Managing Wind Variability through a Combination of Self-reserves and Responsive Demand

J. B. Cardell
Smith College

C. L. Anderson
Cornell University

Today’s Question

Using demand response makes sense to balance wind uncertainty and variability, but…

...why shouldn’t wind provide self reserves?

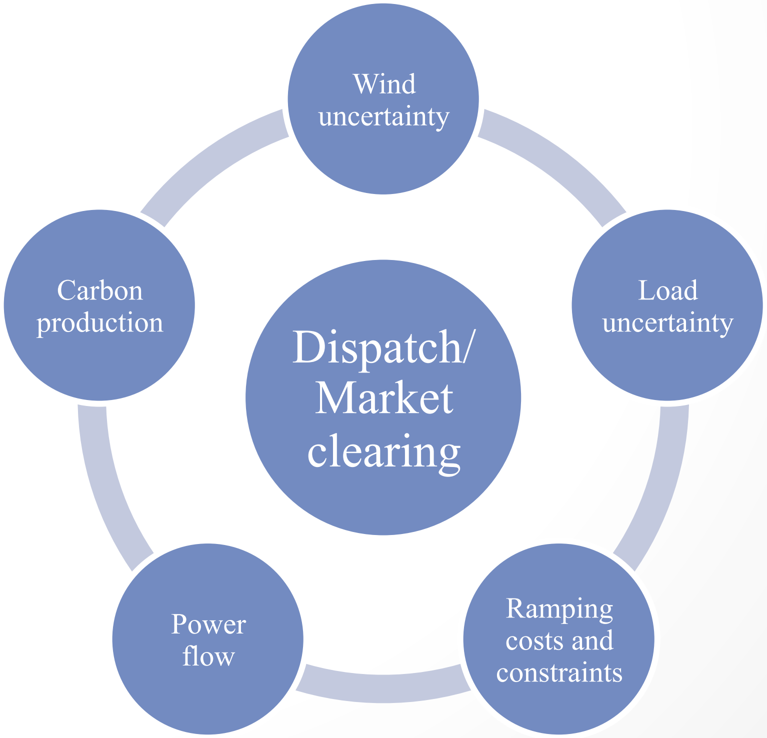
Topics Overview

- Modeling framework
- Quick re-cap of the impact of using DR to balance wind variability and uncertainty
- Representing generator forced outages
- Preliminary results on the use of wind “self-reserves”

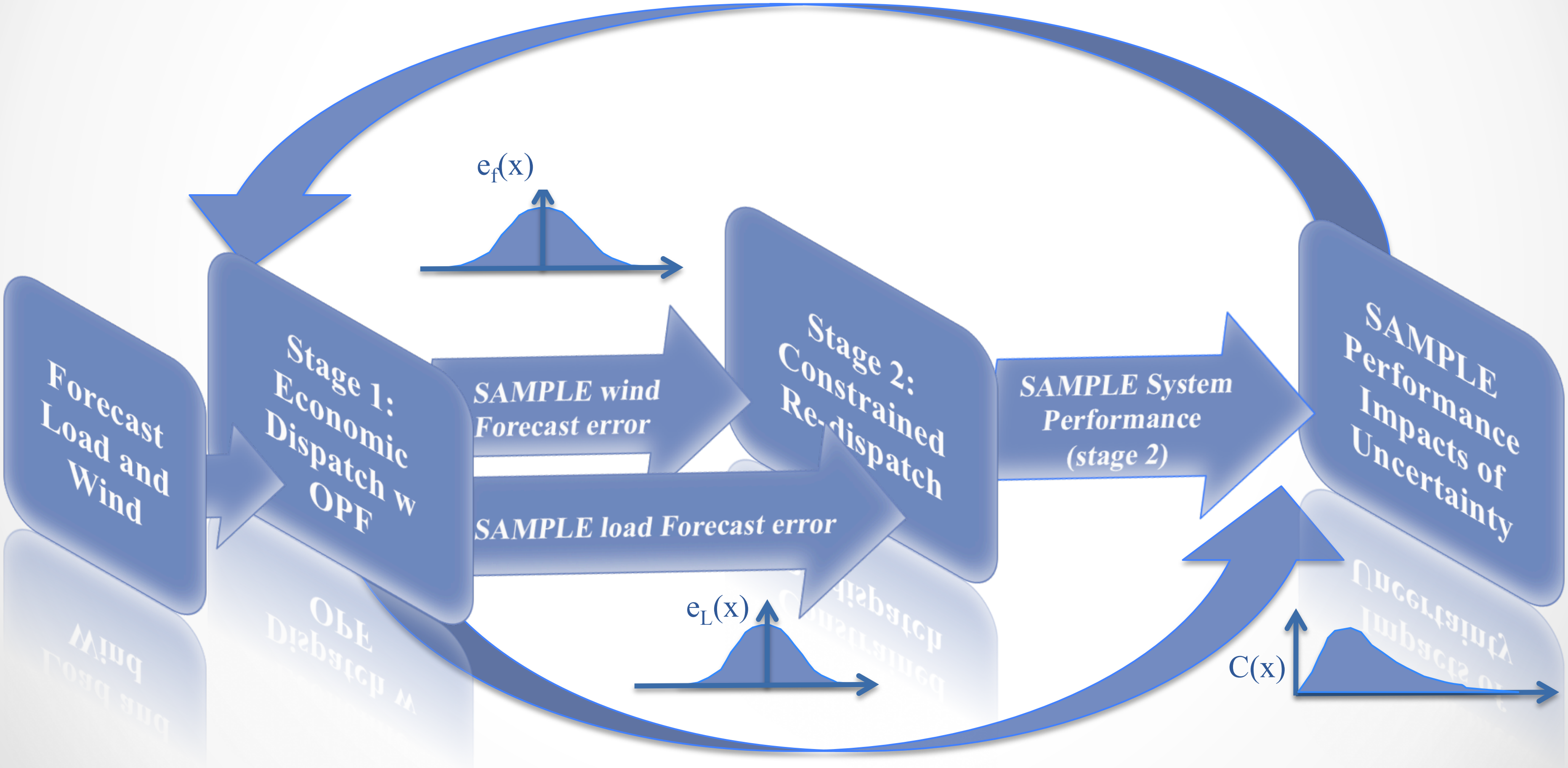
Modeling Framework

Capturing the impact of load and wind forecasting errors on system dispatch

- Achieved through the integration of sub-models



Network Re-Dispatch in a Monte Carlo Framework



Forecast Load and Wind

Stage 1: Economic Dispatch w OPF

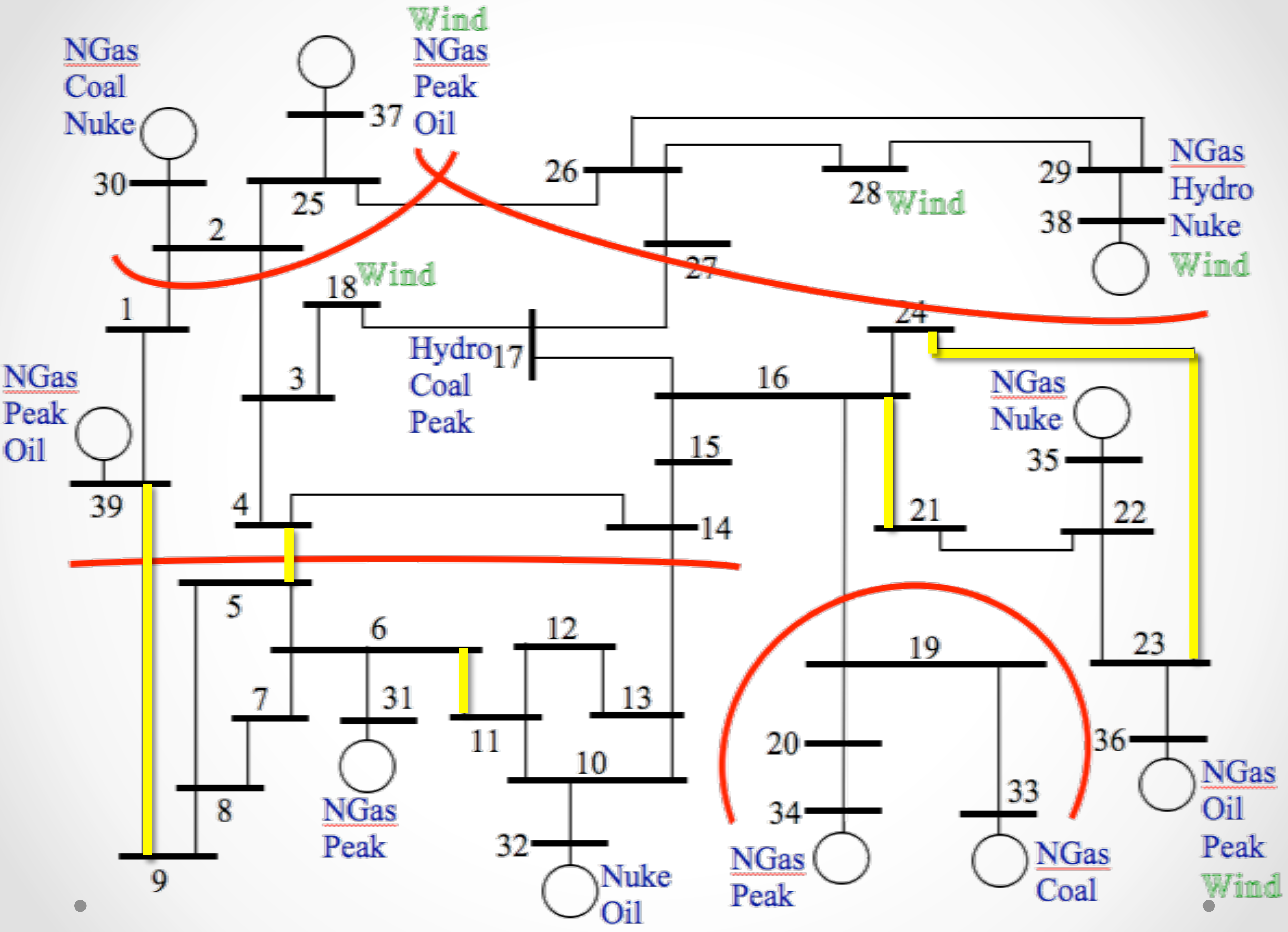
SAMPLE wind Forecast error

SAMPLE load Forecast error

Stage 2: Constrained Re-dispatch

SAMPLE System Performance (stage 2)

SAMPLE Performance Impacts of Uncertainty



NGas
Coal
Nuke
30
37
25
Wind
NGas
Peak
Oil
2
26
28
Wind
29
NGas
Hydro
Nuke
Wind
38
27
18
Wind
1
24
Hydro
17
Coal
Peak
3
16
NGas
Nuke
35
NGas
Peak
Oil
39
15
4
14
21
22
5
6
12
19
23
7
31
13
11
10
36
20
8
NGas
Peak
33
34
32
NGas
Oil
Peak
Wind
9
Nuke
Oil
NGas
Peak
NGas
Coal

Optimizing Demand Response

- 15% of load is responsive in the 'real-time' market
- Optimize use of HA (slower responding & lower cost) demand response:

Cost Minimizing Dispatch*		
Hour Ahead	10 Min Ahead	Real-Time
85%	15%	0%

*Method for determining the cost-minimizing dispatch percentages was discussed previously, see [2]

System benefits of DRR with Wind

- Previous results have shown:
  Use of multi-temporal scale DR may increase the benefits of wind power

Parameter	**No DRR**	**Naïve DRR**	**Optimal DRR**
LMP level & σ	↑	↓	↓↓
Production cost	↑	-	↓
CO_2 emissions	↓	↓	↓↓
Wind Spilled	-	↓	↓↓

Qualitative System Impacts with increasing wind penetration (0-30%)

Generator Forced Outages

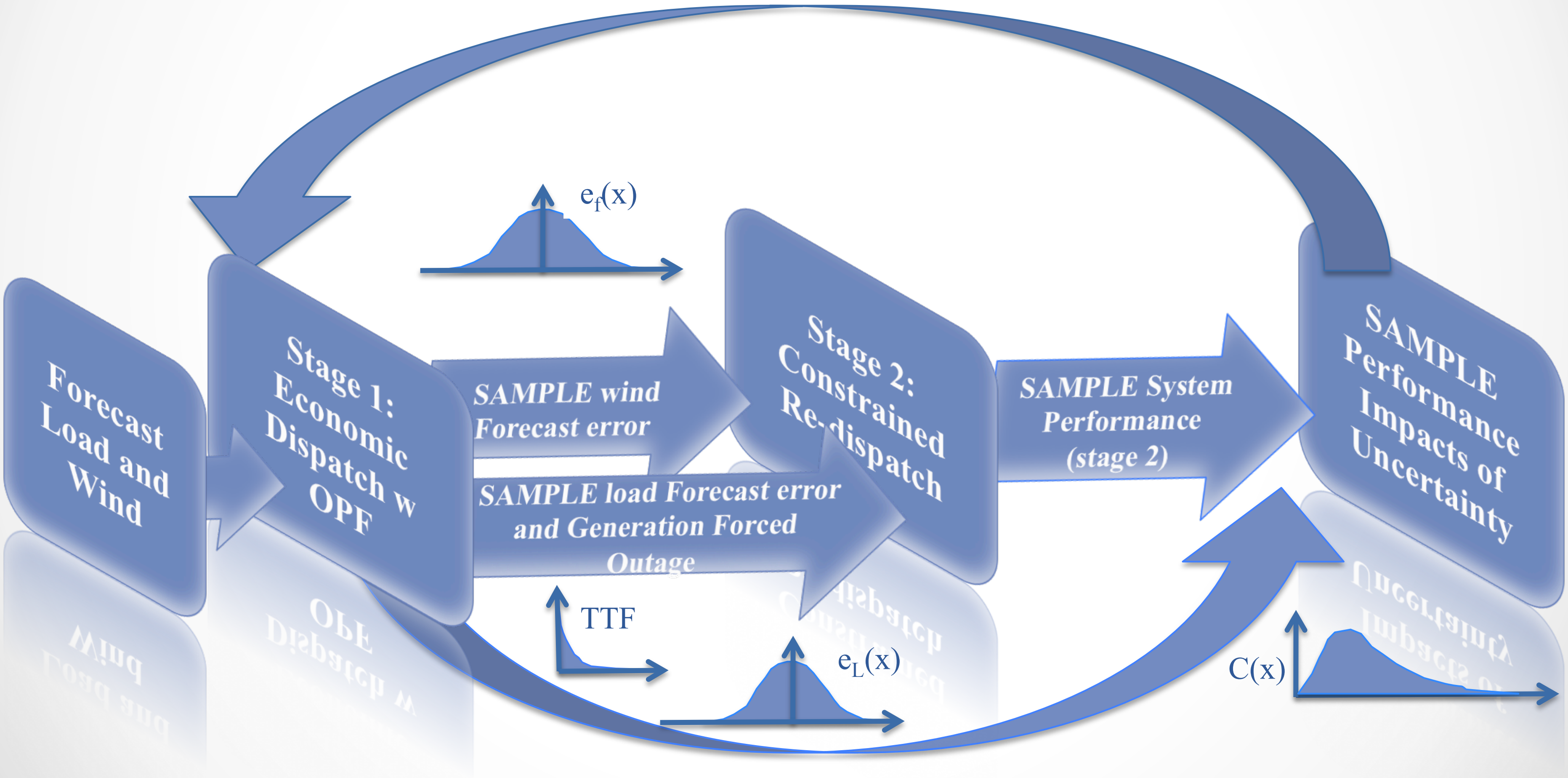
- In the short time-frame of the re-dispatch model, generator outages can occur
- A forced outage sub-model is now included, inducing (probabilistic) random outages:
  - EFOR is differentiated by generator type [1]
  - Generators at each bus "dis-aggregated" to experience individual outages
  - A generator outage also impacts ramp capabilities by reducing flexibility

[1] Applications of Probability Methods Subcommittee. (1979). IEEE Reliability Test System. Power Apparatus and Systems, IEEE Transactions on, (6), 2047–2054. doi:10.1109/TPAS.1979.319398

Mean Time to Failure

Generator Type	MTTF (hours)
Coal	2940
Hydro	1960
Natural Gas	1980
Nuclear	1104
Oil	480
Peaker	480

Network Re-Dispatch in a Monte Carlo Framework



Forecast Load and Wind

Stage 1: Economic Dispatch w OPF

SAMPLE wind Forecast error

SAMPLE load Forecast error and Generation Forced Outage

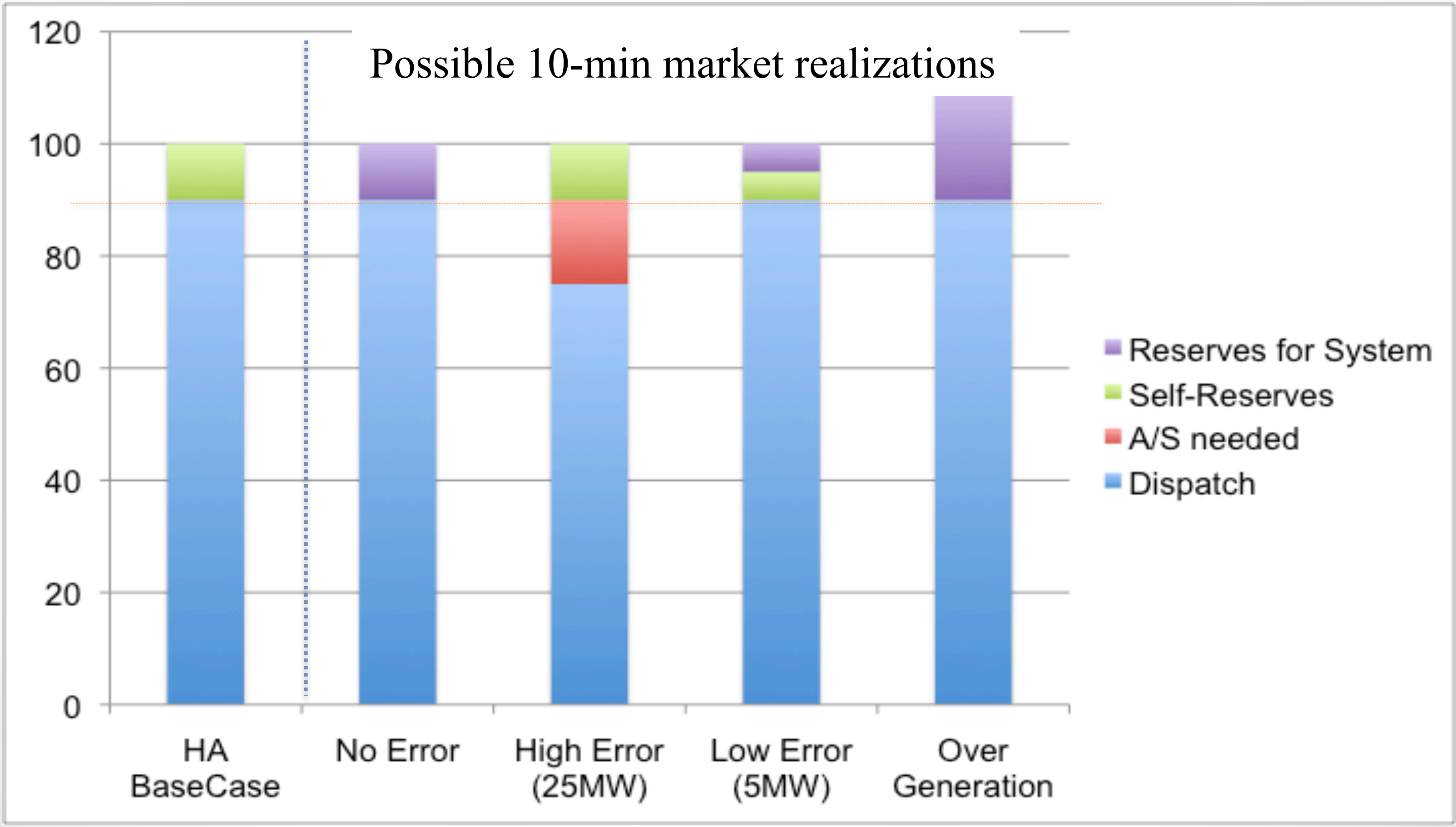
Stage 2: Constrained Re-dispatch

SAMPLE System Performance (stage 2)

SAMPLE Performance Impacts of Uncertainty

Wind Self-Reserves

- To model wind providing self-reserves, the wind generators are dispatched down from expected output
- Operational scenarios:

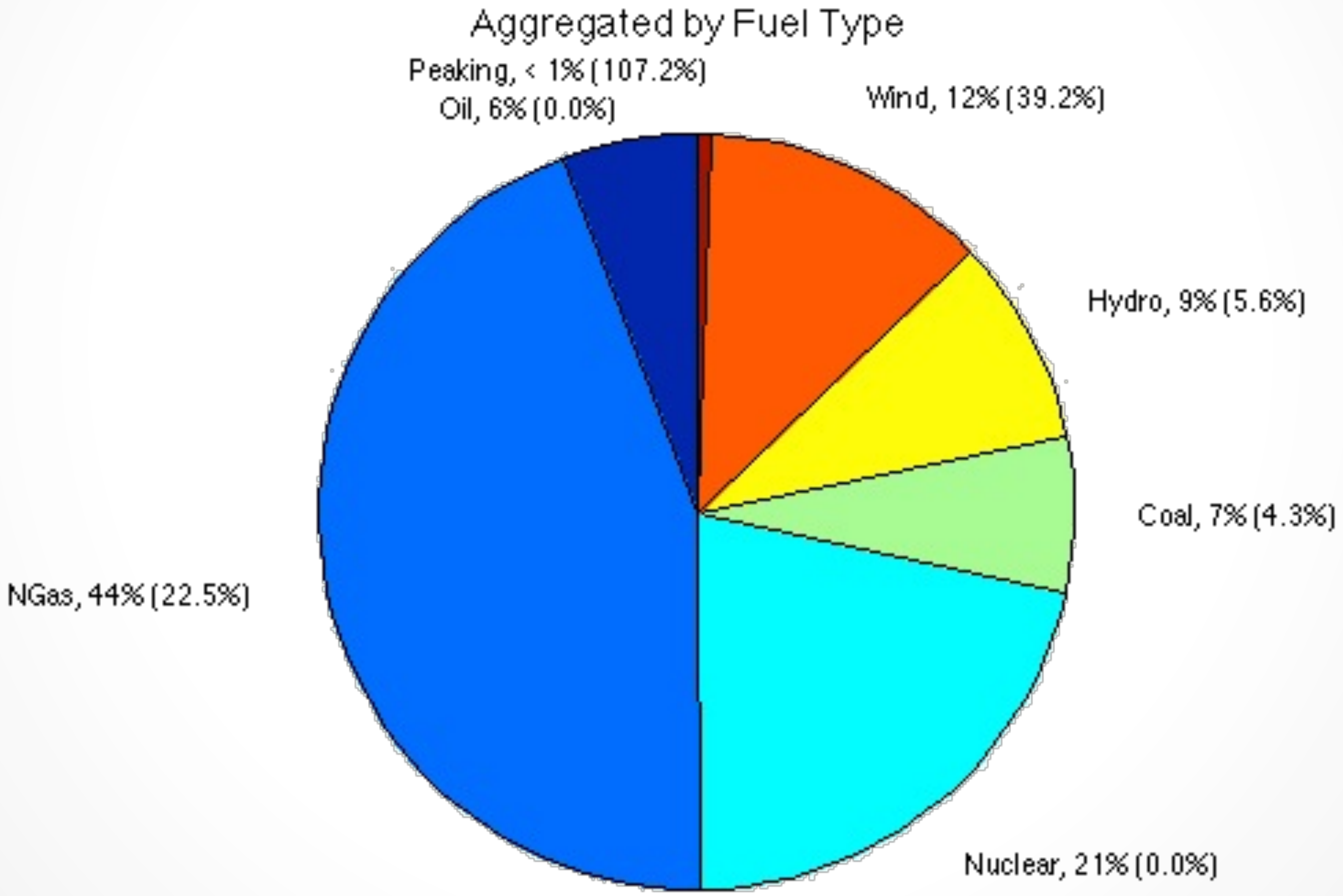


Preliminary Results

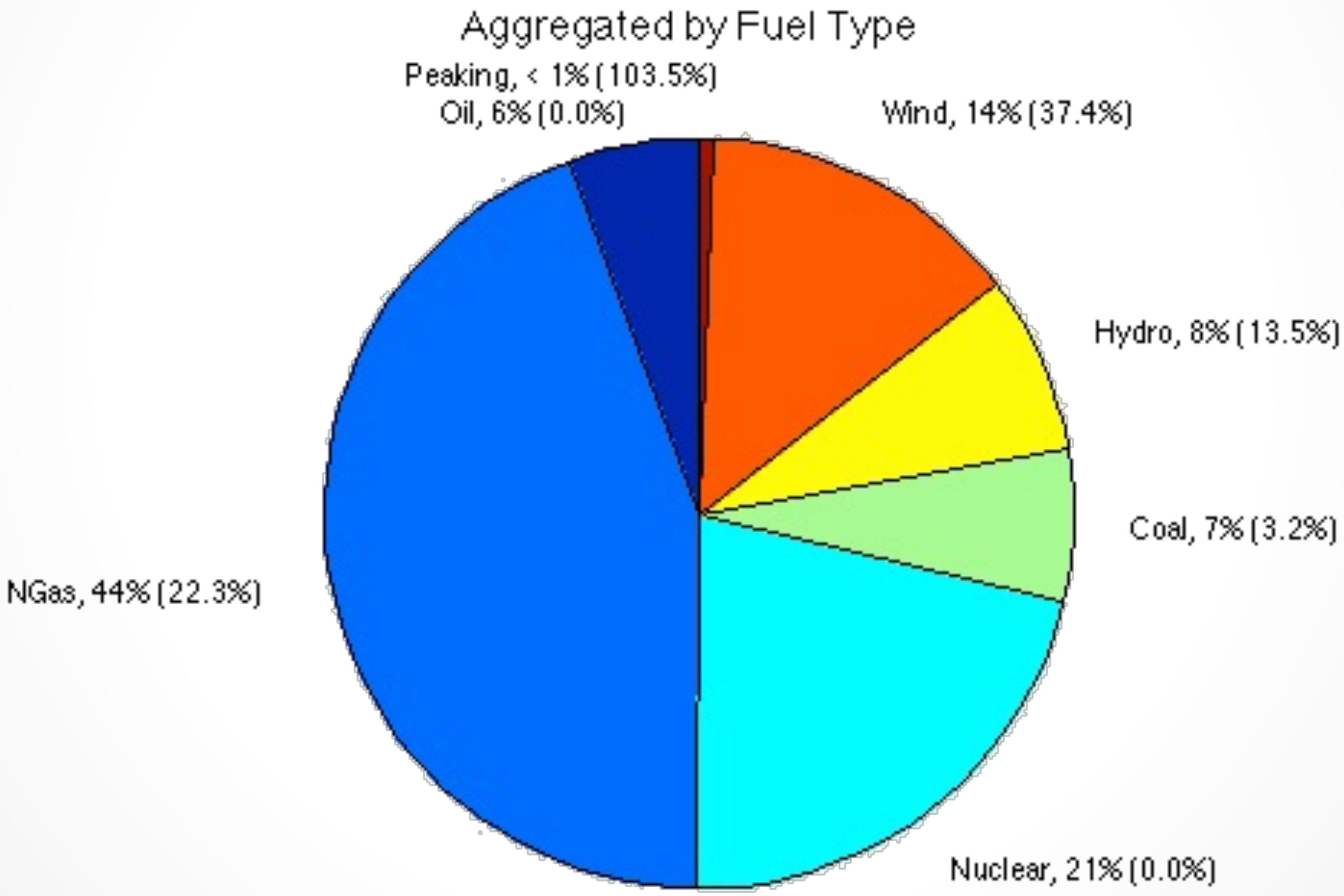
- Recent results available for 10% wind penetration case to compare
    - Demand response without self-reserves
    - Self reserves without demand response
    - Both self reserves and demand response
- Comparison of
    - Aggregate dispatch by generation type (do we use more wind overall?)
    - Locational marginal price (is it economically beneficial?)
    - Wind dispatched and spilled (are we making effective use of the resource?)

Aggregate Dispatch

Generator Dispatch: Demand Response

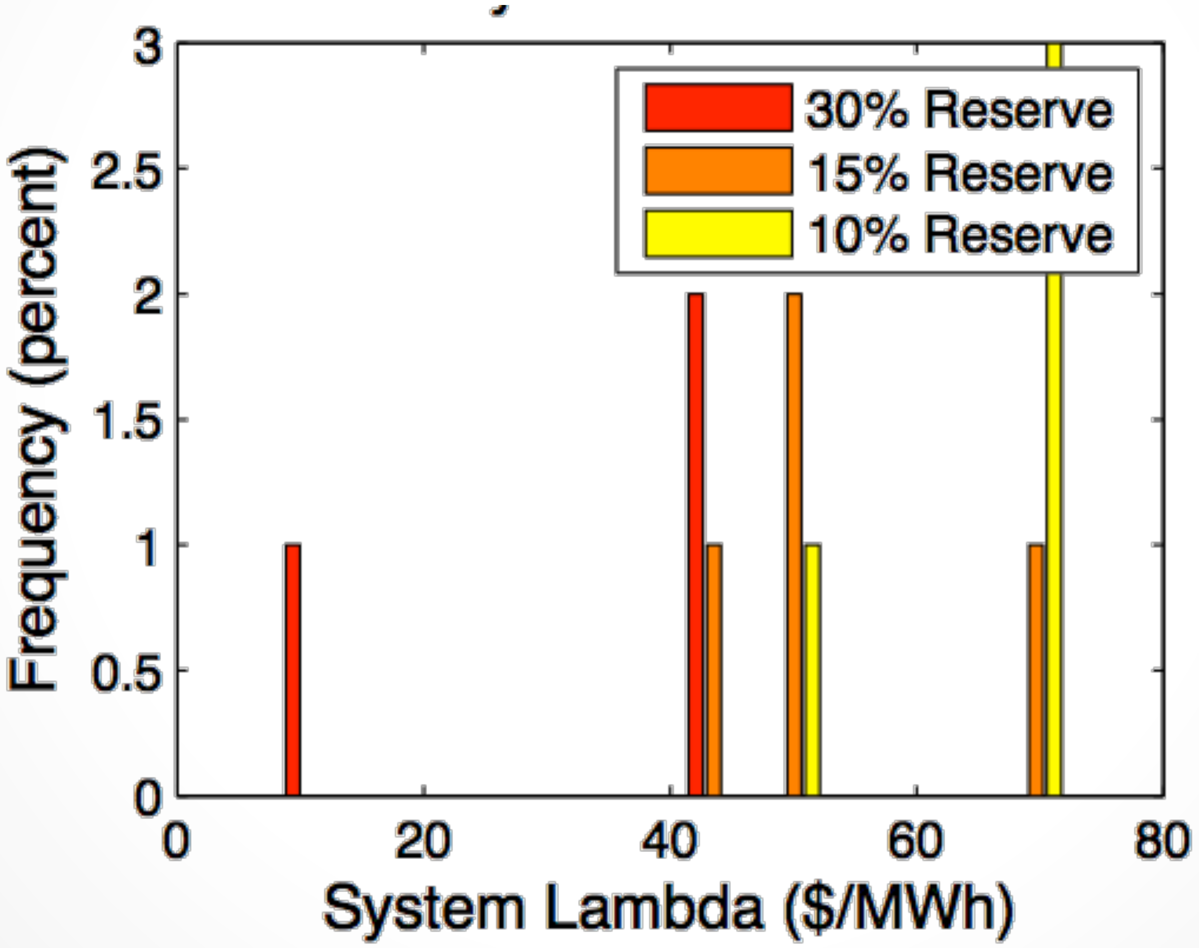


Generator Dispatch: Self-Reserves and Demand Response

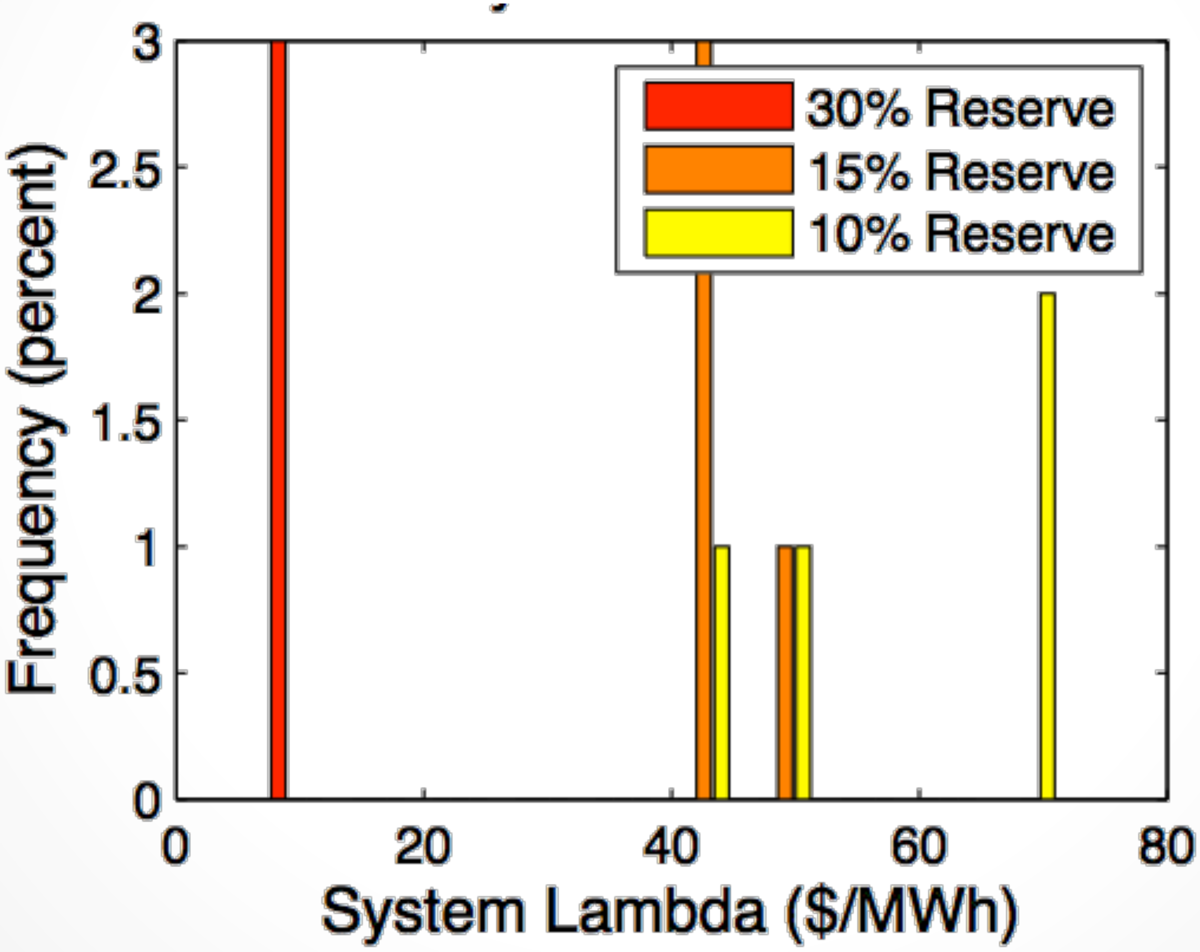


Price Results

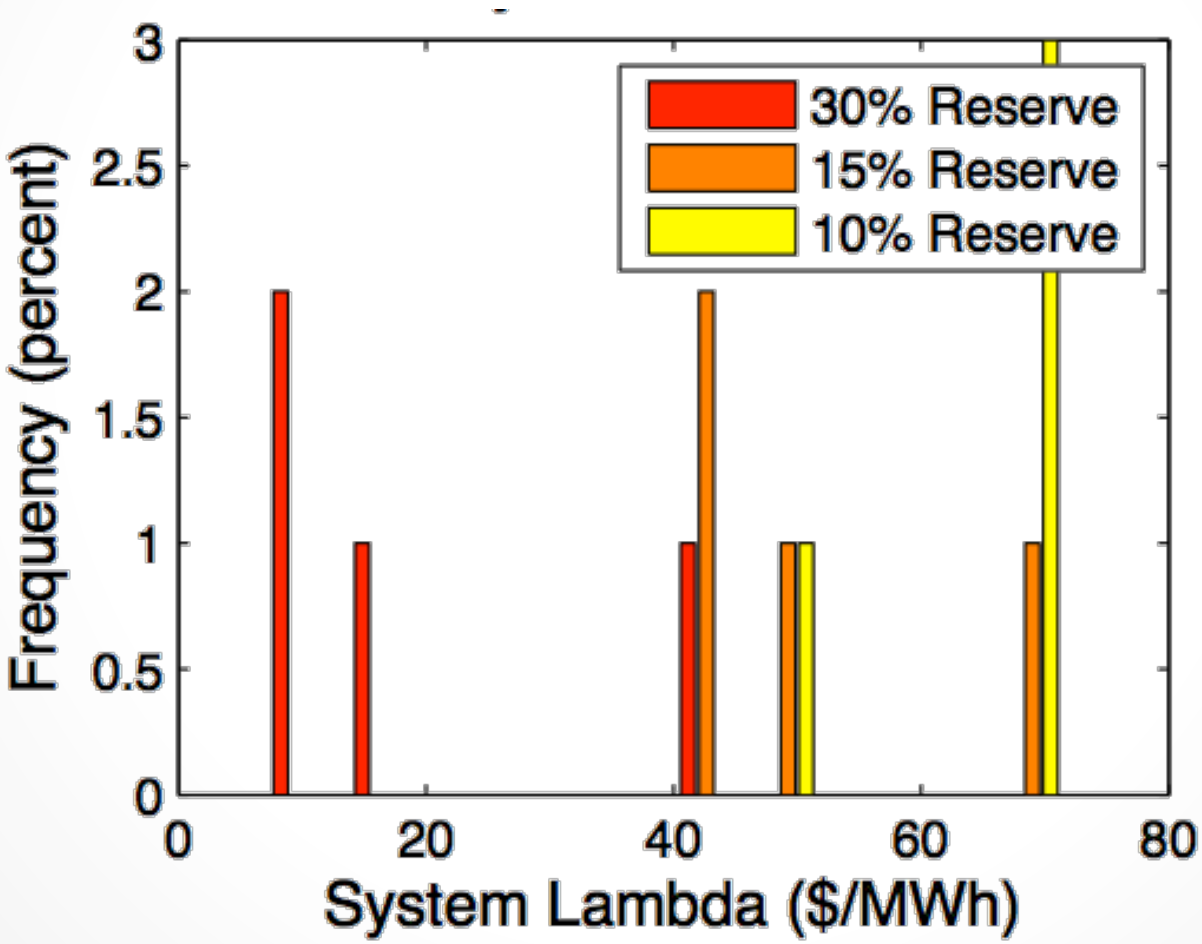
Locational Marginal Price: Demand Response, no Self-Reserves



Locational Marginal Price: Self-Reserves, no Demand Response

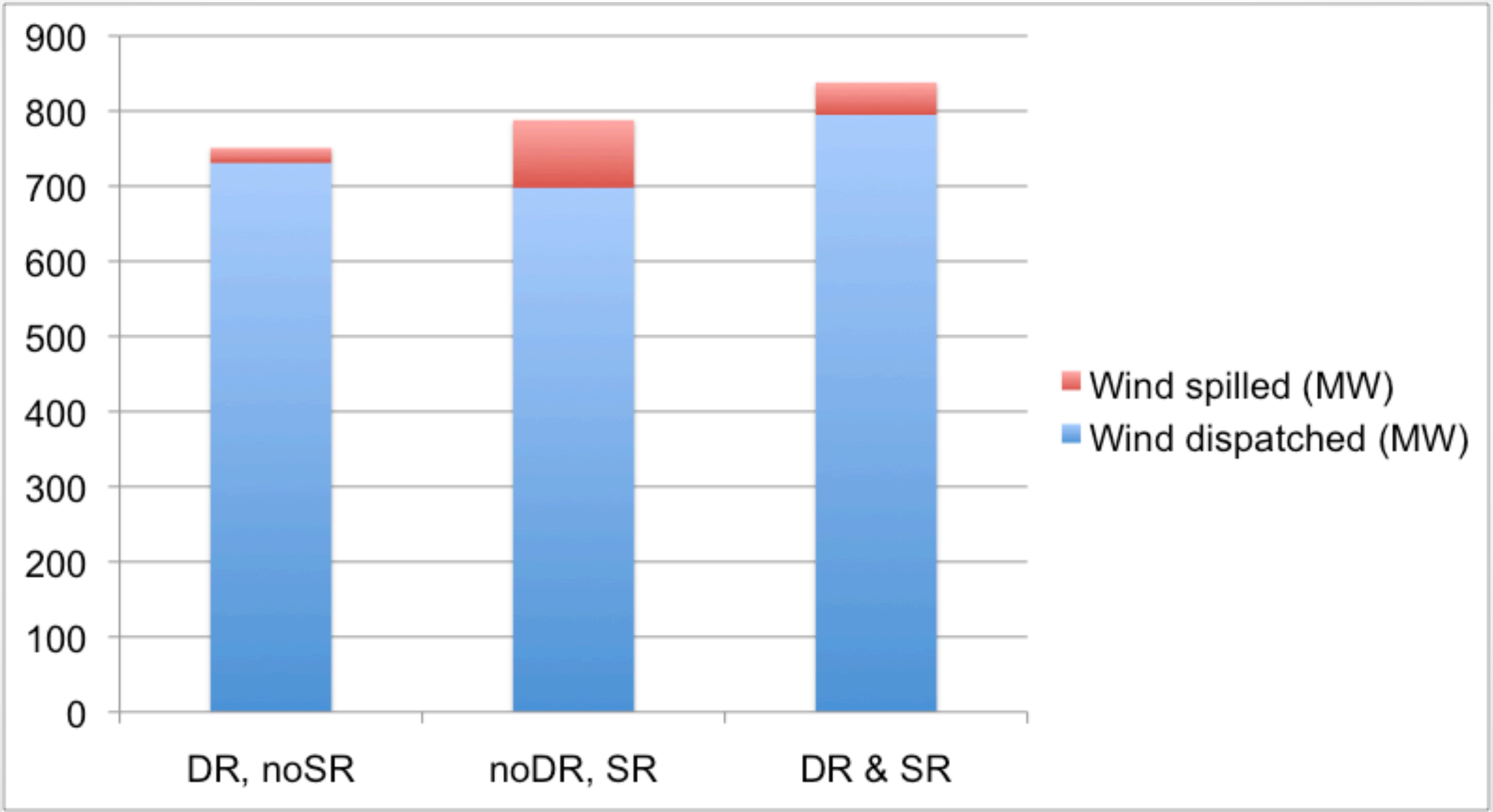


Locational Marginal Price: Demand Response and Self-Reserves



Wind Dispatch & Spill

Average Wind: Dispatched and Spilled



Results Summary

Parameter	**DRR***	**Self-Reserves**	**DRR* with Self-Reserves**
LMP level & σ	↓	↓	↓↓
Production cost	↓	-	
CO_2 emissions		↓	
Wind Spilled			↓
Wind Dispatched			↑↑

**DRR is implemented using optimized fractions*

- Qualitative summary of impacts with wind integrated

Conclusions

For 10% wind penetration

- Including forced outage uncertainty has impacts on LMP and production costs
- Use of wind resources can be improved through use of either demand response or self-reserves
- The *combination demand response with self-reserves* provides additional benefits by increasing wind utilization and reducing required ancillary services
- Challenges of wind are increased at higher penetration, likely the benefit of self-reserves and demand response will be more significant (results TBD)