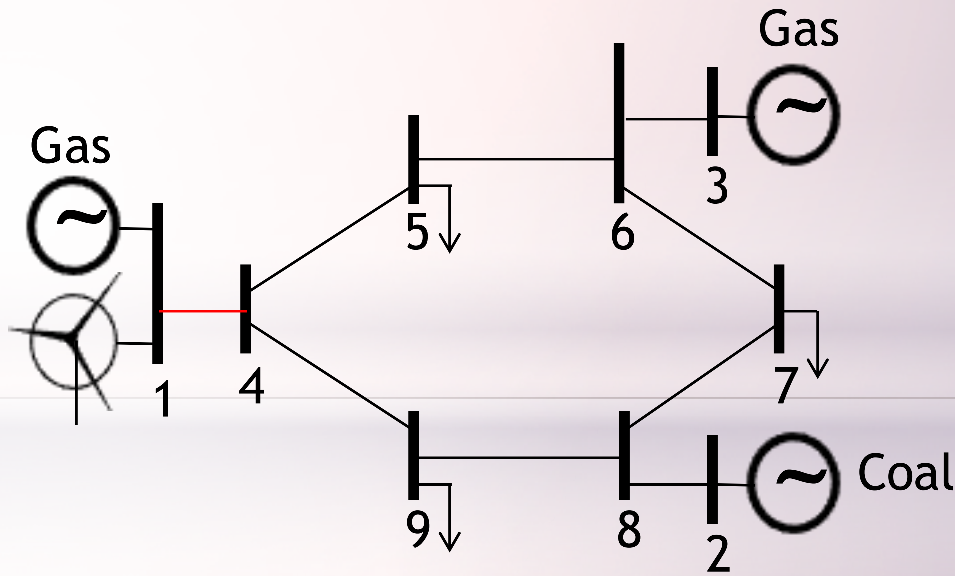
Summary of Case Studies

Modified IEEE 9-bus system

- Features: renewable energy producers, controllable load, congestion, different types of generators for CO_2 emissions analysis.
- A base case is defined as comparison reference using empirical wind/temperature data

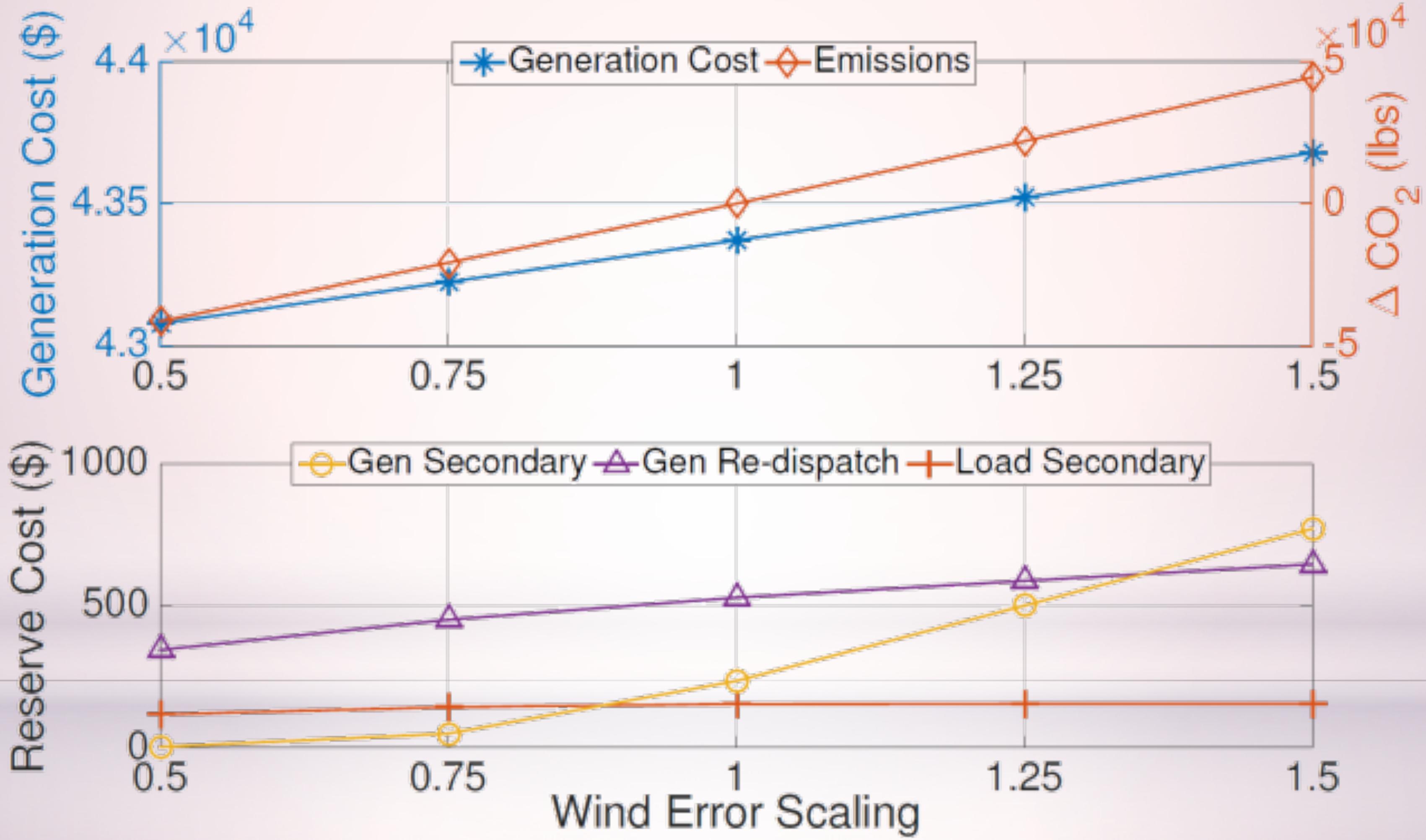
We vary the following factors that influence the dispatch:

- Wind forecast error
- Temperature forecast error
- Temperature forecast
- Load energy capacity
- Generation secondary reserve cost
- *Methods to solve the problem*

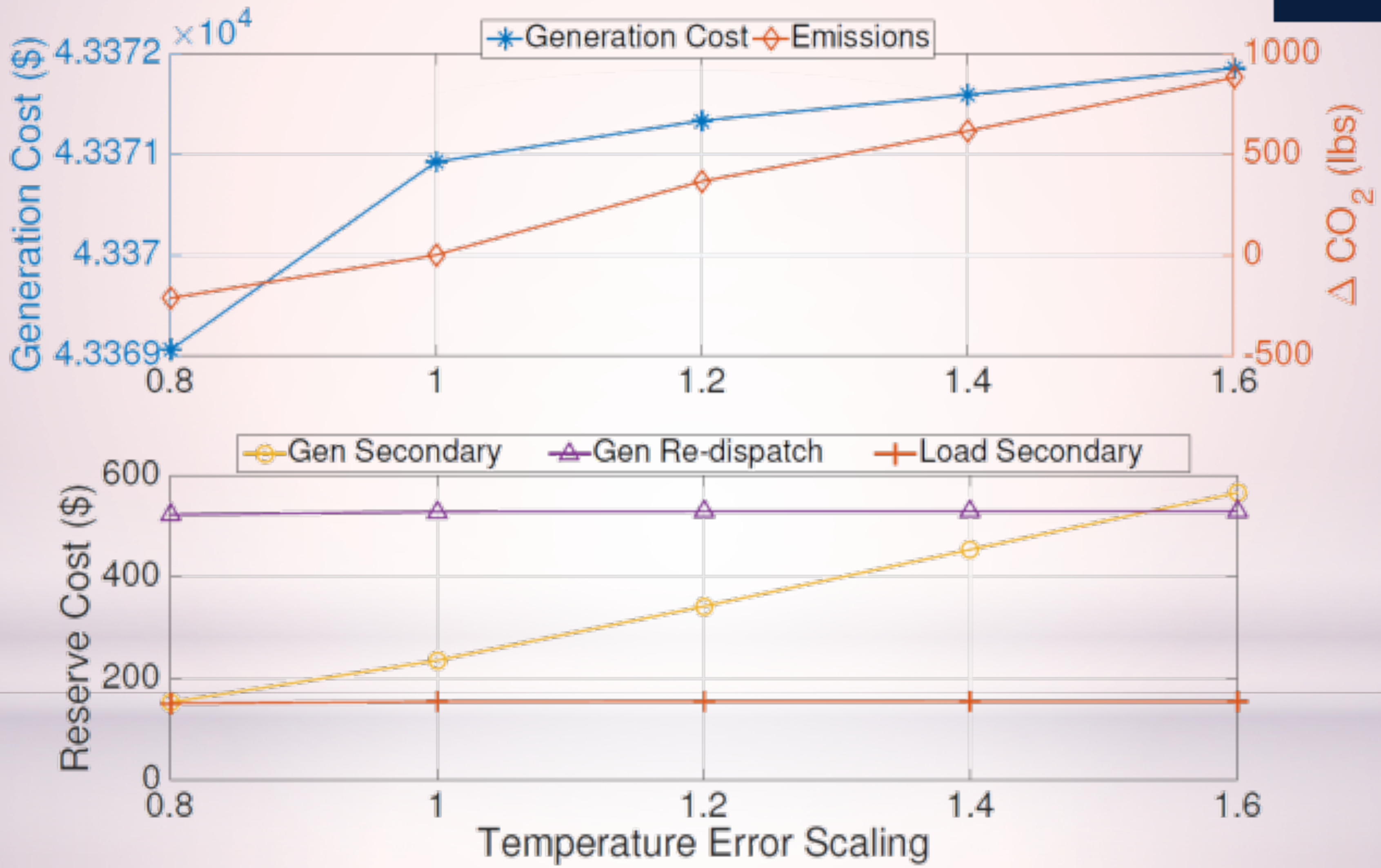


15% of each load is controllable but uncertain

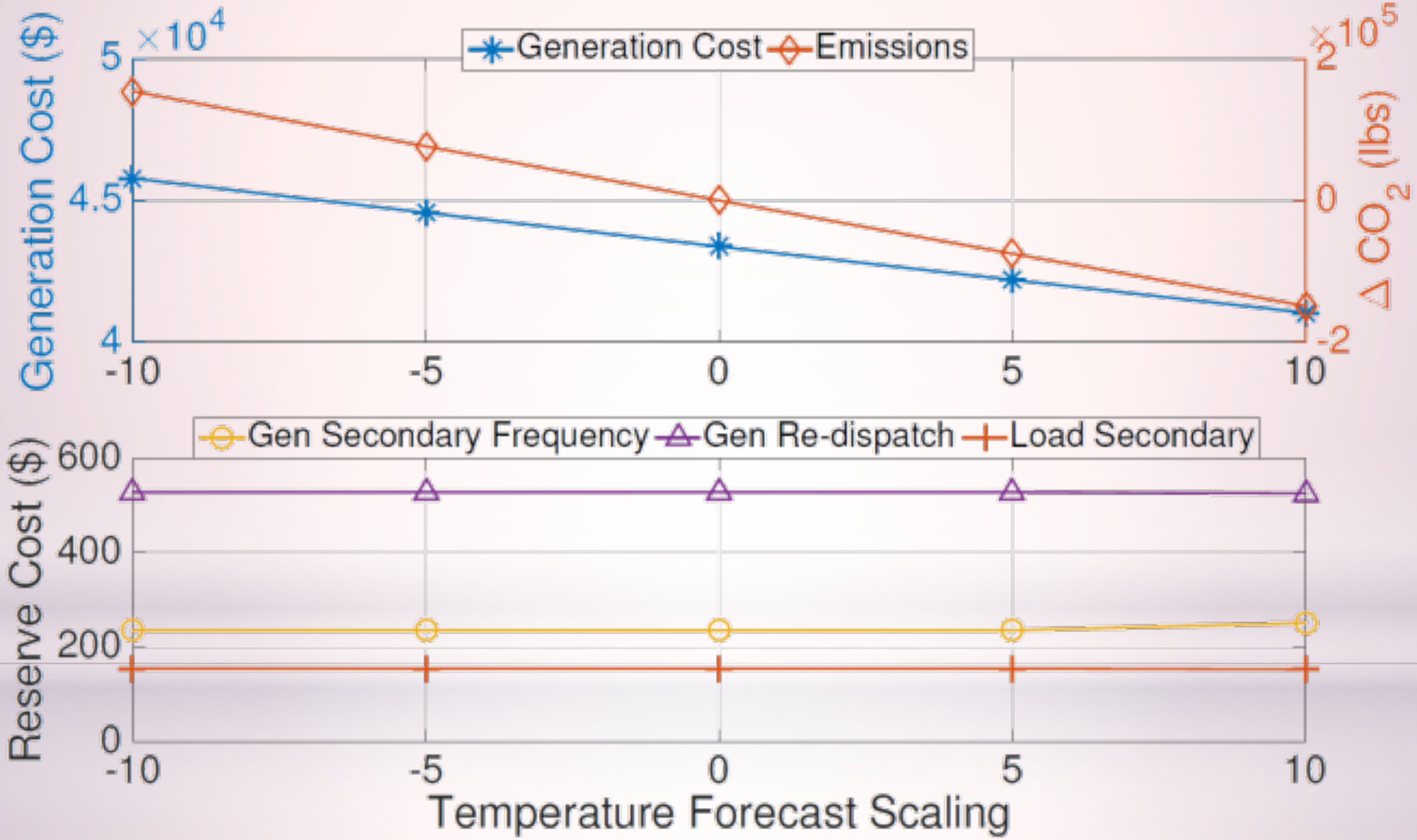
Results: wind forecast error



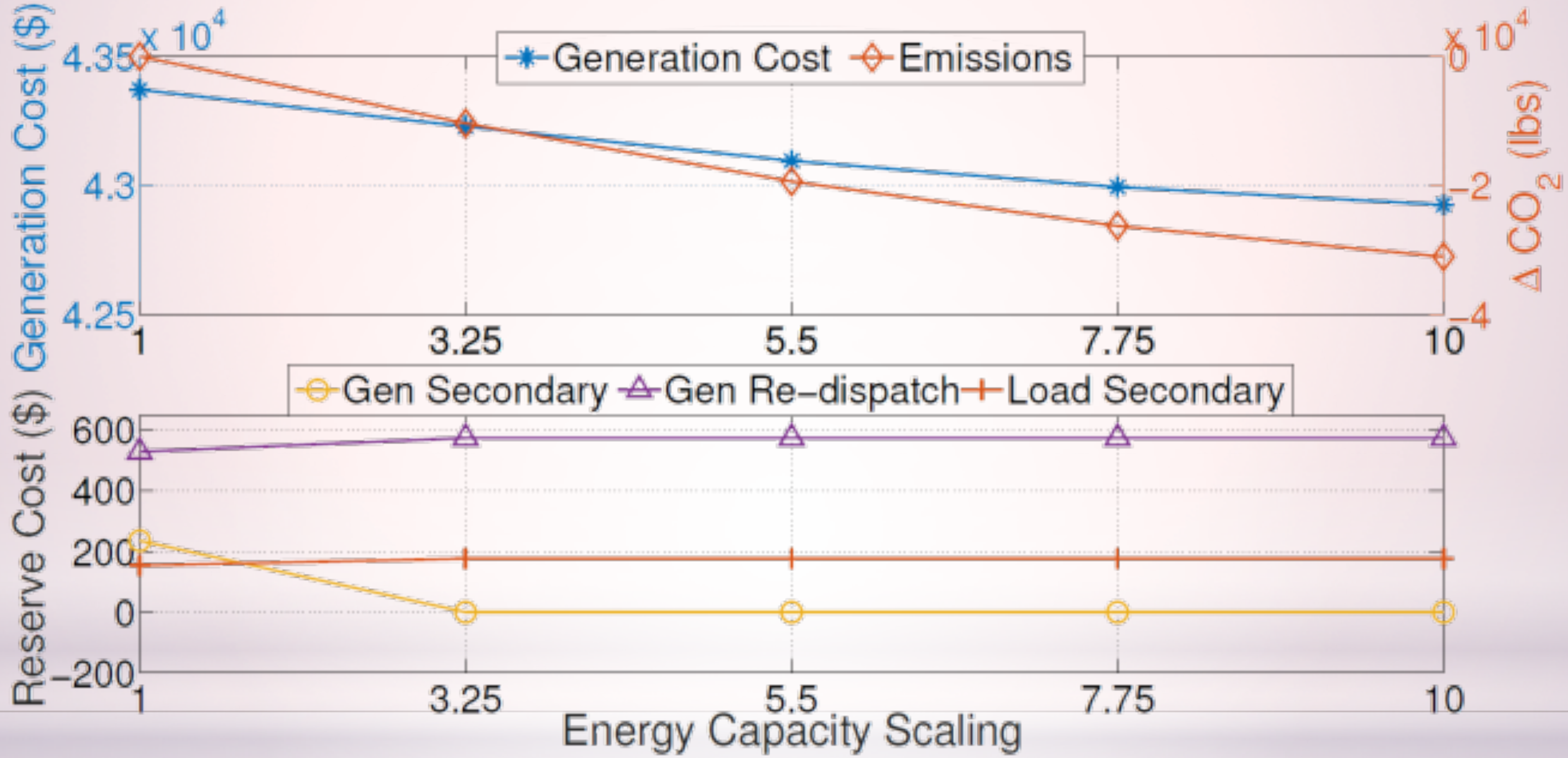
Results: temperature forecast error



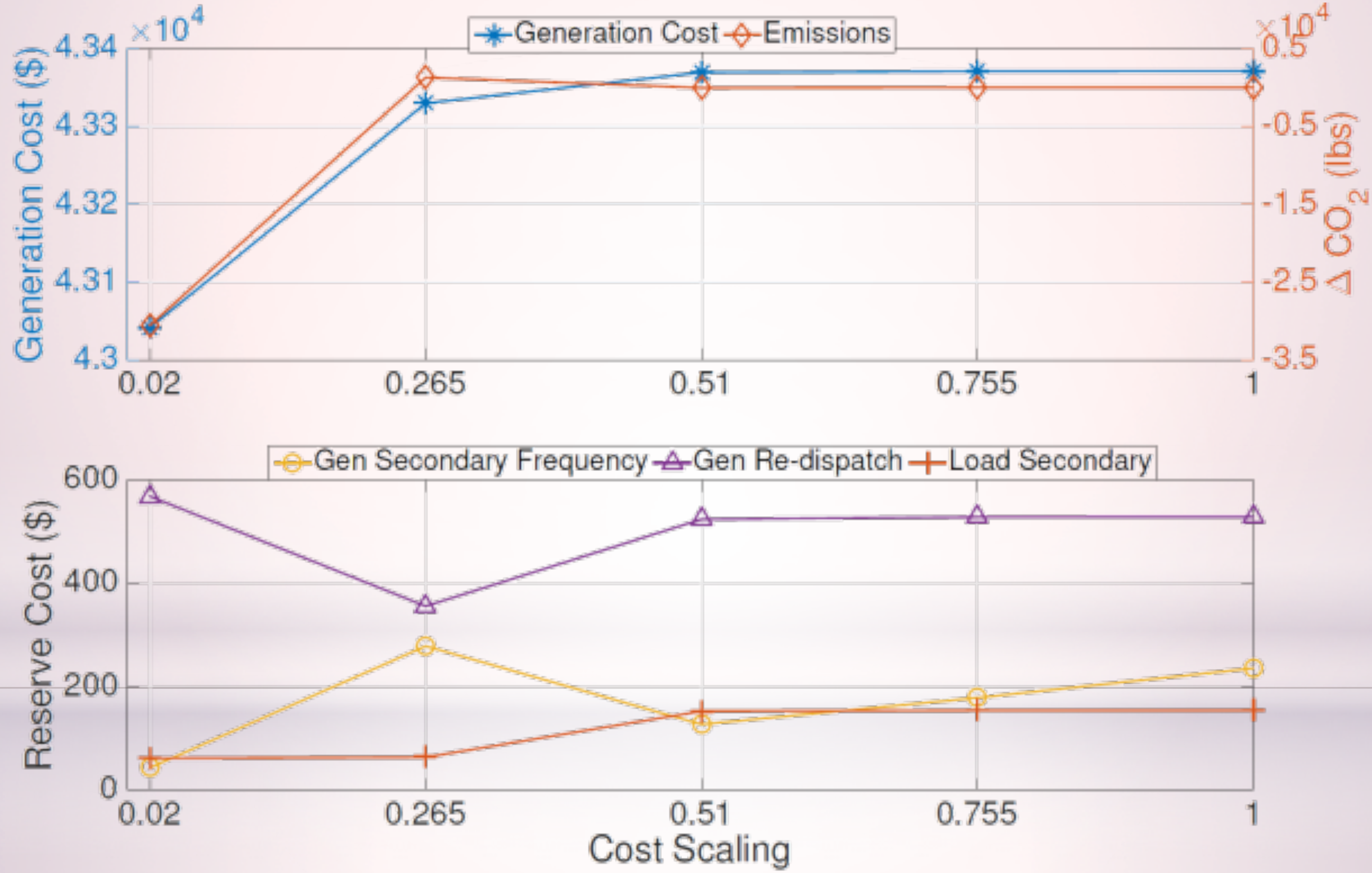
Results: temperature forecast



Results: load energy capacity



Results: generator secondary reserve cost



Conclusions

- Wind uncertainty has larger impact on dispatch and emissions
- Controllable loads are used to provide reserve first until the capacity is reached
- Changes on generation dispatch has larger effect on emissions
- Higher load capacity results in more load reserve provision, more load shifting and reduced emissions
- Analytical reformulation gives less conservative results.
- Future Work
    - Improve the aggregated load model
    - Impact of forecast profiles on results
    - Quantify the results

Questions

Thanks!

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TABLE I. BASE CASE COSTS & EMISSIONS RESULTS

	Dispatch ($)	Gen. Sec. ($)	Re-dispatch ($)	Load Sec. ($)	Emissions (lbs)
Robust	43371	235.4	528.5	154.1	2.59e+06
Gaussian	43022	0	222.8	72.0	2.54e+06