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# R&M Project 2A: Evaluating the Effects of Managing Controllable Demand and Distributed Energy Resources Locally on System Performance and Costs

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# OUTLINE OF THE PRESENTATION



**PART I: Storage (Mount)**
**PART II: Ramping* (Lamadrid)**
**PART III: Robust Optimization* (Bitar)**
*(Note: This is a new part of the project that began on 3/30/13)

# PART I: Storage

**Wooyoung Jeon**
**Hao Lu**
**Jung Youn Mo**

# Context of the Research:
# An Integrated Multi-Scale Framework

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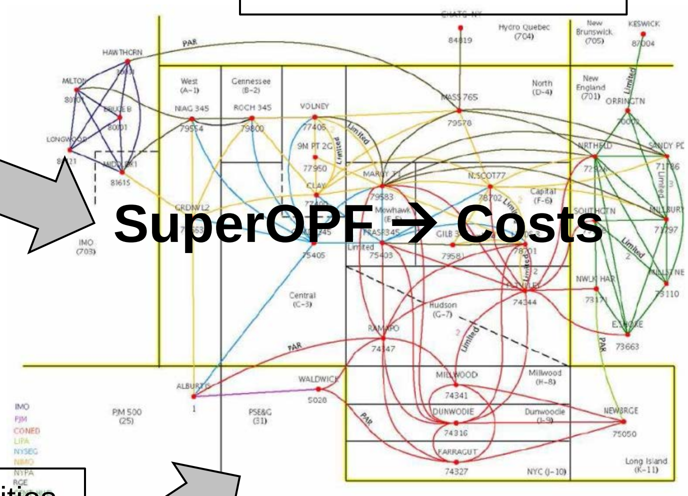
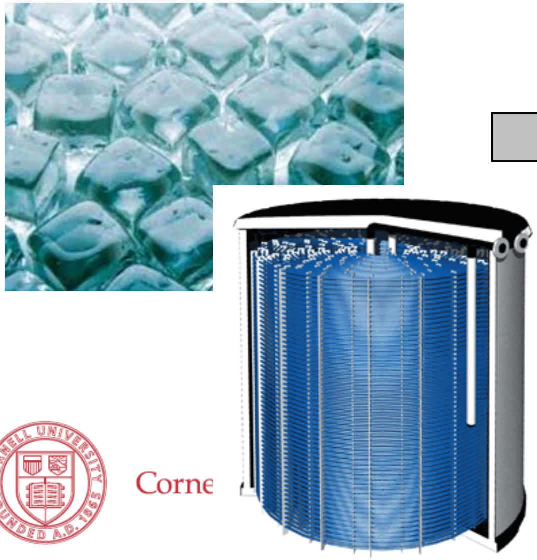
PEV charger capacities → Commuting Patterns → Nodal Capabilities

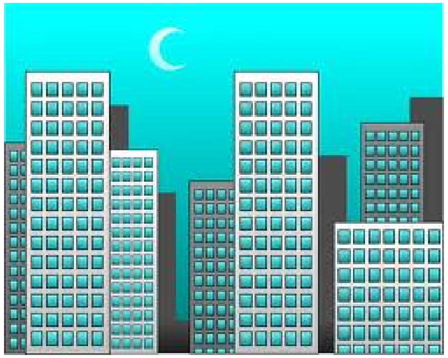
North East Test Network

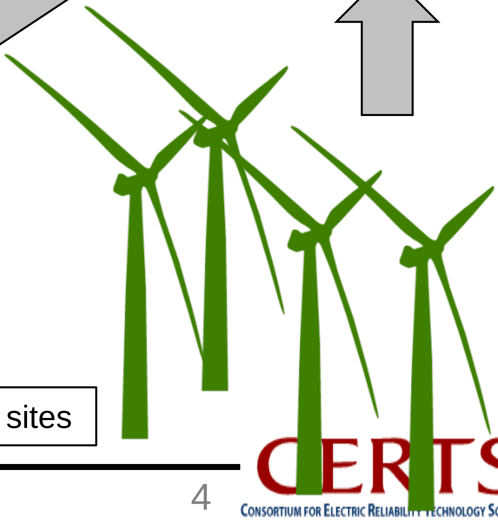


SuperOPF → Costs

Ice storage systems → Buildings → Nodal Capabilities







Stochastic wind at 16 sites

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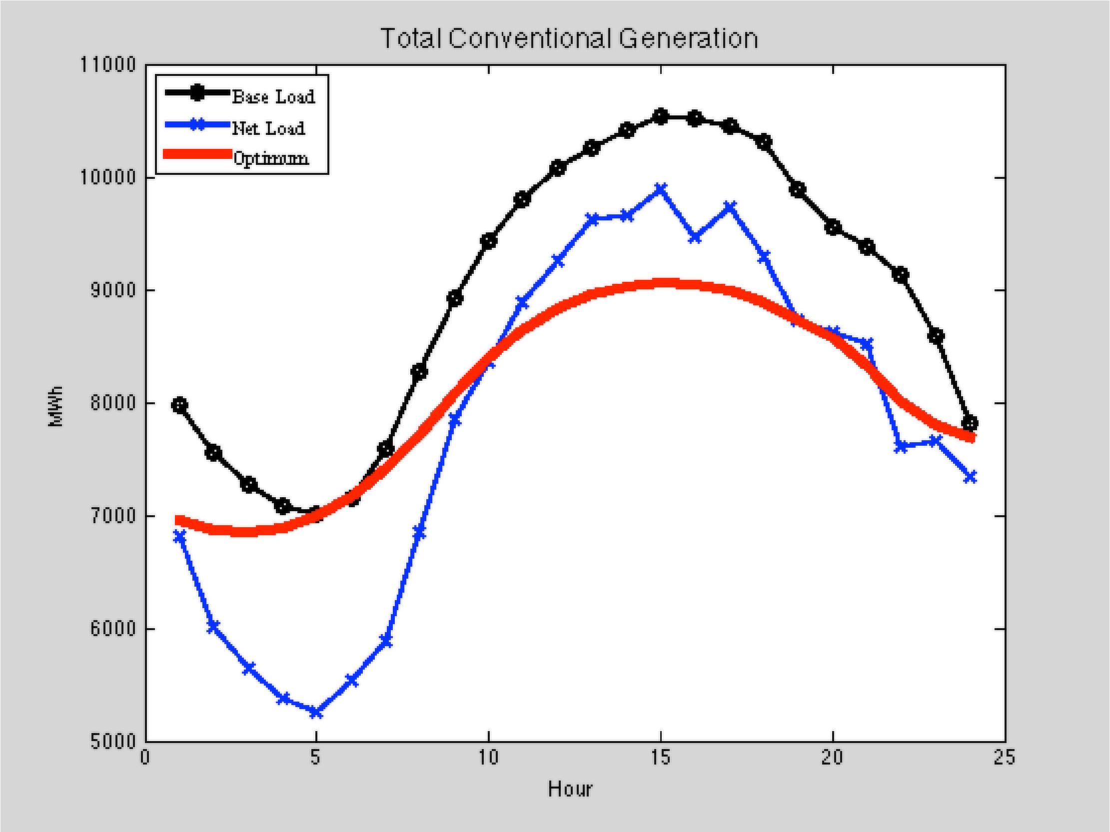
# Characterizing the Economic Problem of Meeting the Daily Demand for Electricity in NYC




- **Net Load** is defined as Base Load – Wind Generation
- **Optimum** is the least cost dispatch with 5 GWh of PHEV and 5 GWh of thermal storage
- The optimum dispatch is flatter and smoother than Net Load
- **WHAT HAPPENS WHEN A POWER NETWORK IS CONSIDERED?**

# North Eastern Test Network (NETNet)

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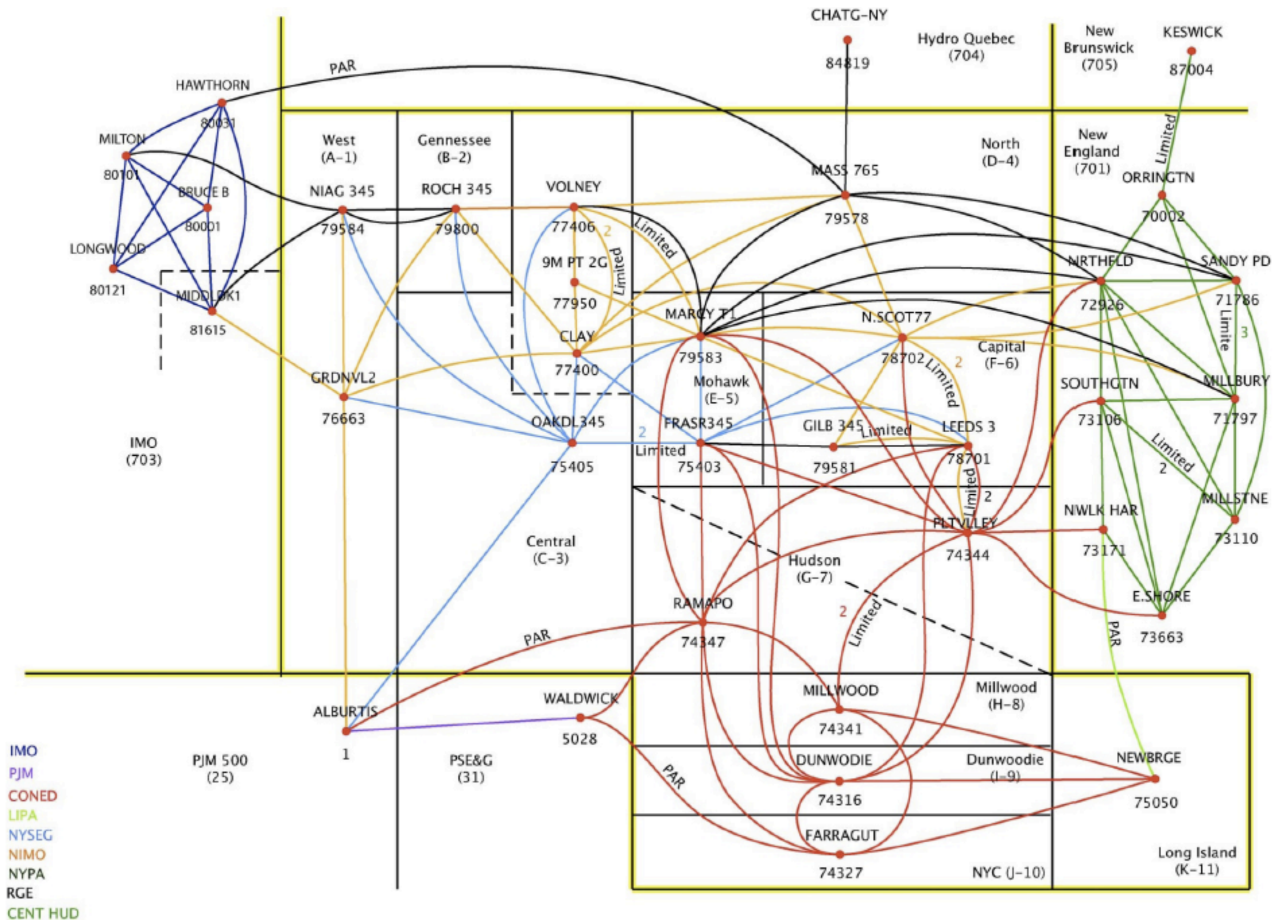
Reduced NPCC System (Allen, Lang and Ilic (2008))

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# NREL Wind Site Clusters (EWITS)

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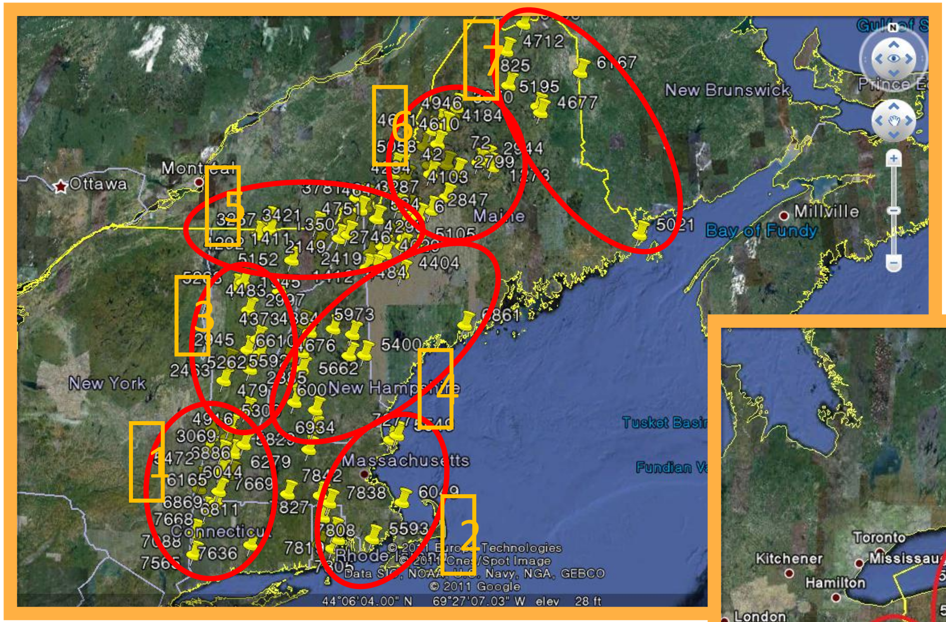
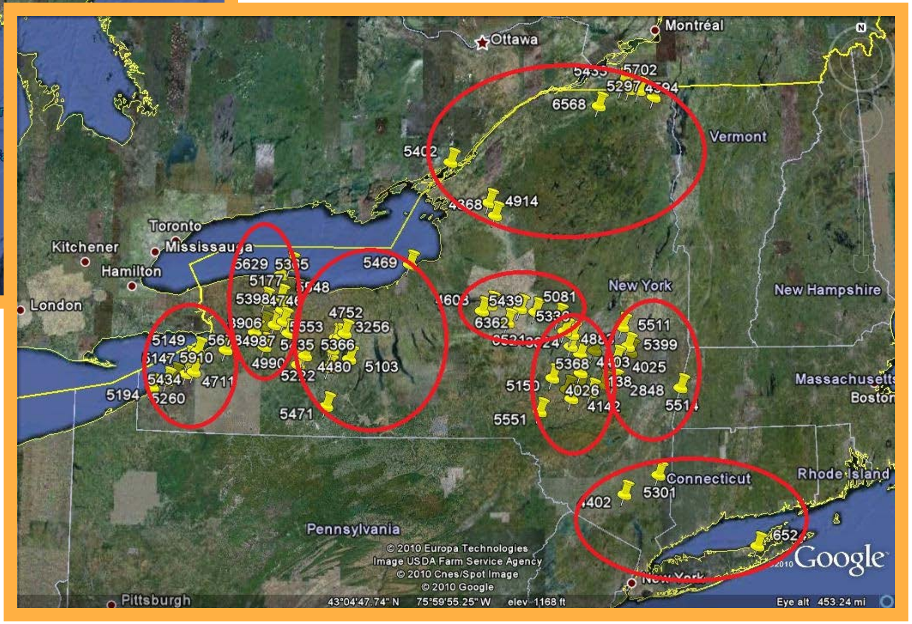
New England




New York State



# Uncertainty of Load and Wind Speed

## (New York City as an example)

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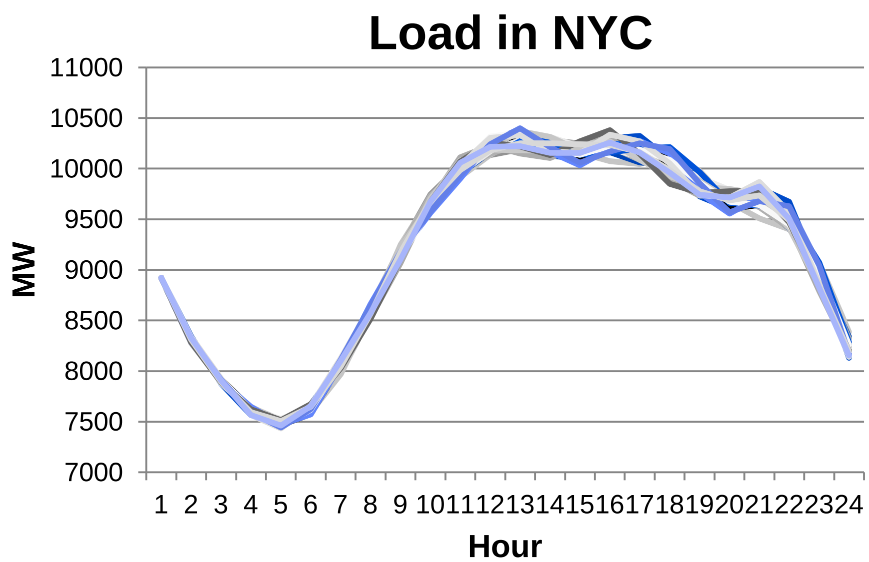
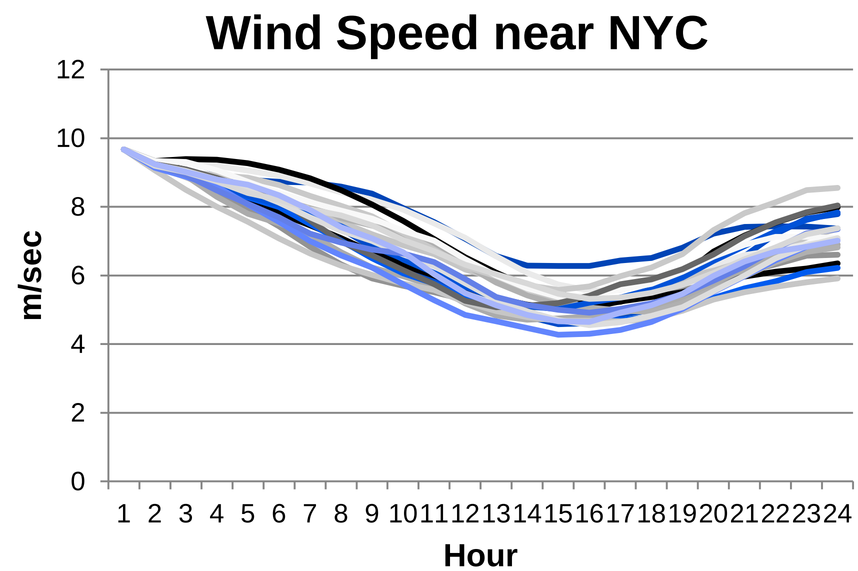
16 ARMAX models estimated for hourly Temperature = f(Cycles)
16 ARMAX models estimated for hourly Log[Wind Speed + 1] = f(Temperature, Cycles)
7 ARMAX models estimated for hourly Log[Load] = f(CDD, HDD, Cycles)
→ Simulate hourly profiles of Wind Speed and Load for any specified day given a forecast of Temperature




| Dependent Variable | Temperature | Log[Wind Speed + 1] | Log[Load] |
|---|---|---|---|
| OLS R2 | 79% | 8% | 90% |
| ARMAX Pseudo R2 | 99% | 75% | 99% |

# System Characteristics of the NE Test Network and the Five Cases

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| NYNE GENERATING CAPACITY | |
|---|---|
| Peaking (GW) | 37 |
| Baseload (GW) | 26 |
| Fixed Imports (GW) | 3 |
| **TOTAL (GW)** | **66** |
| New Wind (GW) | 29 |
| Storage Capacity (GW) | 5.5 |
| Storage Energy (GWh) | 33 |
| **Peak Load (GW)** | **60** |
| **Average Load (GW)** | **49** |

**Characteristics of Wind Input**

Wind/conventional capacity: 48%,
Capacity factor of wind: 21%,
Expected potential wind generation could supply 13% of the daily energy.

**Properties of Deferrable Demand**

For each hour, the level of demand (system load) is divided into conventional demand (85%) and cooling demand (15%) that can be covered by ice batteries or by air conditioning.

Case 1: No Wind: Initial base system

Case 2: Wind, 32 GW of wind capacity at 16 locations added.

Case 3: Case 2 + Deferrable Demand (DD) at five load centers with a total capacity of 5.7GW (34GWh)

Case 4: Case 2 + Energy Storage System (ESS) collocated at the wind sites with a total capacity of 5.7GW (34GWh)

Case 5: Case 2 + DD/2 + ESS/2

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# Summary of the Reductions in System Costs

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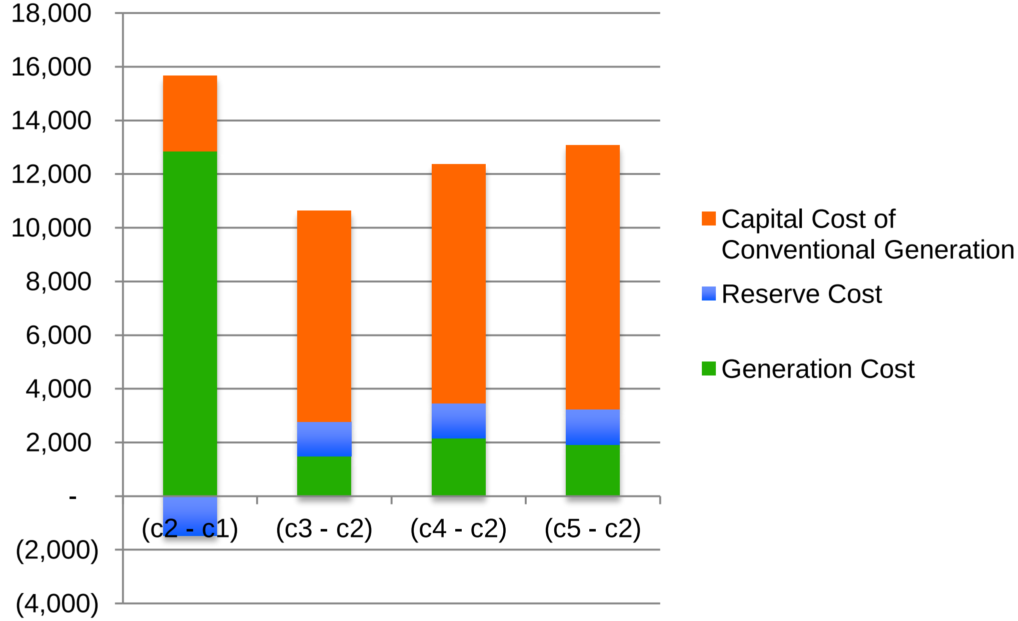
**Composition of Savings in Total System Costs ($k/day)**




**Adding Wind Capacity (c2 – c1)**
- Large reduction in Generation Cost,
- Small reduction in Capital Cost,
- Increase in Reserve Cost.

**Adding Storage ((c3, c4, c5) – c2)**
- Small reductions in Generation Cost,
- Small reductions in Reserve Cost,
- Large reductions in Capital Cost (c5 > c4 > c3)

**Column 1:** Adding Wind (c2 – c1)
**Column 2:** Adding DD (c3 –c2)
**Column 3:** Adding ESS (c4 – c2)
**Column 4:** Adding (DD + ESS)/2 (c5 – c2)

BUT → are the savings big enough to cover the Capital Cost of storage?

# Marginal Savings in System Costs with Additional Amounts of DD and ESS

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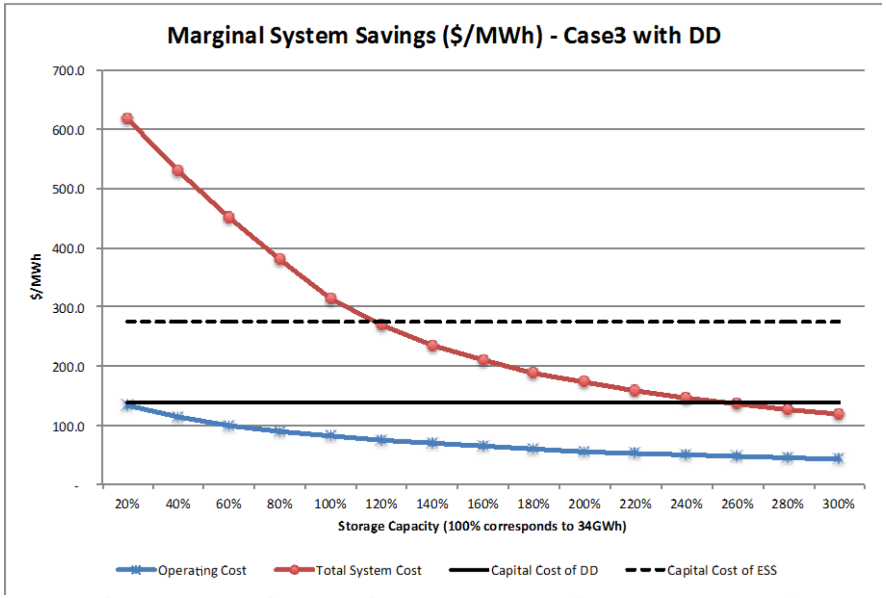
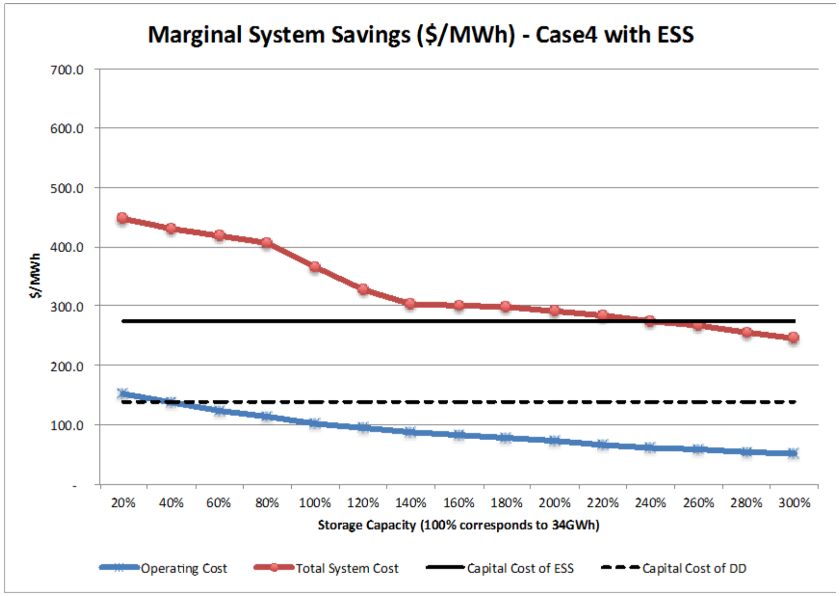
## Adding DD (Case 3 is 100%)




## Adding ESS (Case 4 is 100%)




Marginal savings in **Operating Cost** (Generation + Ramping) are not high enough to the cover the low Capital Cost of DD for either DD (Case 3) or ESS (Case 4).

Marginal savings in **System Cost** (Operating + Capital) are high enough at 100% to cover the high Capital Cost of ESS for both DD and ESS.

The marginal savings of **System Cost for DD** are limited by the hourly levels of demand for cooling services ("discharging" DD is not fungible for other services).

# The Hourly Ranges of Conventional Generation with and without Storage

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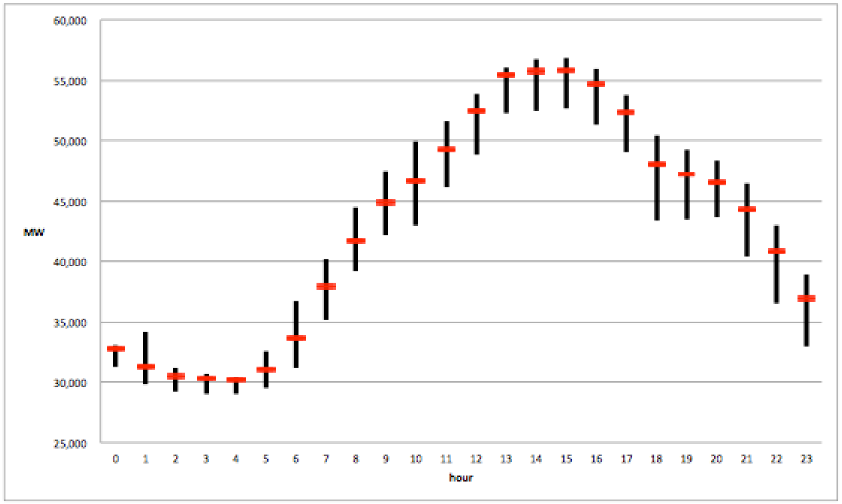
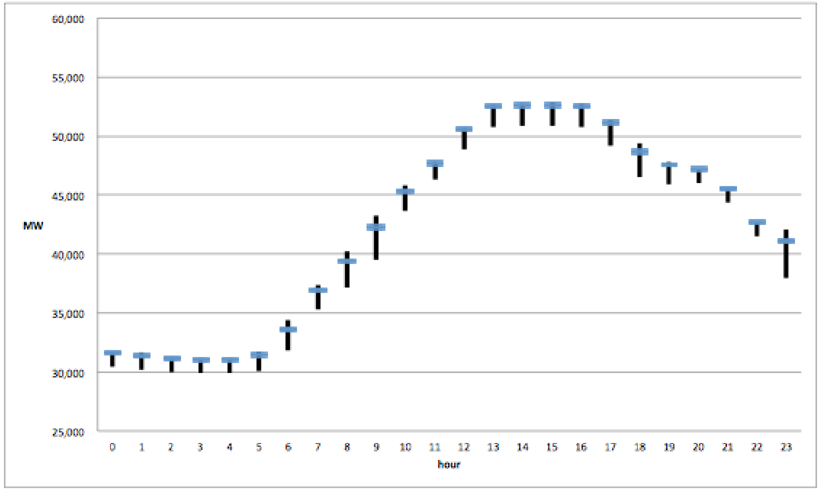
**Case 2: Wind with no Storage**




**Case 3: Wind with DD Storage**




**Adding DD (Thermal Storage) Capacity (similar results for Case 4 with ESS)**

1) Reduces the range of conventional generation in the system states
2) Reduces the amount of ramping purchased from conventional generators
3) Lowers the peak level of conventional generation
4) Increases the minimum level of conventional generation

# The Effects of Thermal Storage on the Optimum Dispatch in Different System States



**OPTIMUM DISPATCH AT THE PEAK HOUR**

| | Case 2: Wind with NO Storage | | | | | | Case 3 - Case 2: Wind with DD (Thermal Storage) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Intact States* | | *Contingency 1* | | *Contingency 2* | | *Intact States* | | *Contingency 1* | | *Contingency 2* | |
| | ***Wind 1*** | ***Wind 4*** | ***Wind 1*** | ***Wind 4*** | ***Wind 1*** | ***Wind 4*** | ***Wind 1*** | ***Wind 4*** | ***Wind 1*** | ***Wind 4*** | ***Wind 1*** | ***Wind 4*** |
| **Supply** | | | | | | | | | | | | |
| Conventional Generation | 56821 | 54330 | 56326 | 52698 | 56821 | 53183 | -4038 | -1795 | -4468 | -1804 | -4468 | -1795 |
| Wind Generation | 1603 | 4094 | 1603 | 5725 | 1603 | 5240 | 0 | 2132 | 0 | 2687 | 0 | 2882 |
| ESS (Discharging > 0) | - | - | - | - | - | - | - | - | - | - | - | - |
| Import | 3388 | 3388 | 3388 | 3388 | 3388 | 3388 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Energy Supply** | **61812** | **61812** | **61318** | **61812** | **61812** | **61812** | **-4038** | **338** | **-4468** | **883** | **-4468** | **1087** |
| Wind Spilled | 0 | 7482 | 0 | 5851 | 0 | 6336 | 0 | -2132 | 0 | -2687 | 0 | -2882 |
| Unforced Outage | - | - | 1641 | 1641 | 1147 | 1147 | - | - | 0 | 0 | 0 | 0 |
| **Demand** | | | | | | | | | | | | |
| Conventional Demand | 61812 | 61812 | 61318 | 61812 | 61812 | 61812 | -4468 | -4468 | -4468 | -4468 | -4468 | -4468 |
| Deferrable Demand | - | - | - | - | - | - | 430 | 4468 | 0 | 4468 | 0 | 4468 |
| Charging Thermal Storage | - | - | - | - | - | - | 0 | 338 | 0 | 883 | 0 | 1087 |
| **Total Energy Purchased** | **61812** | **61812** | **61318** | **61812** | **61812** | **61812** | **-4038** | **338** | **-4468** | **883** | **-4468** | **1087** |
| Discharging Thermal Storage | - | - | - | - | - | - | 4038 | 0 | 4468 | 0 | 4468 | 0 |
| Load Not Served | 0 | 0 | 494 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Wind 1:** System State with a LOW Wind Speed (54%)
**Wind 4:** System State with a HIGH Wind Speed (7%)
**Wind 2 and Wind 3:** Not shown (39%)

# GENERAL CONCLUSIONS



- High penetrations of renewable generation lower the wholesale price of energy BUT increase the ramping and capacity costs for the conventional generators → **"missing money"**
- All market participants should pay for the services they use and get paid for the services they provide → **new rate structures**
- Wholesale customers and aggregators who manage deferrable demand (DD) should get substantial economic benefits by:
  - Purchasing more energy at less expensive off-peak prices (**pay real-time wholesale prices**)
  - Reducing their demand (capacity) during expensive peak-load periods (**pay "correct" demand charge**)
  - Selling ancillary services (ramping) to mitigate wind variability (**participate in the ramping market by metering DD separately to distinguish between "instructed" versus "uninstructed" demand**)

# PART II: Ramping

# PART III: Robust Optimization

**Thank you**
**Questions?**