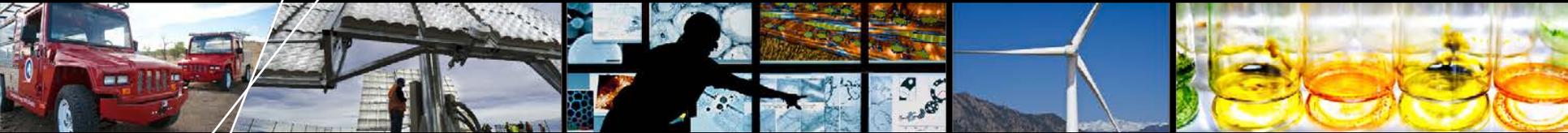


# The Impact of Improved Solar Forecasts on Bulk Power System Operations in ISO-NE



## 4<sup>th</sup> Solar Integration Workshop

**Carlo Brancucci Martinez-Anido,  
Anthony Florita, and  
Bri-Mathias Hodge**

**Berlin, Germany  
November 10, 2014**

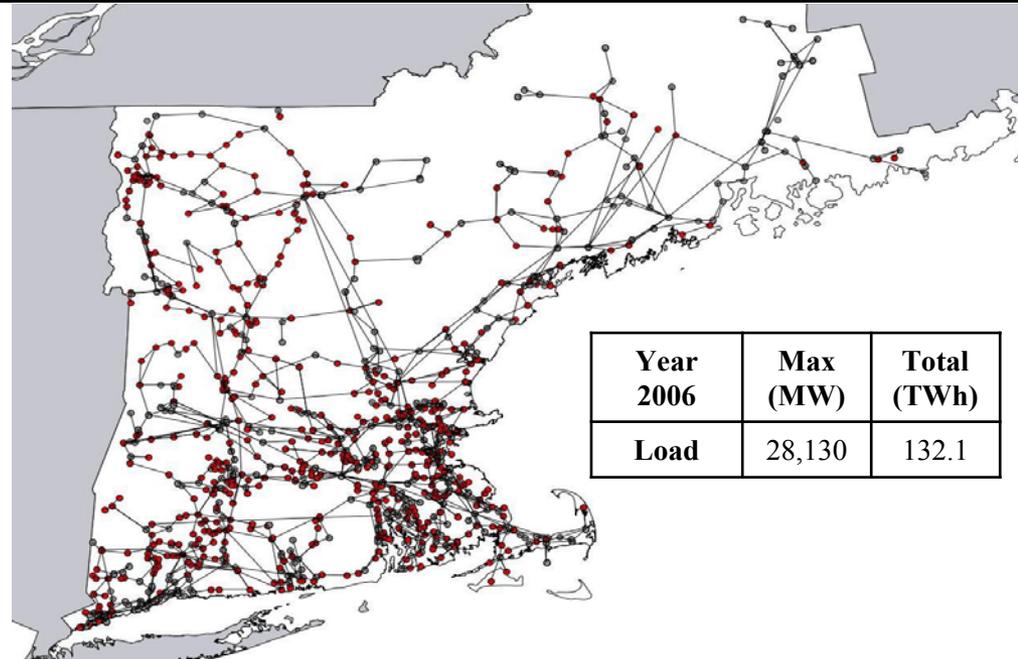
# Motivation and Scope

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- **The economic benefits from renewable energy forecasting are largely unquantified in the power community**
  - Current renewable energy penetration levels in the United States are often too low to appreciably quantify the value of improving renewable energy forecasting
  - The power system is so complex that it is often difficult to assign costs or benefits to a single generator
- **Solar power installations are rapidly growing**
  - Future penetration levels will soon require increased attention to the value of forecasting
- **Scope: To study the impact of improved solar forecasts on bulk power system operations**
- **Case Study: Independent System Operator New England (ISO-NE)**
  - Future scenario with 25% solar power penetration

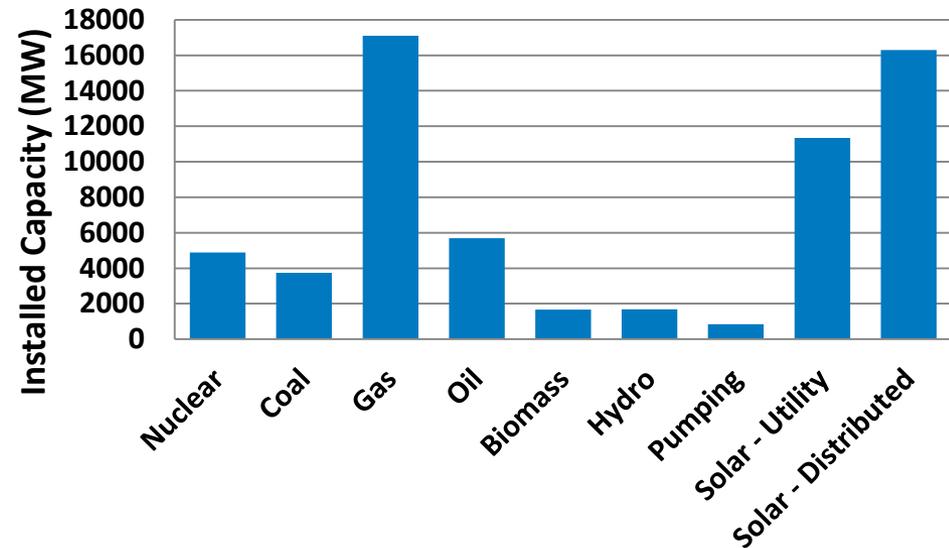
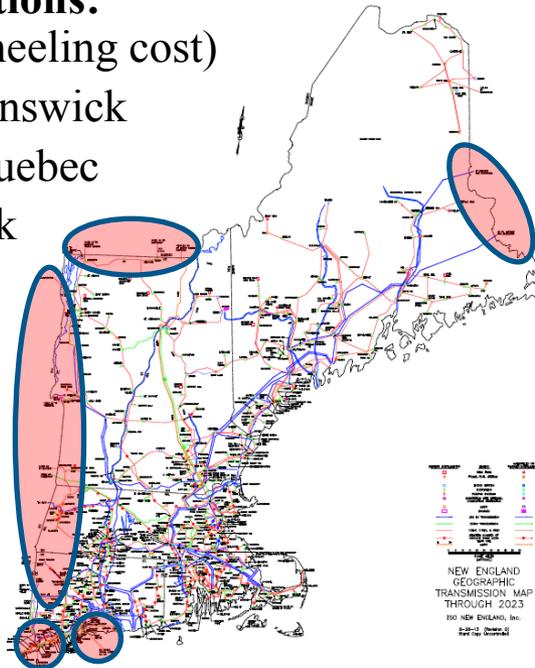
# ISO-NE PLEXOS Model

- **3,314** nodes (1,862 above 69 kV)
- **2,485** lines (2,085 above 69 kV)
- **1,830** transformers
- **468** generators (excluding solar)
- **DA/4HA/RT** (load and solar forecasts)
- **Contingency** and **regulation** reserves

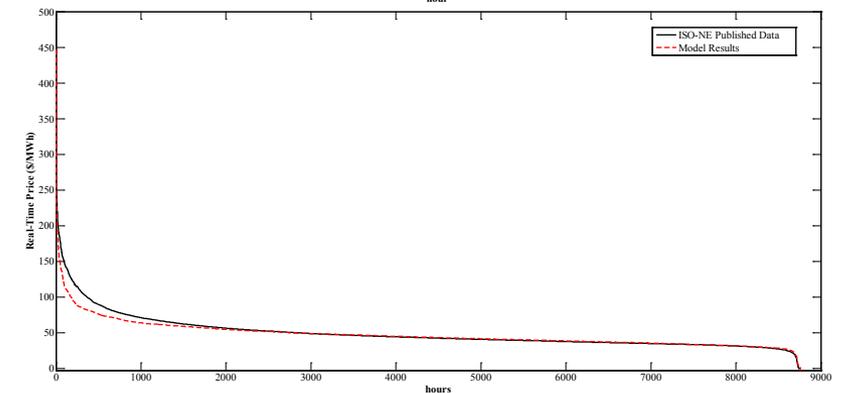
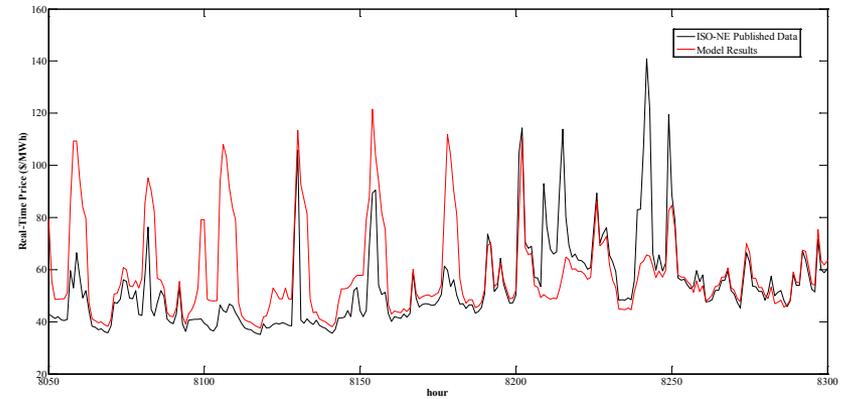
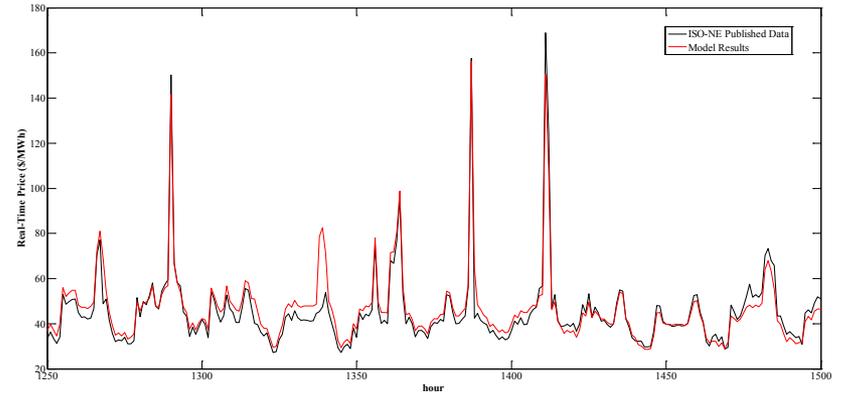
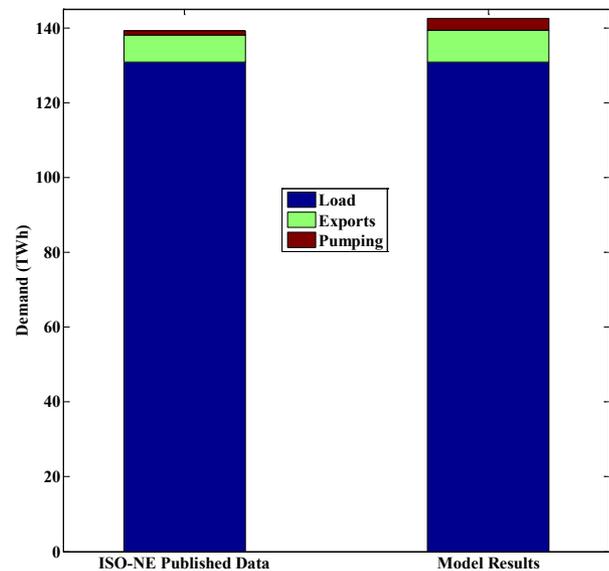
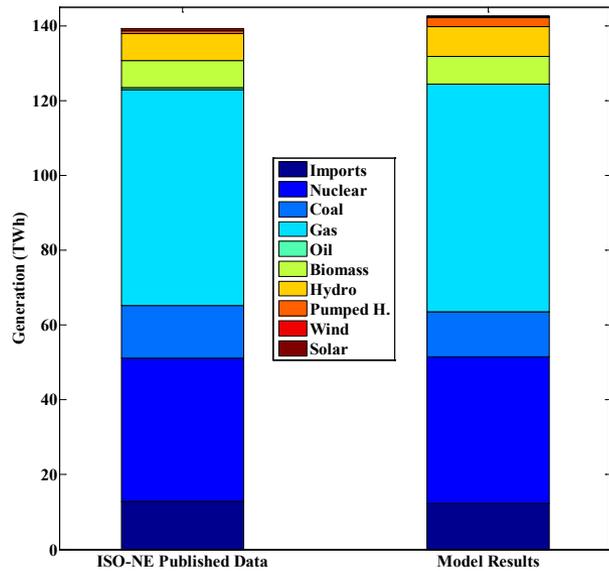


## Interconnections: (\$3/MWh wheeling cost)

- New Brunswick
- Hydro Quebec
- New York



# ISO-NE PLEXOS Model—Validation



# Solar Power Data

## NREL Solar Power Data for Integration Studies

(also used within the Eastern Renewable Generation Integration Study)

4,874 MW installed capacity in ISO-NE:

- 68 utility-scale solar power plants (x4)
- 76 distributed solar power plants (x8)

Both utility-scale and distributed solar power plants are already well distributed throughout the ISO-NE power system. The solar output smoothing for high solar penetrations is almost the same in the case with additional solar sites as in our case, in which we multiply the units included in the database.

Solar Penetration Level (%)	Solar Capacity (MW)	Normalized Hour-to-Hour Solar Variability (%)
0.54	584	6.85
1.08	1,180	6.78
2.08	2,246	6.77
2.5	2,424	6.81
4.5	4,874	6.73
12.5	13,824	6.73
25	27,648	6.73

## Solar Power Forecasts

- **4HA** included in the database
- **DA** derived from state-of-the-art numerical weather prediction, the Weather Research and Forecasting Model (National Center for Atmospheric Research)

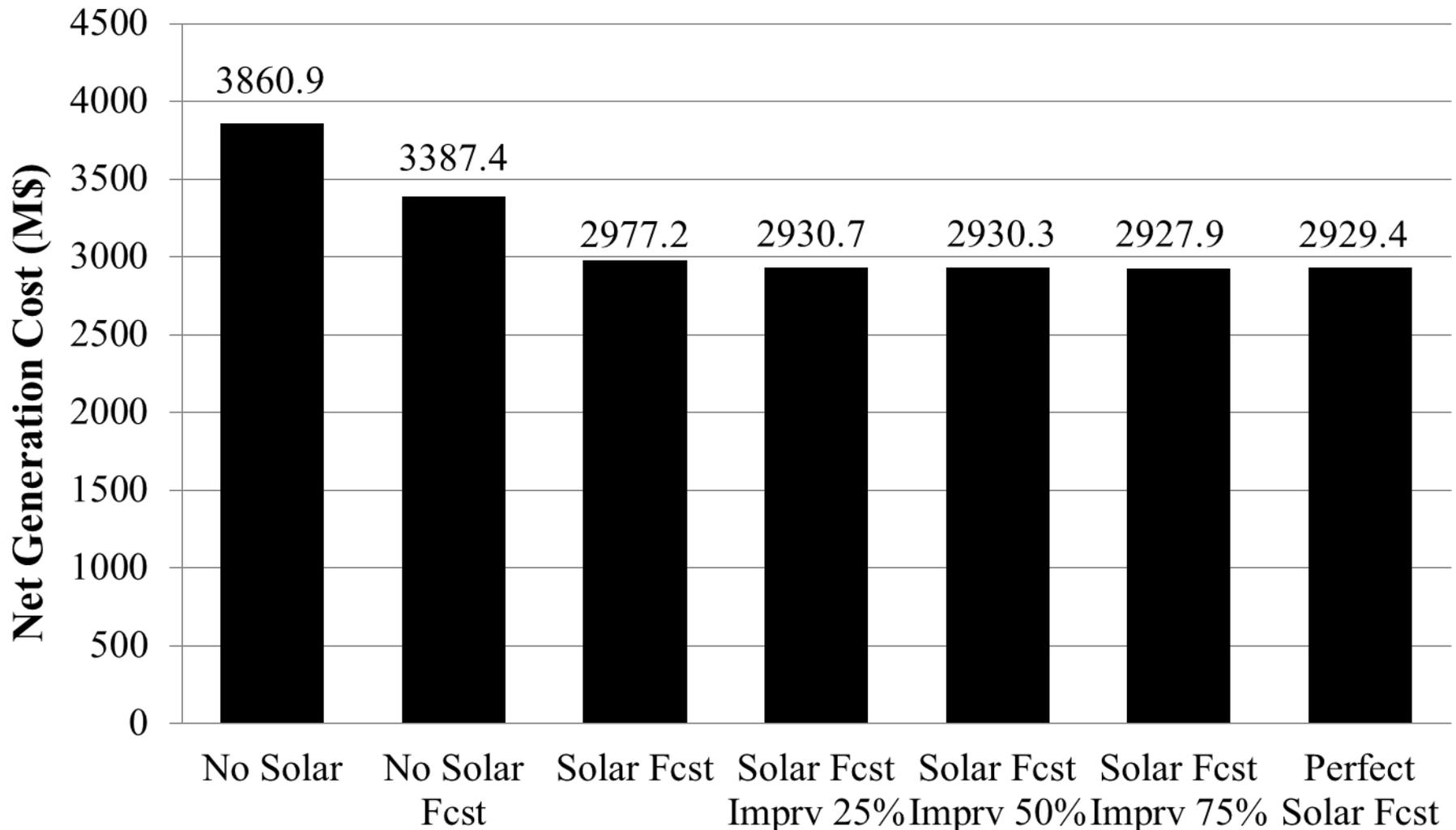
# Seven Scenarios

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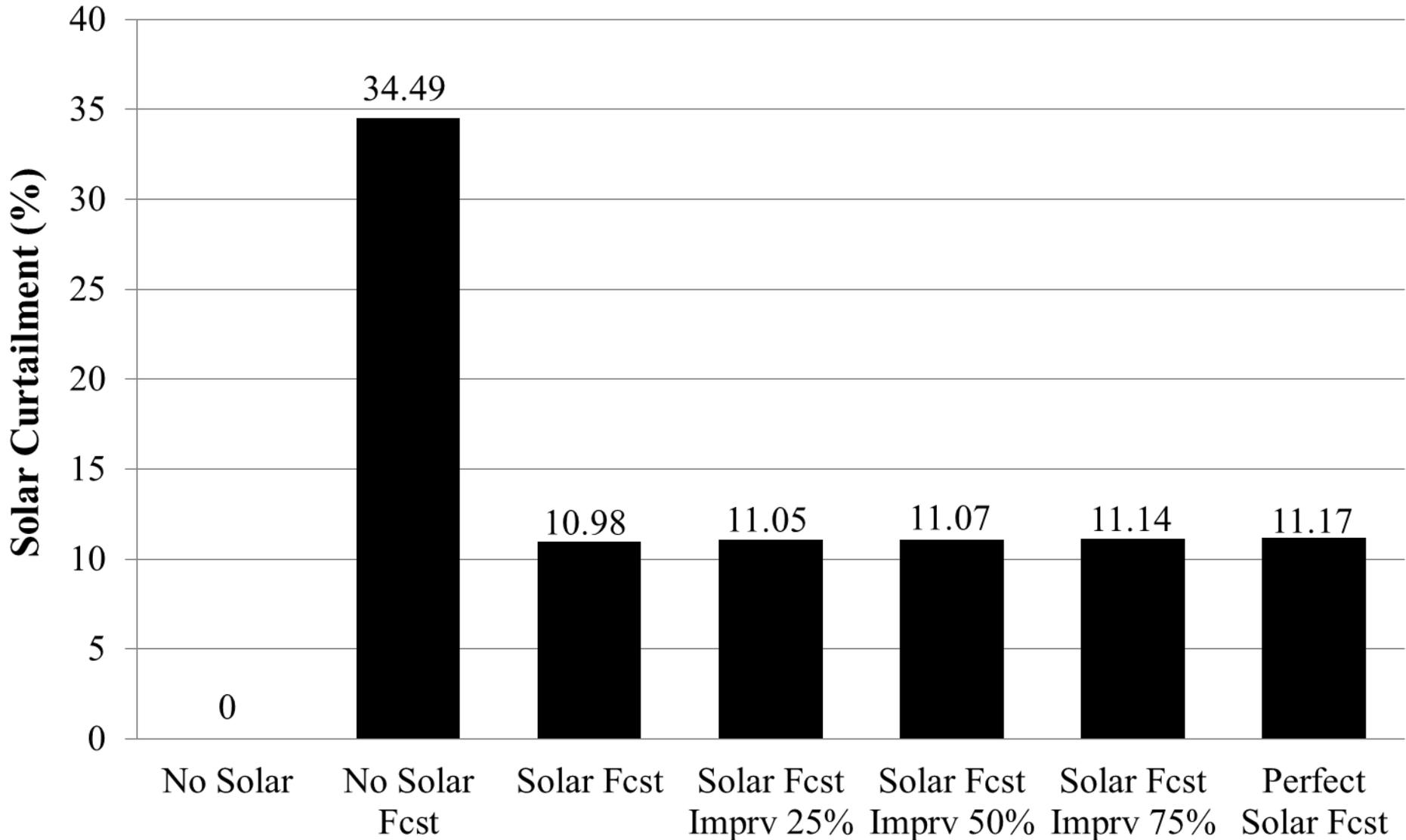
- **No solar power**
- **No solar power forecasting**
- **Solar power forecasting**
- **Solar power forecasting—25% uniform improvement**
- **Solar power forecasting—50% uniform improvement**
- **Solar power forecasting—75% uniform improvement**
- **Perfect solar power forecasting—100% uniform improvement**

# Net Generation Costs

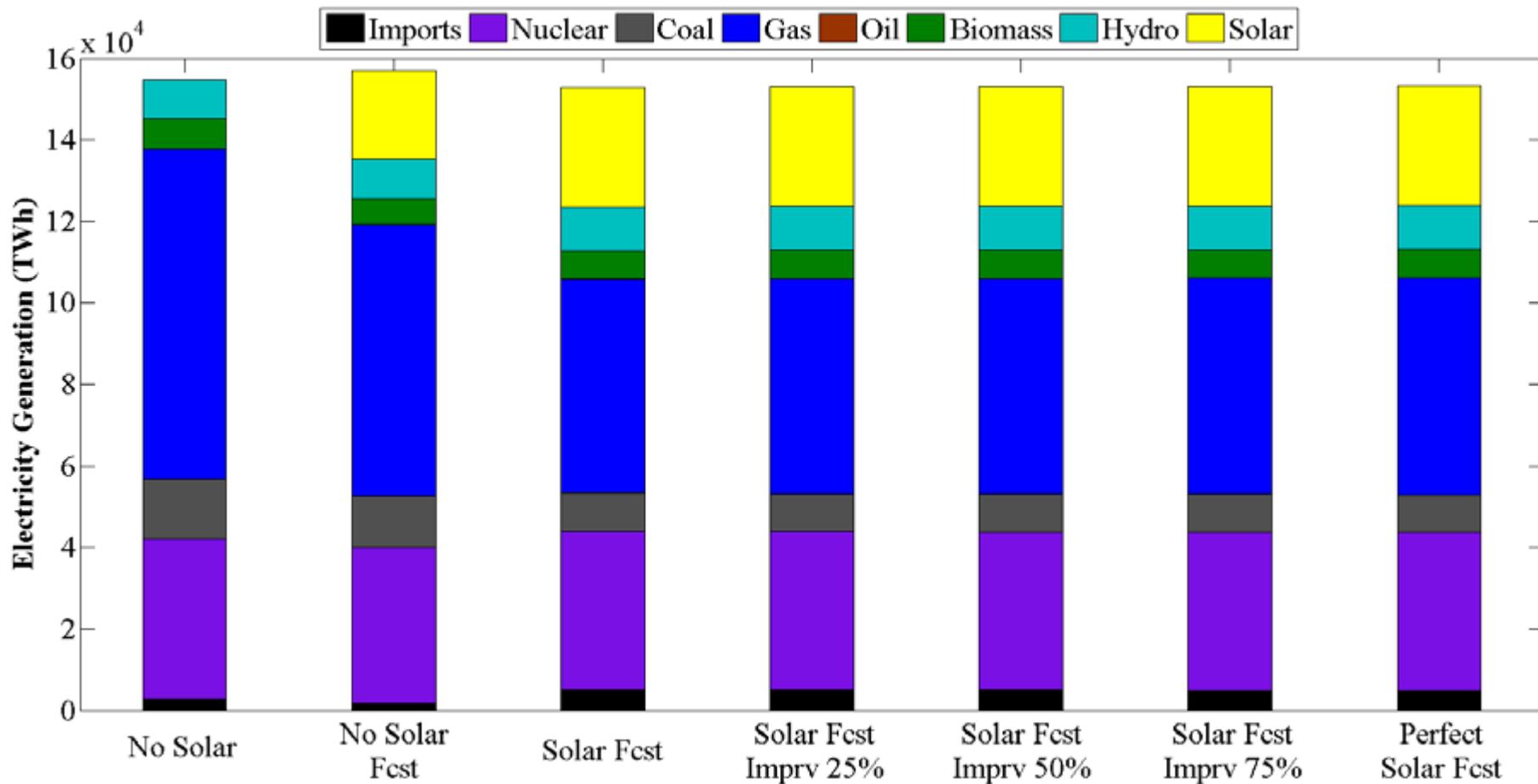
**Net Generation Costs = Fuel Costs + Variable Operations and Maintenance Costs + Start-Up and Shutdown Costs + Import Costs – Export Revenues**



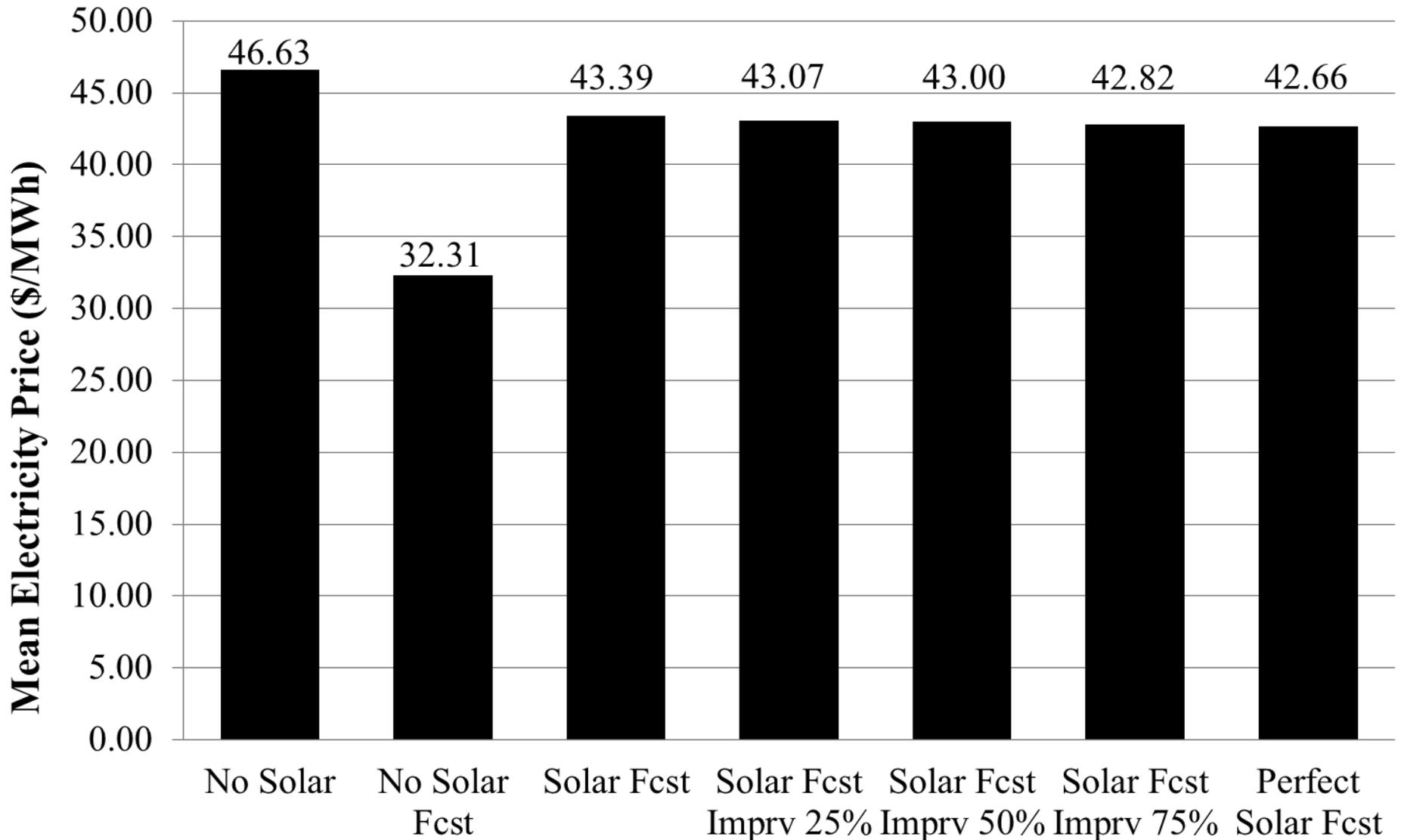
# Solar Power Curtailment



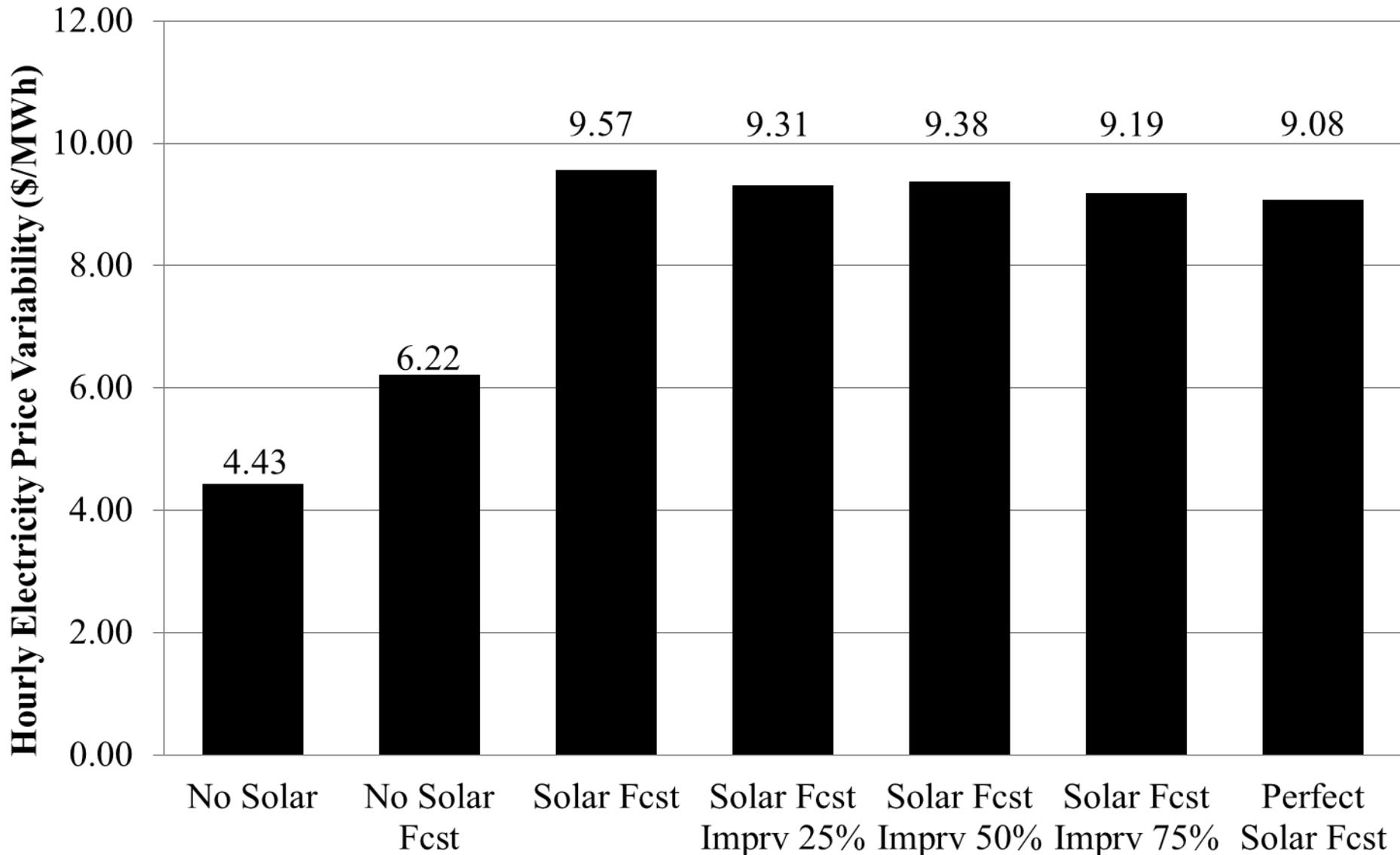
# Electricity Generation Mix



# Mean Electricity Price



# Hourly Electricity Price Variability



# Conclusions—Generation Costs

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- **Integrating 25% solar power penetration in ISO-NE with DA and 4HA forecasts reduces net generation costs by 22.9%**
- **Without solar power forecasts, the reduction in net generation costs is only 12.3%**
  - Overcommitment of generation
  - Higher solar power curtailment
- **If solar power forecasts are uniformly improved by 25%, net generation costs are further reduced by 1.56% (\$46.5 M)**
- **There are no significant differences if solar power forecasts are further improved**
  - Very large share of gas-fired generators
  - Relatively small share of “base load” power plants
- **However, better solar power forecasts at the HA or subhourly timescale could still provide additional savings**

# Conclusions—Prices

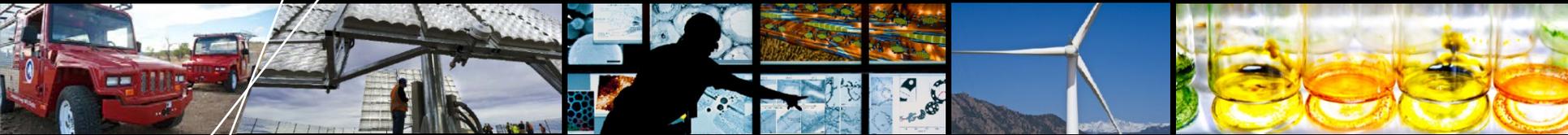
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- **Integrating 25% solar power penetration reduces the mean electricity price in ISO-NE by 31% when solar power forecasts are not considered**
- **If solar power forecasts are used, the reduction is only 7%**
- **Integrating 25% solar power penetration increases the hourly electricity price variability by 116% when solar power forecasts are considered**
- **If solar power forecasts are not used, the increase is only 40%**
  - Overcommitment of generation
  - System is less flexible when integrating variable and uncertain solar power (higher curtailment)
- **Solar power forecasting improvements show small reduction in electricity prices and their variability**

# Future Work

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- **Analyze the impact and value of solar power forecasting improvements when solar curtailment is not allowed**
- **Study interactions among load and solar power uncertainties**
- **Study the economic benefits of DA solar power forecasts without assuming any 4HA market**
- **Study the impact and value of solar power forecasts at the HA or subhourly timescale**



**Thank you!**

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# “Markets”

	<b>DA</b>	<b>4HA</b>	<b>RT</b>
Horizon	1 year	1 year	1 year
Time Step	1 hour	1 hour	5 minutes
Optimization Window	1 day	4 hours	5 minutes
Look-Ahead (Resolution)	1 day (4 hours)	10 hours (2 hour)	-

# Generators' Commitment

**DA:**  
Nuclear  
Coal\_ST  
Biomass

**4HA:**  
CC  
Gas\_ST  
Oil\_ST

**RT:**  
Gas\_GT  
Gas\_IC  
Jet\_Oil\_GT  
Oil\_GT  
Oil\_IC  
Solar

**Hydro:** DA generation is passed on to 4HA and RT

**Pumped Storage:** Special commitment based on pumped load, available capacity, and price received in previous market

# Reserves

	<b>Contingency (Spin)</b>	<b>Up Regulation</b>	<b>Down Regulation</b>
On	Yes	Yes	Yes
Time Frame (seconds)	600	300	300
Minimum Provision	824 MW	1% load	1% load
Available Generation	All (except for nuclear and solar)		