



Western Wind & Solar Integration Study

Operational Impacts Part 1

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Stakeholder Meeting
July 30, 2009



imagination at work

Overview

- Operational observations.
- Study assumptions.
- Annual operational impacts.
- Hourly commitment/dispatch results for selected weeks.

Operational Observations

- Forecasts are critical
 - Significant variations in impact for the same wind variability with different forecasts
- No significant issues at penetrations up to 20% in study footprint and 10% outside
- Impact more severe at 30% inside and 20% outside
- Operational impact dependent on what your neighbor is doing
- At higher penetrations it is essential that “demand” is an active participant.

Operational Analysis on In-Area Scenario

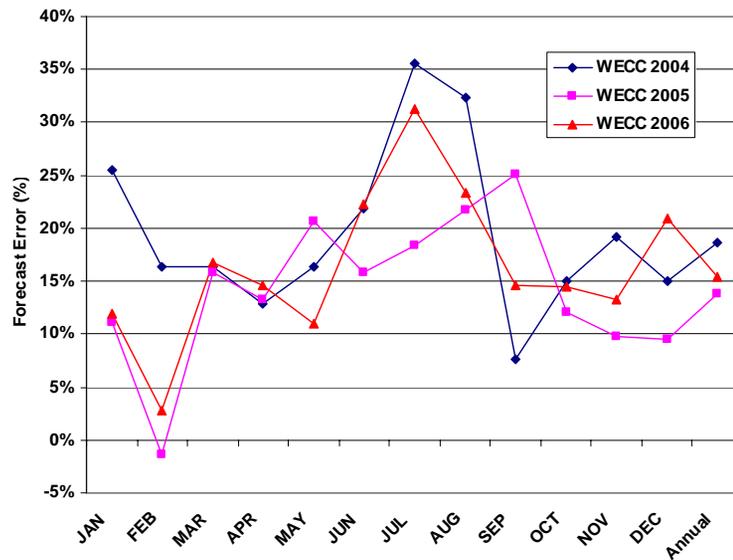
Study Assumptions

- 2017 Fuel Prices:
 - Coal ~ \$2.00/MBtu
 - Natural Gas ~\$9.5/MBtu
- Carbon Tax : \$30/ton
- Energy Velocity Database
 - ~24 GW capacity added 2009-2017 timeframe to maintain reserve margins (~11GW not in plans)
- NERC ES&D Peak Load Projections
- Economically Rational, WECC-wide Commitment and Dispatch recognizing transmission limitations.

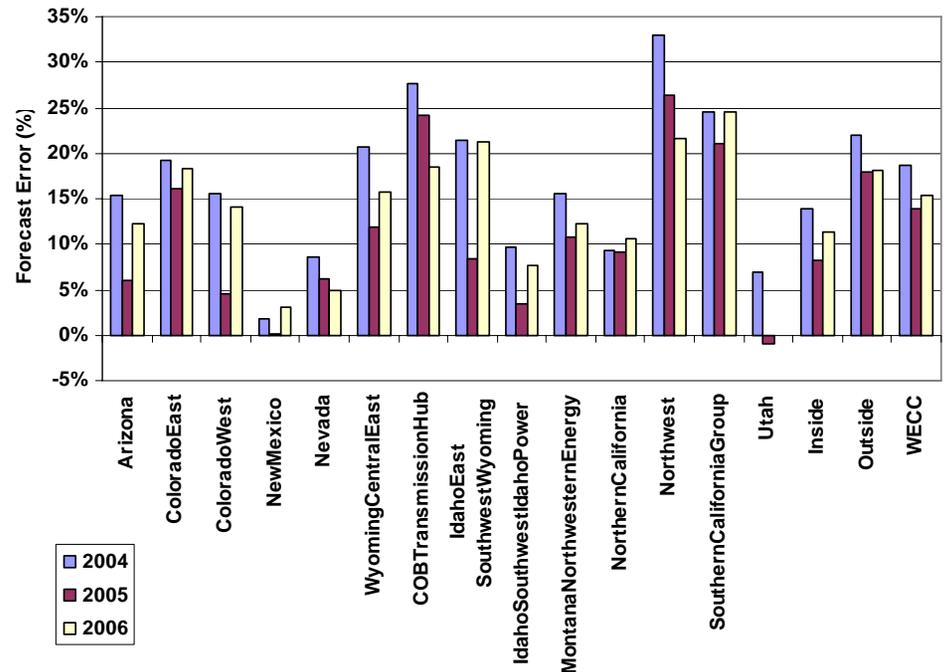
Forecast Error

- Forecast error varied annually and regionally
- Reduced forecast 10% in study footprint and 20% outside
 - “R” scenarios
- Also considered perfect forecasts
 - “P” scenarios

Forecast Error - WECC



Annual Forecast Error



Operational Analysis

- Comparison of Spot Price duration curves
 - Penetration
 - Preselected, 10%, 20%, 30%
 - Forecast
 - Perfect, State-of-the-Art
 - Siting Scenario
 - In-Area, Local Priority, Mega Project
- Unserved Energy
- Unit Starts

Case Naming Convention

- Scenario – Penetration – Forecast – Sensitivity
- For Example : I 20 R t

In Area

20% penetration

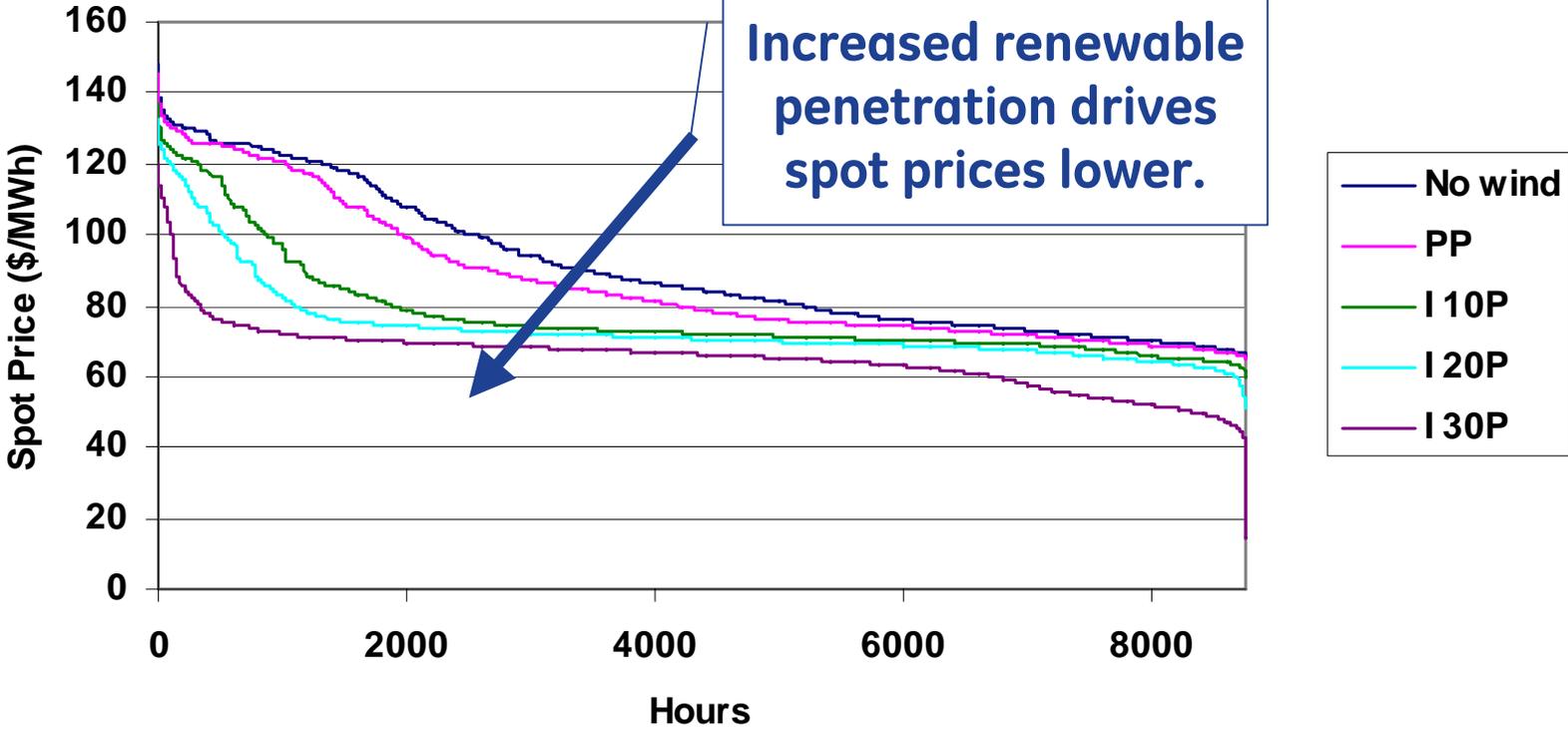
Reduced (unbiased) Forecast

transmission sensitivity

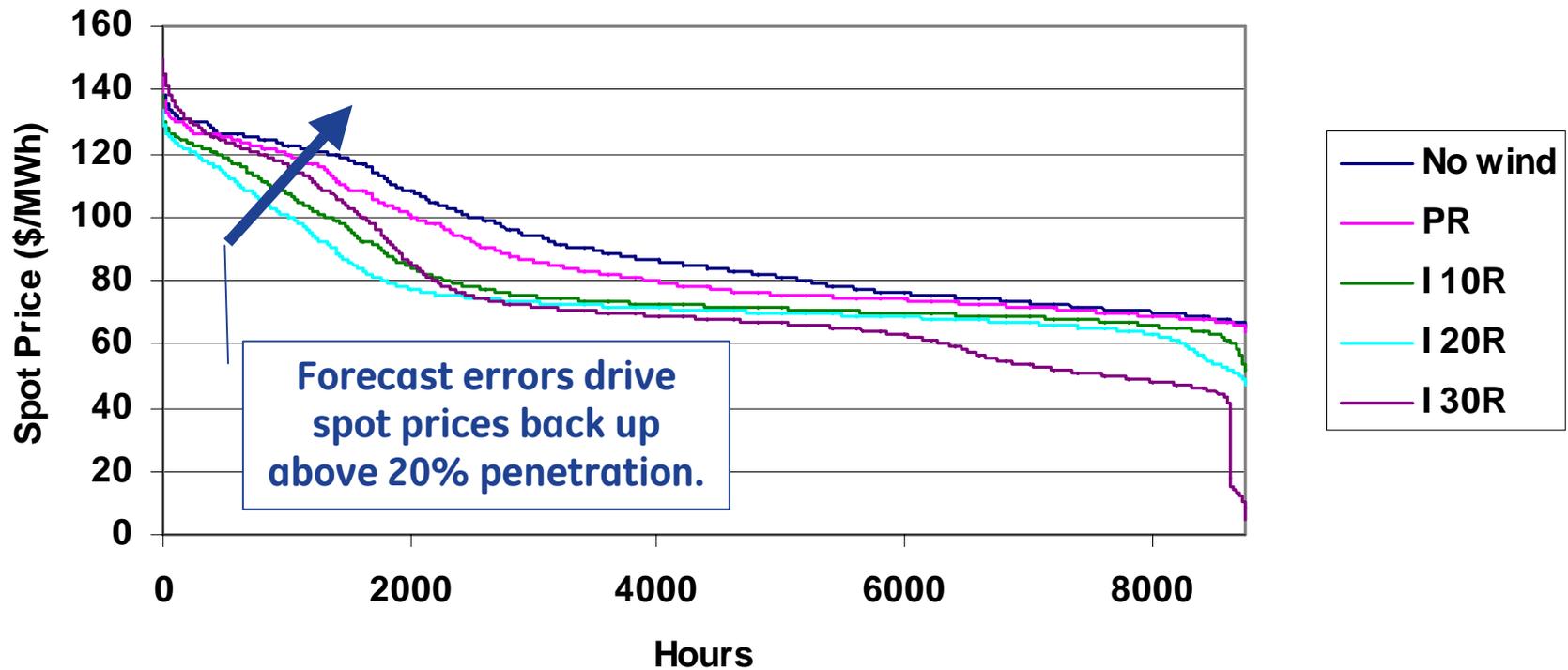
Locational Marginal Cost Impact

- Wind is assumed to enter the market as a “zero cost” price taker.

Annual Spot Price Duration Curve Perfect Forecast, In-Area Scenarios



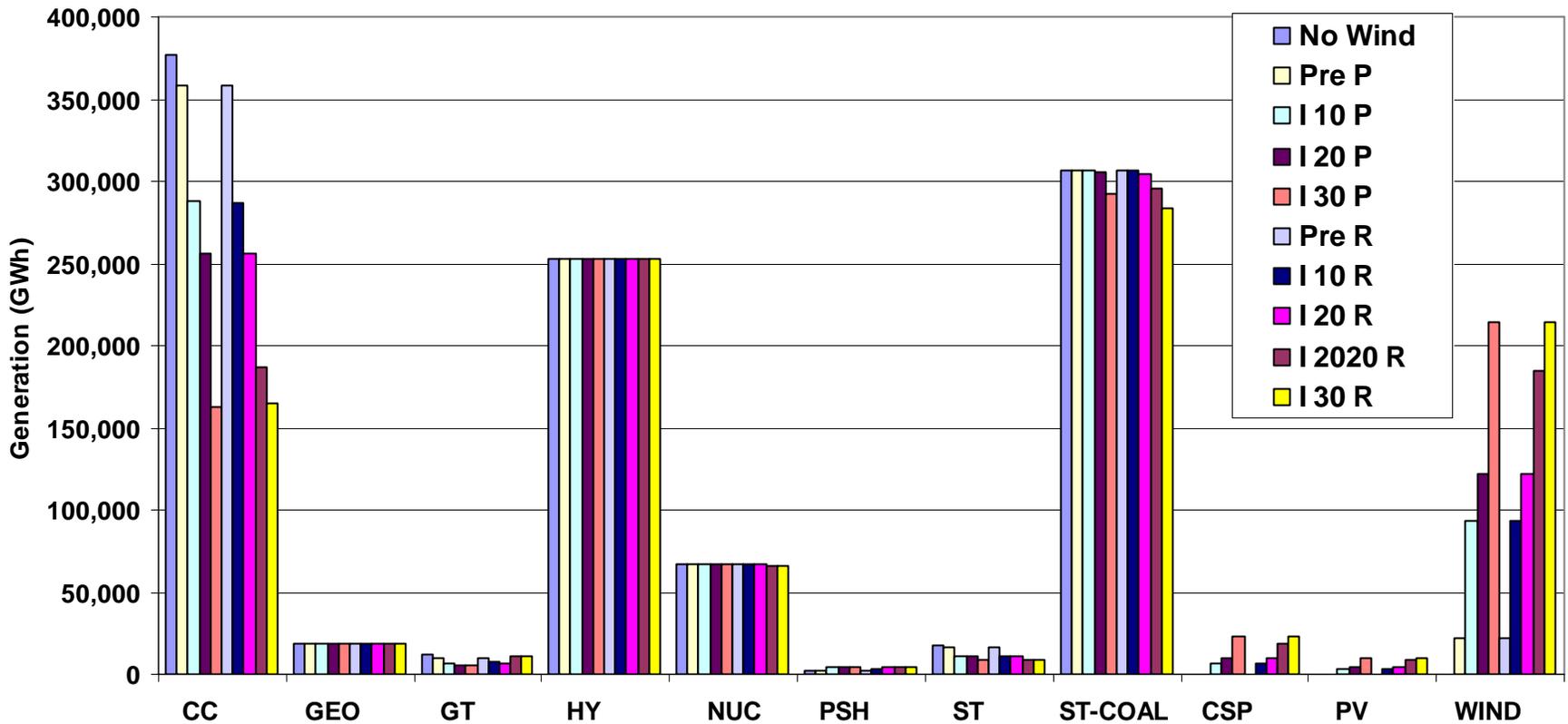
Annual Spot Price Duration Curve S-o-A Forecast, In-Area Scenarios



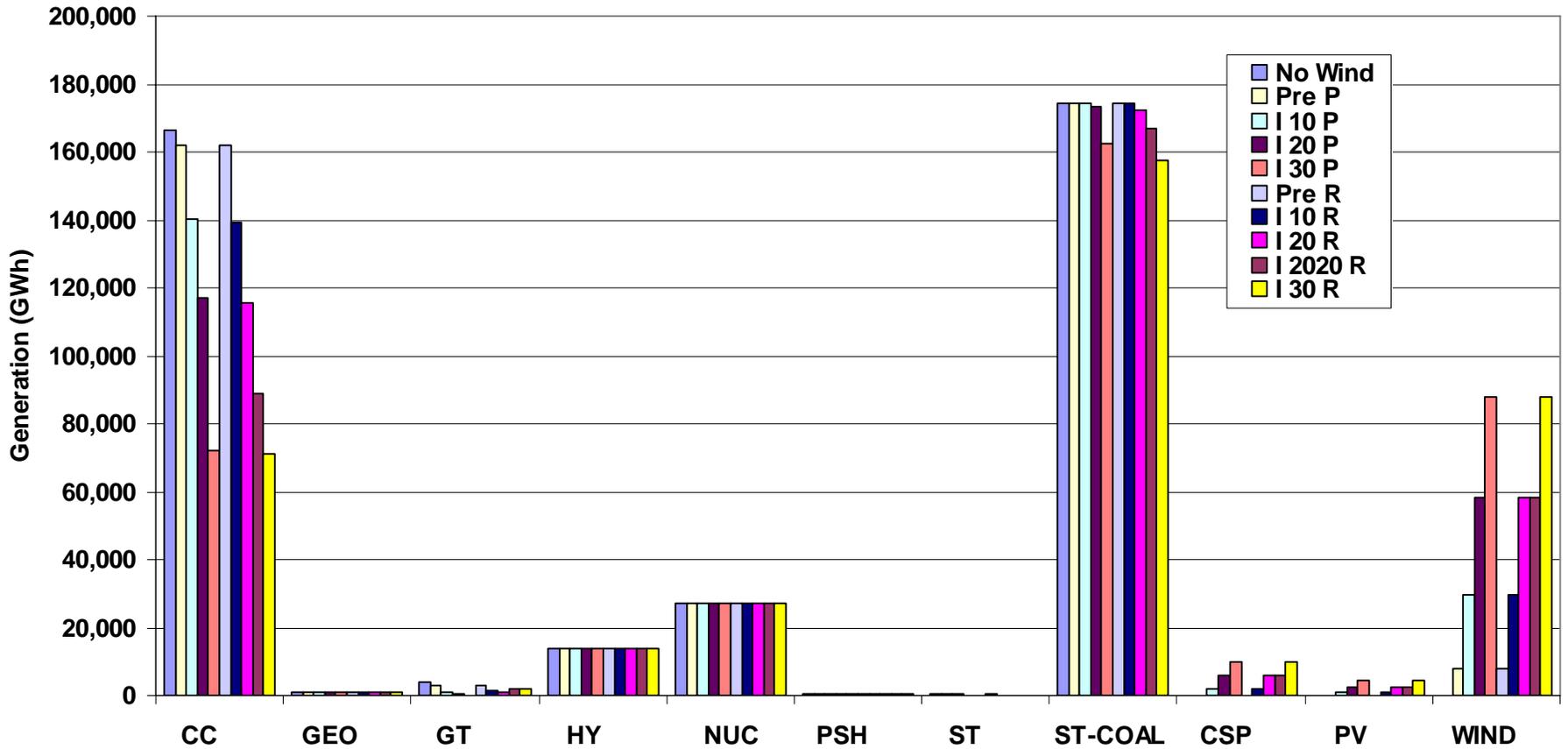
Unit Operation

- Examines unit displacement as a function of renewable penetration.

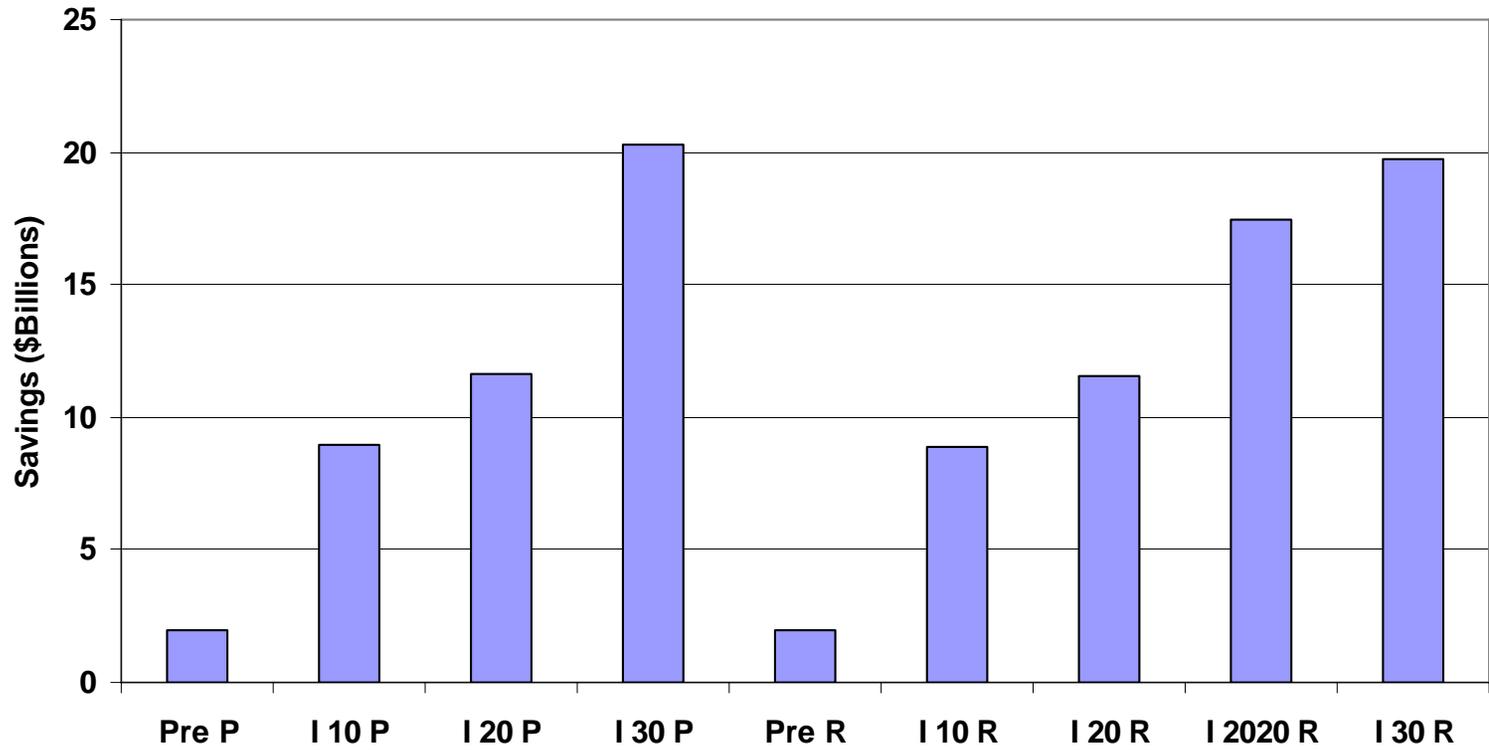
Generation by Type - WECC - 2006



Generation by Type - Study Area - 2006

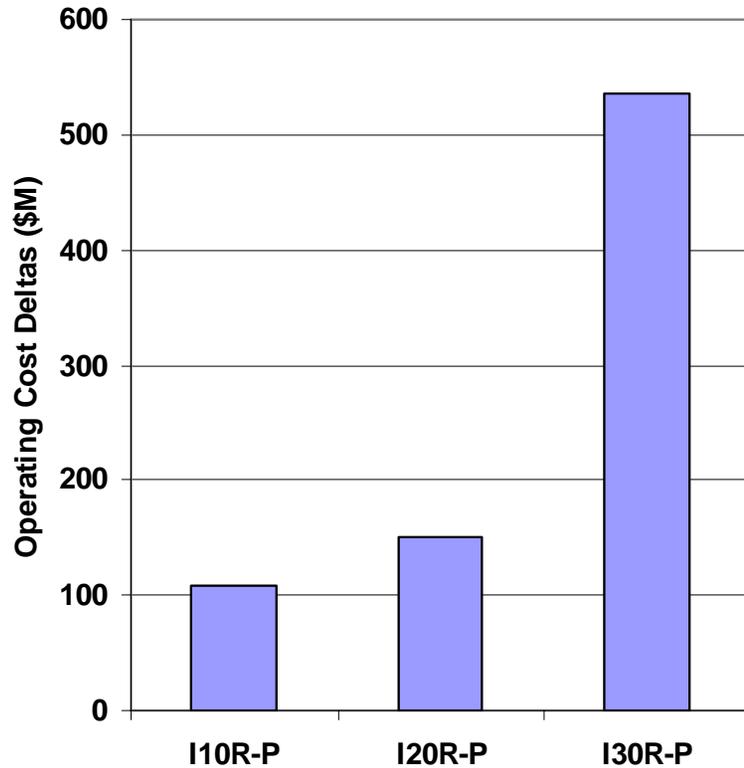


Operating Cost Savings (\$B) - WECC - 2006

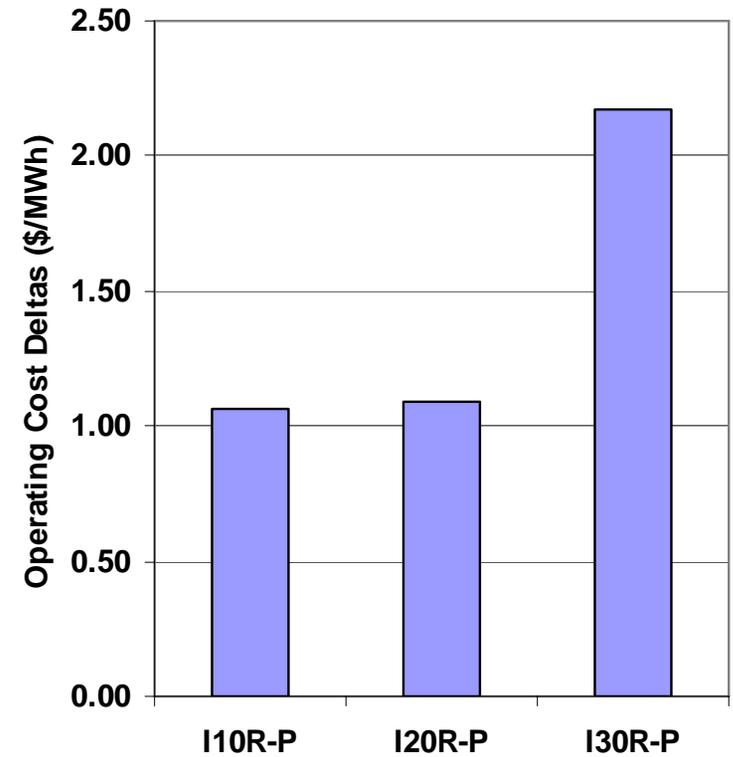


Value of Renewable Forecast

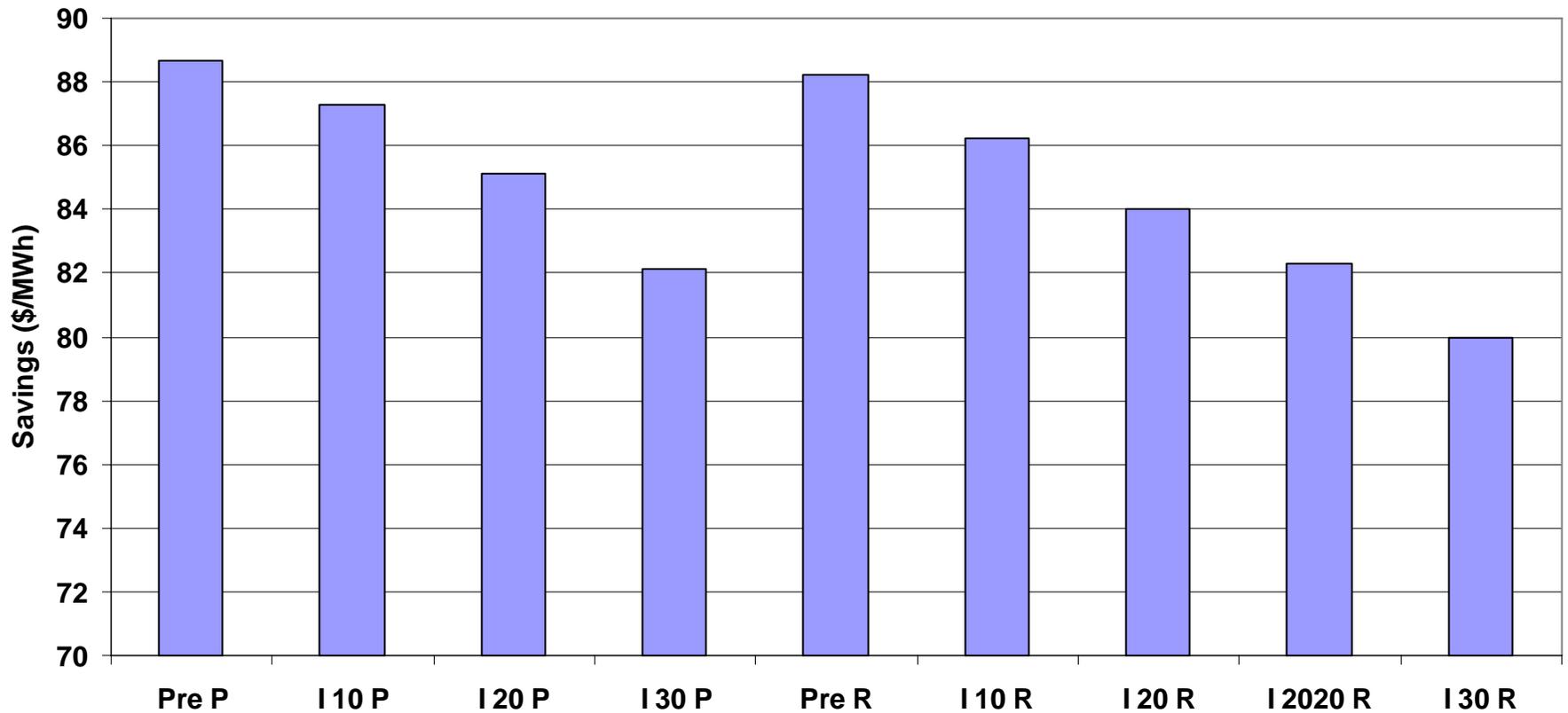
WECC Operating Cost Impact of Forecast (\$M)



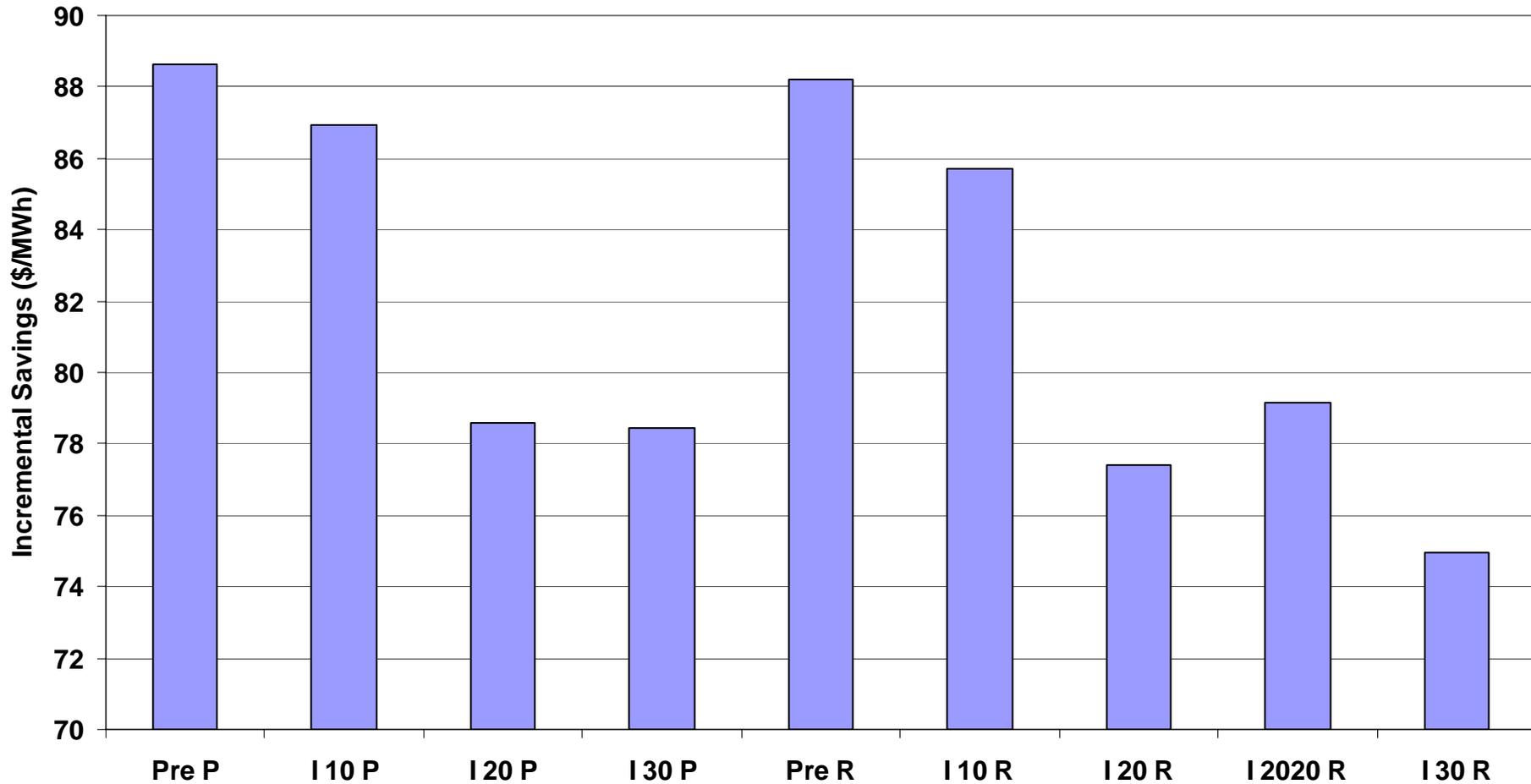
WECC Operating Cost Impact of Forecast (\$/MWh)



Operating Cost Savings per MWh of Renewable Energy (\$/MWh) - WECC - 2006

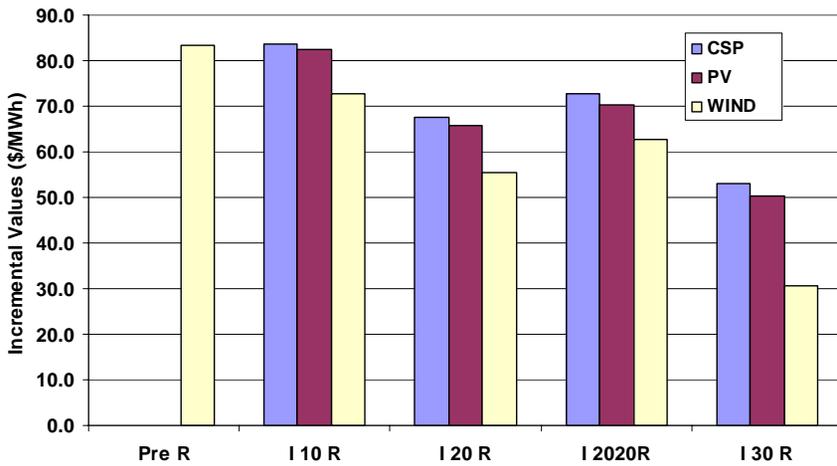


Incremental Savings per Incremental Renewable Energy (\$/MWh) - WECC - 2006

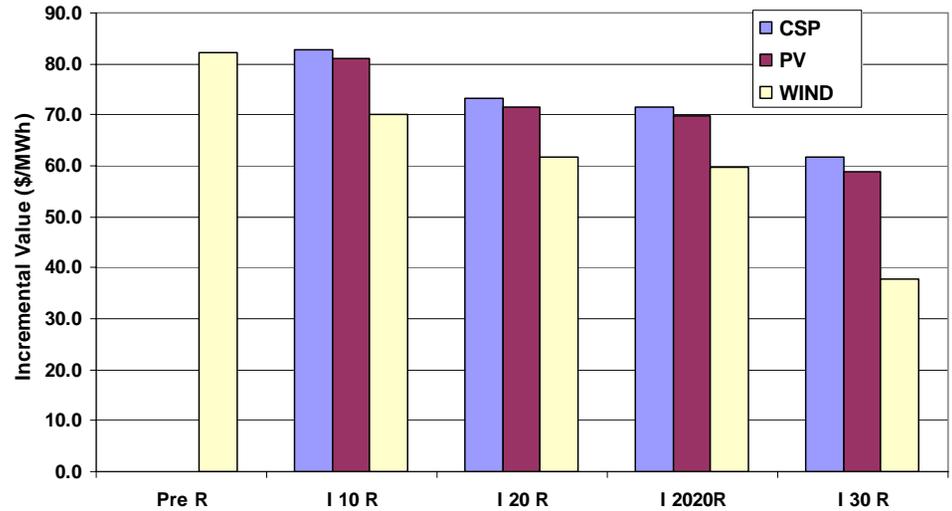


Revenue based Values

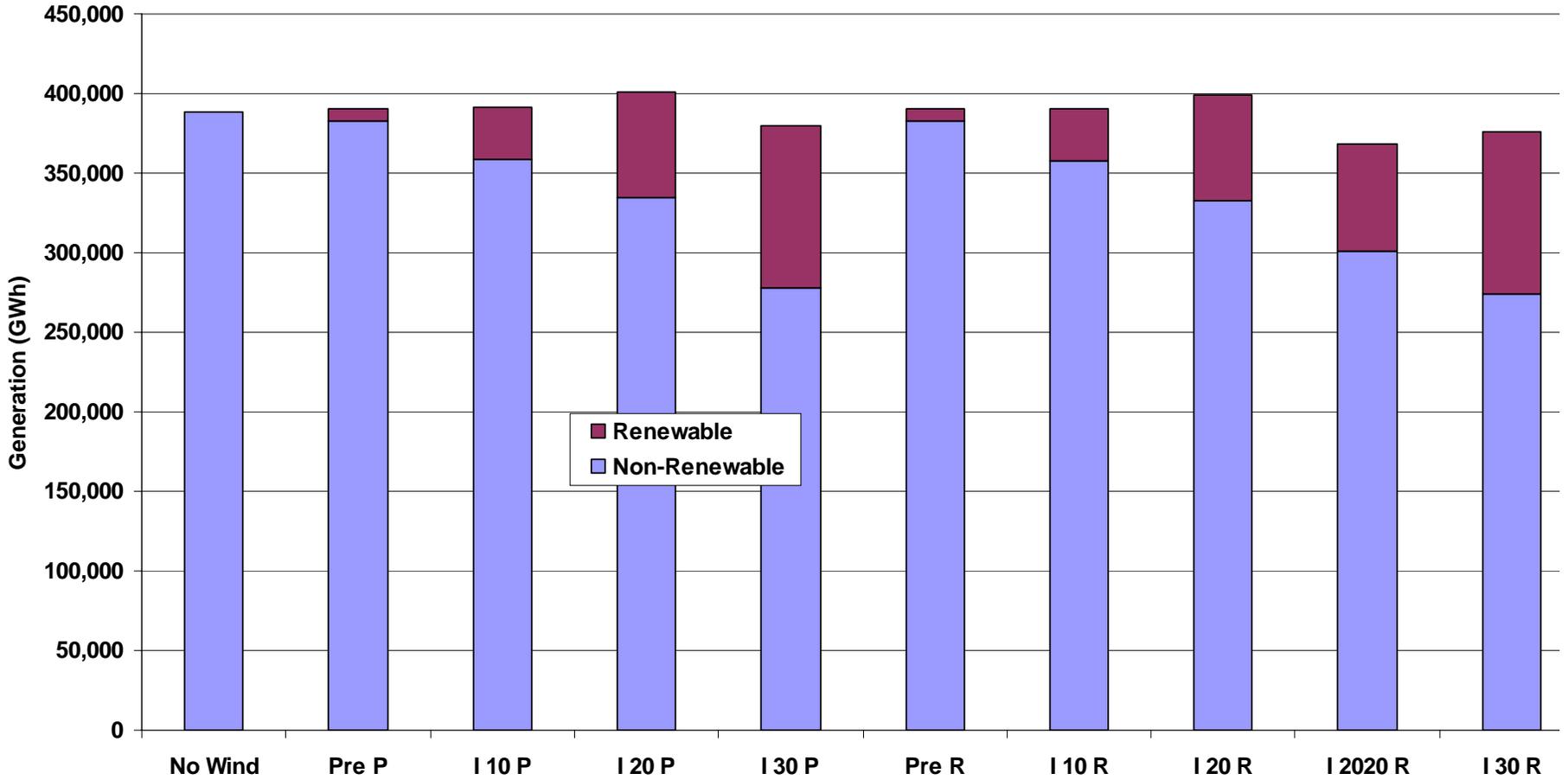
WECC Incremental Value of Renewables based on Spot Price Revenue



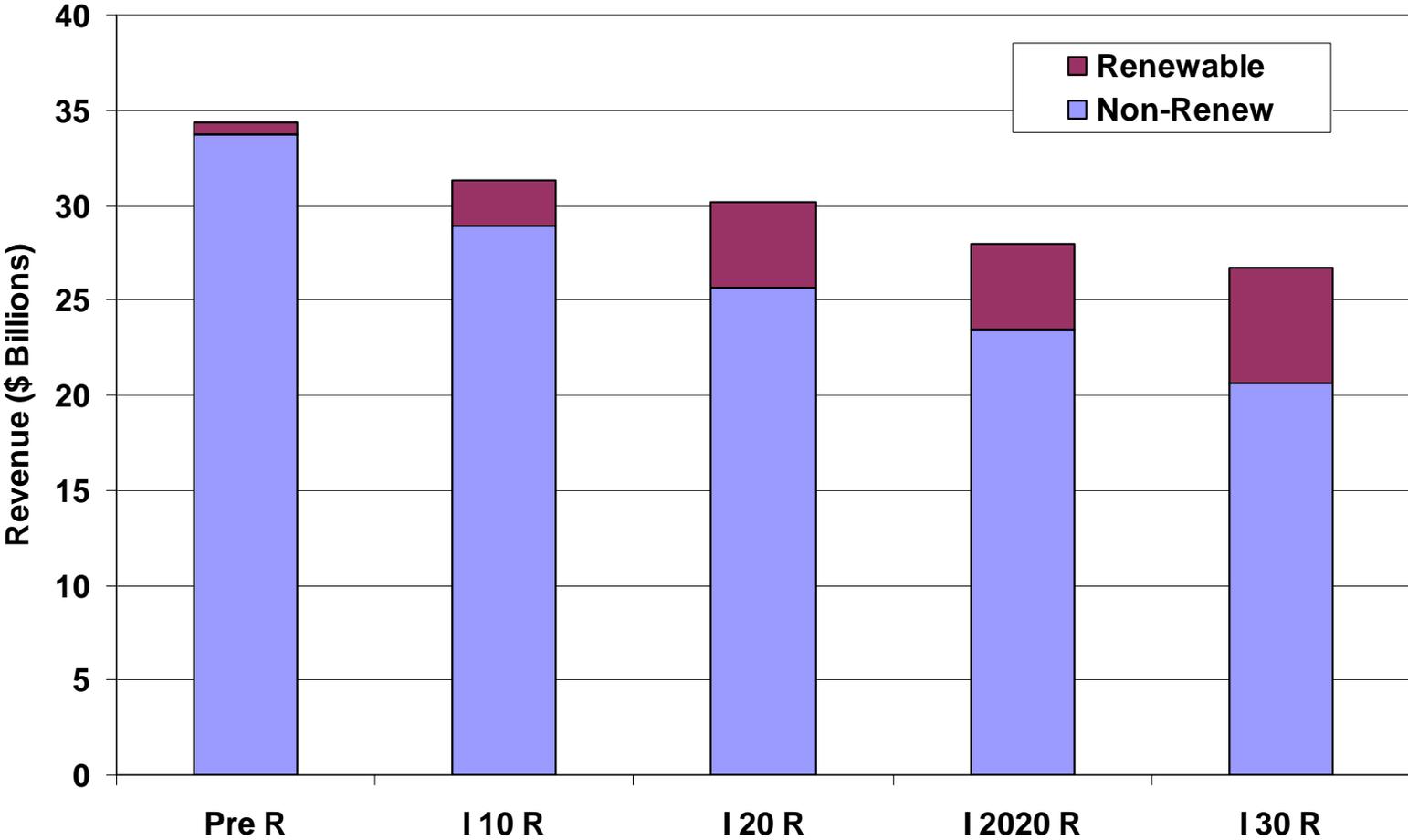
Study Area Incremental Value of Renewables based on Spot Price Revenue



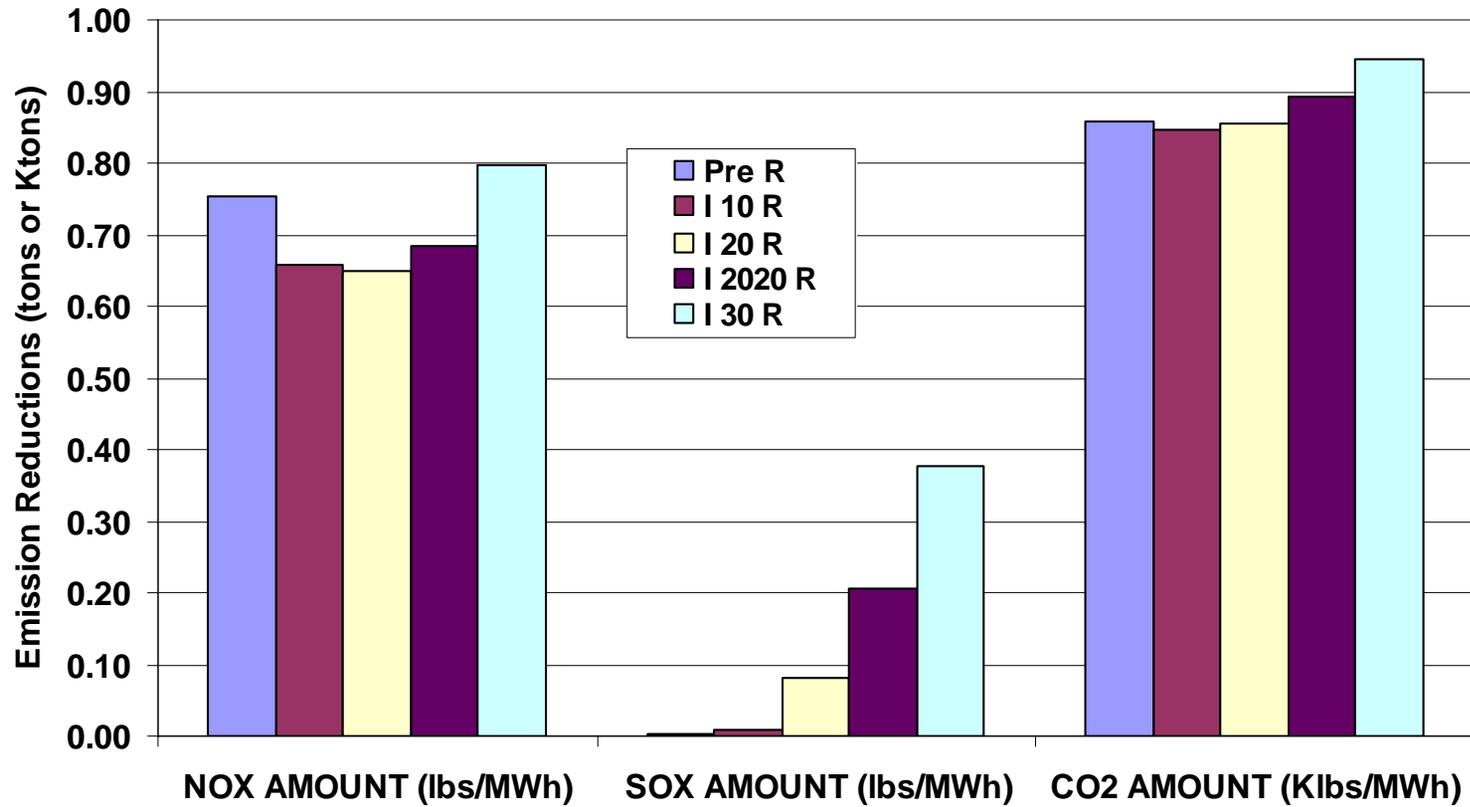
Total Generation - Study Area - 2006



Generator Revenue - Study Area - 2006



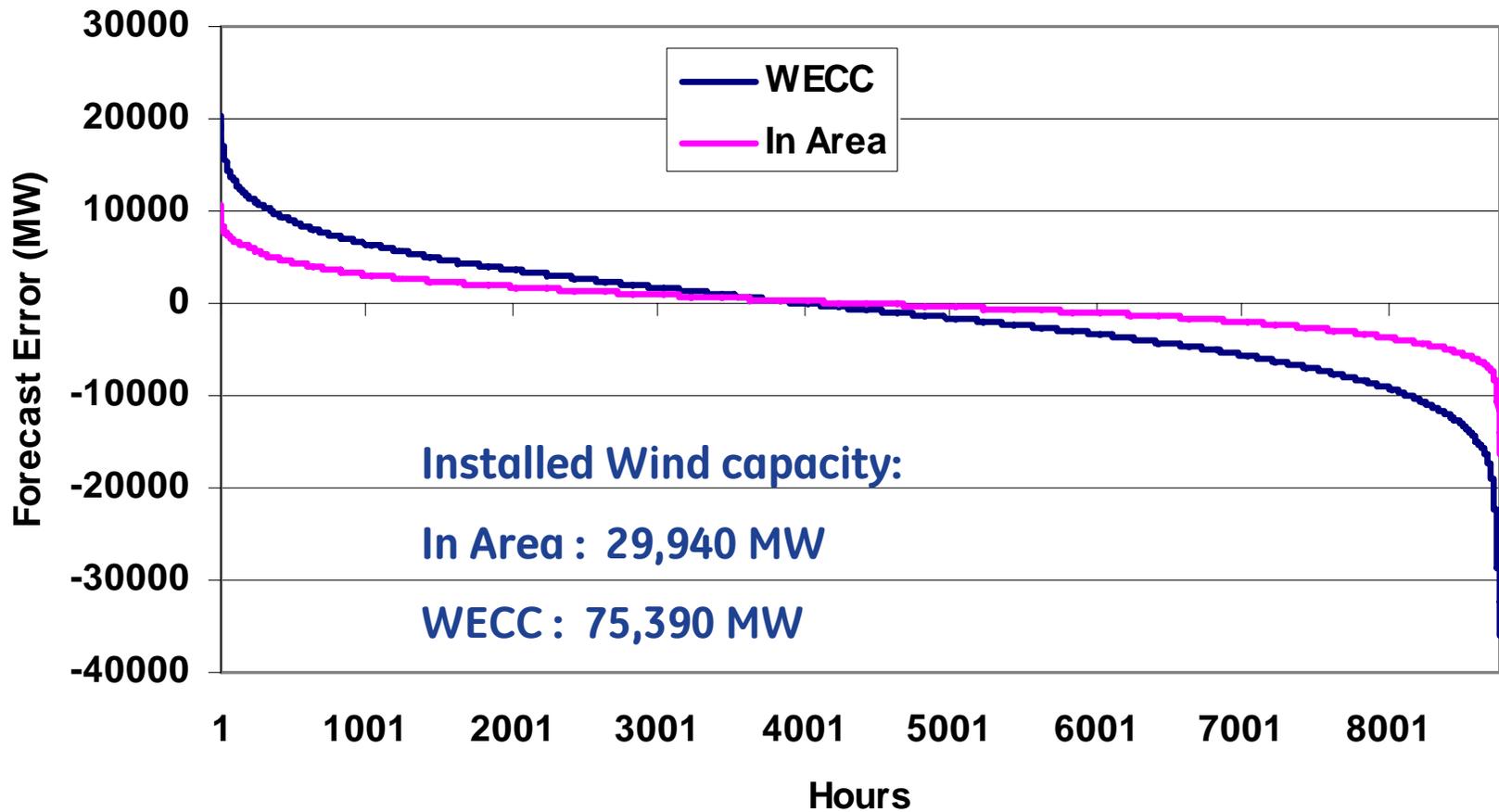
Total Emission Reductions per MWh of Renewable Generation - WECC - 2006



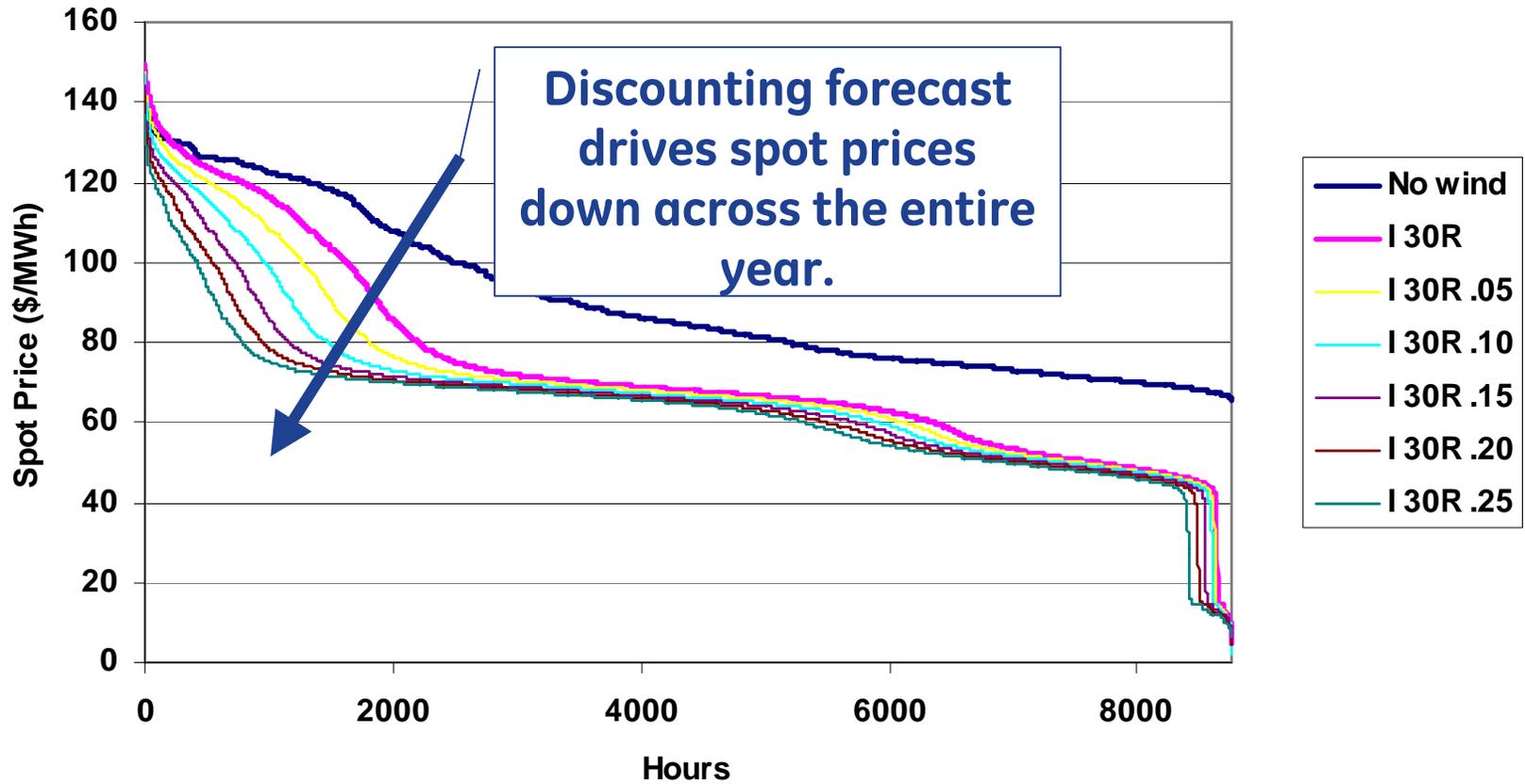
Unserved Energy with High Wind Penetration

- Higher wind penetrations resulted in significant increases in unserved energy due to occasional over forecasting of the wind generation.
- Additional cases were run with the In-Area, 30% penetration scenario.
- Starting from the annual unbiased forecasts the the forecasts were discounted an additional 5% to 25%

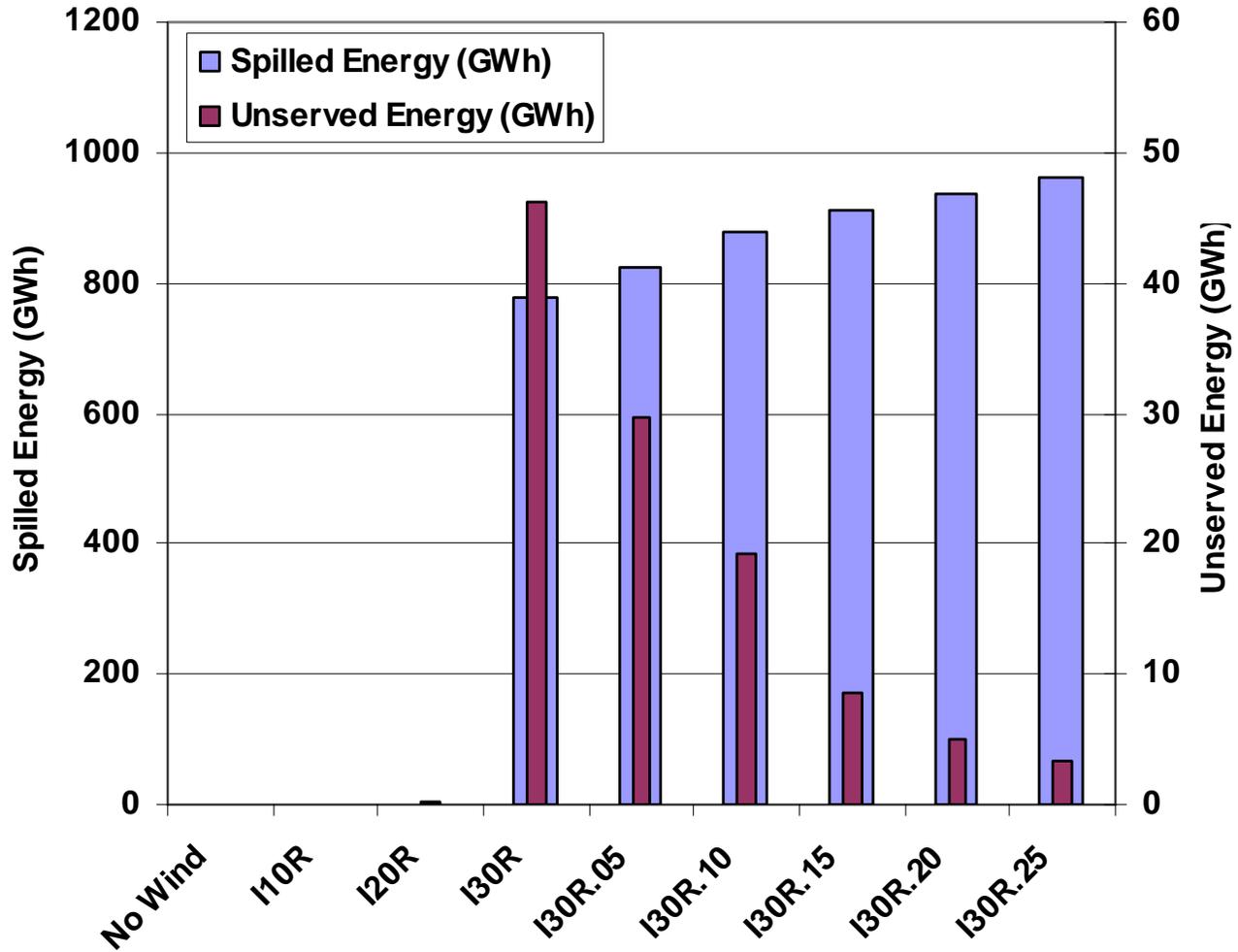
Adjusted Wind Forecast Error, I30R



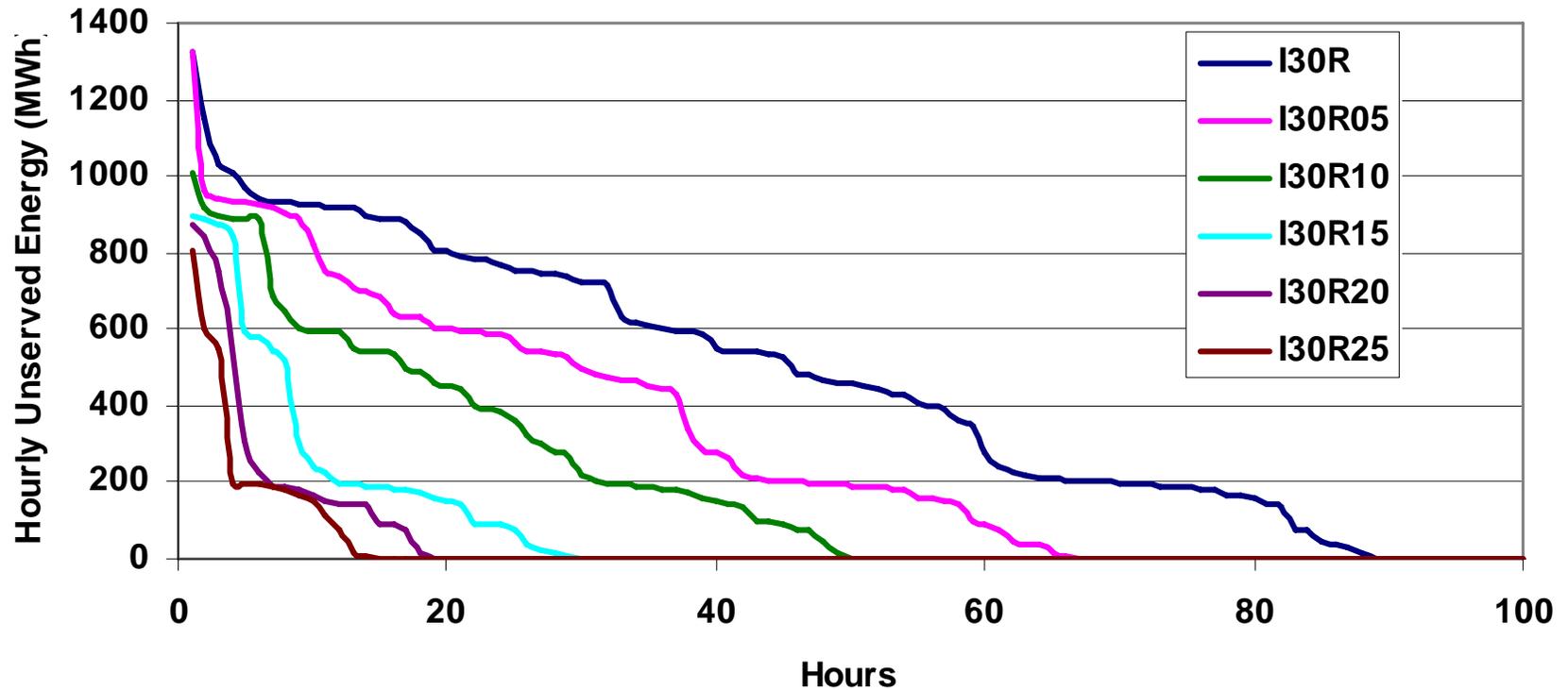
Annual Spot Price Duration Curve - I30R Impact of Discounting Forecast



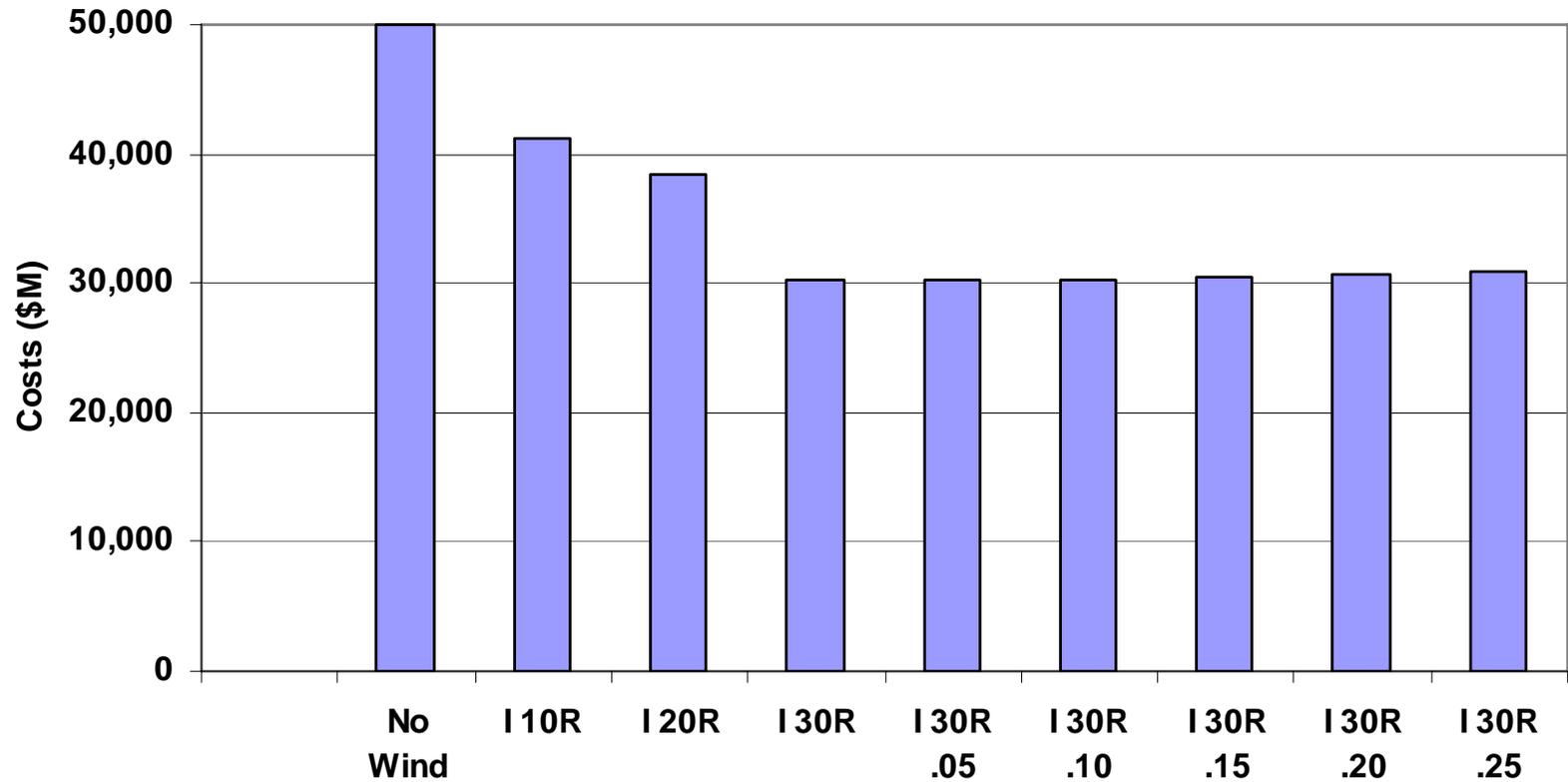
Spilled and Unserved Energy



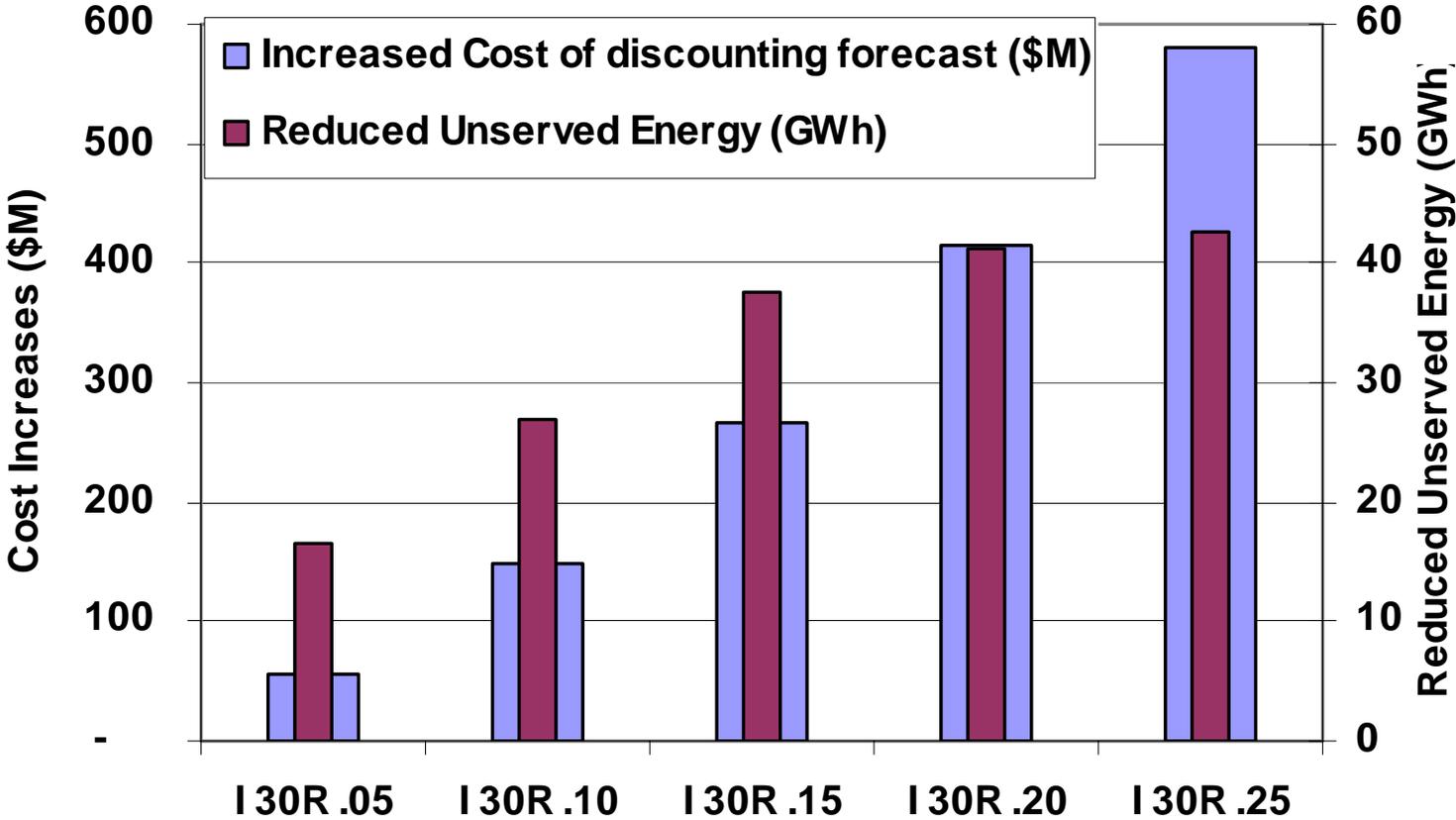
Distribution of Unserved Energy versus Discounting of Wind Forecast



Total WECC Operating Costs (M\$)

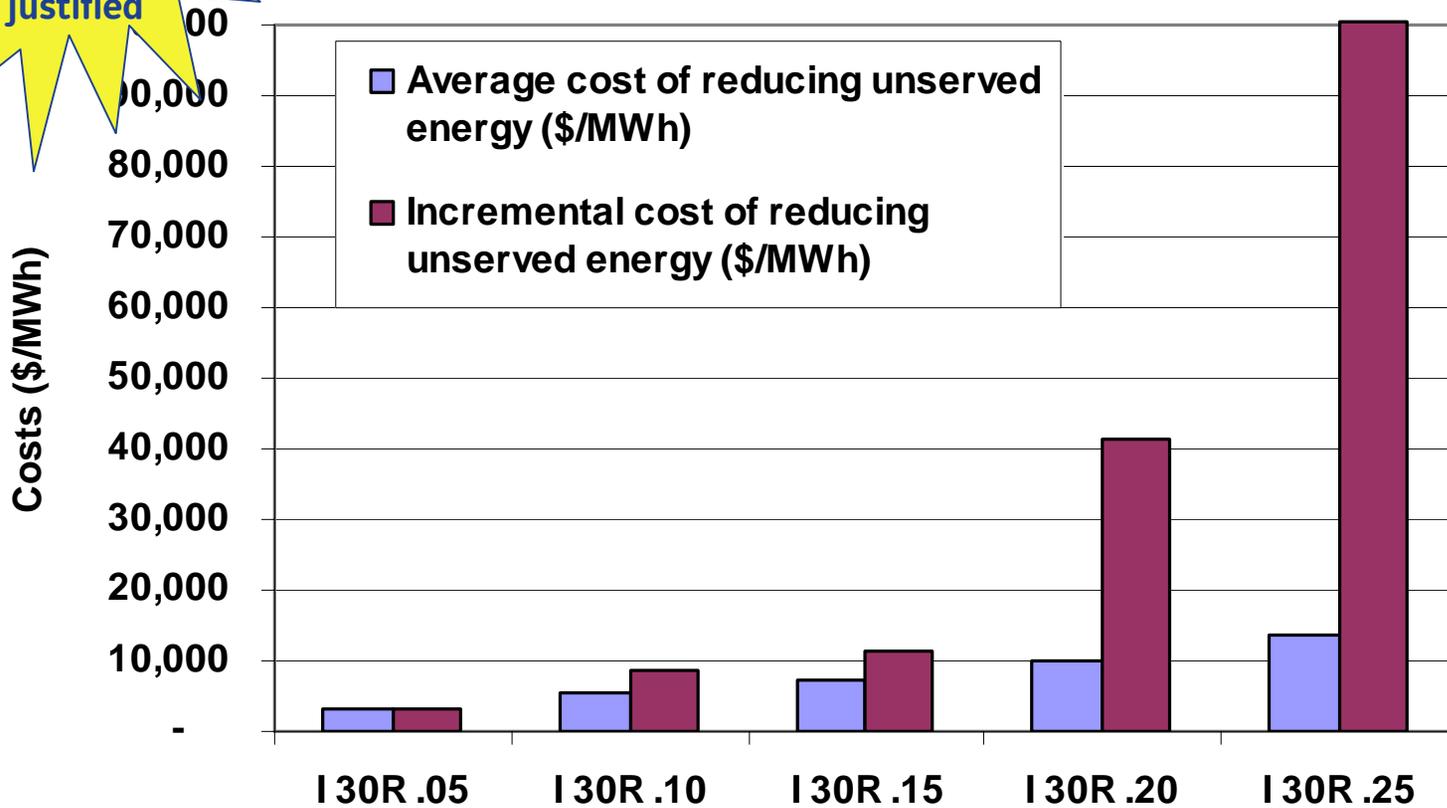


Unserviced Energy



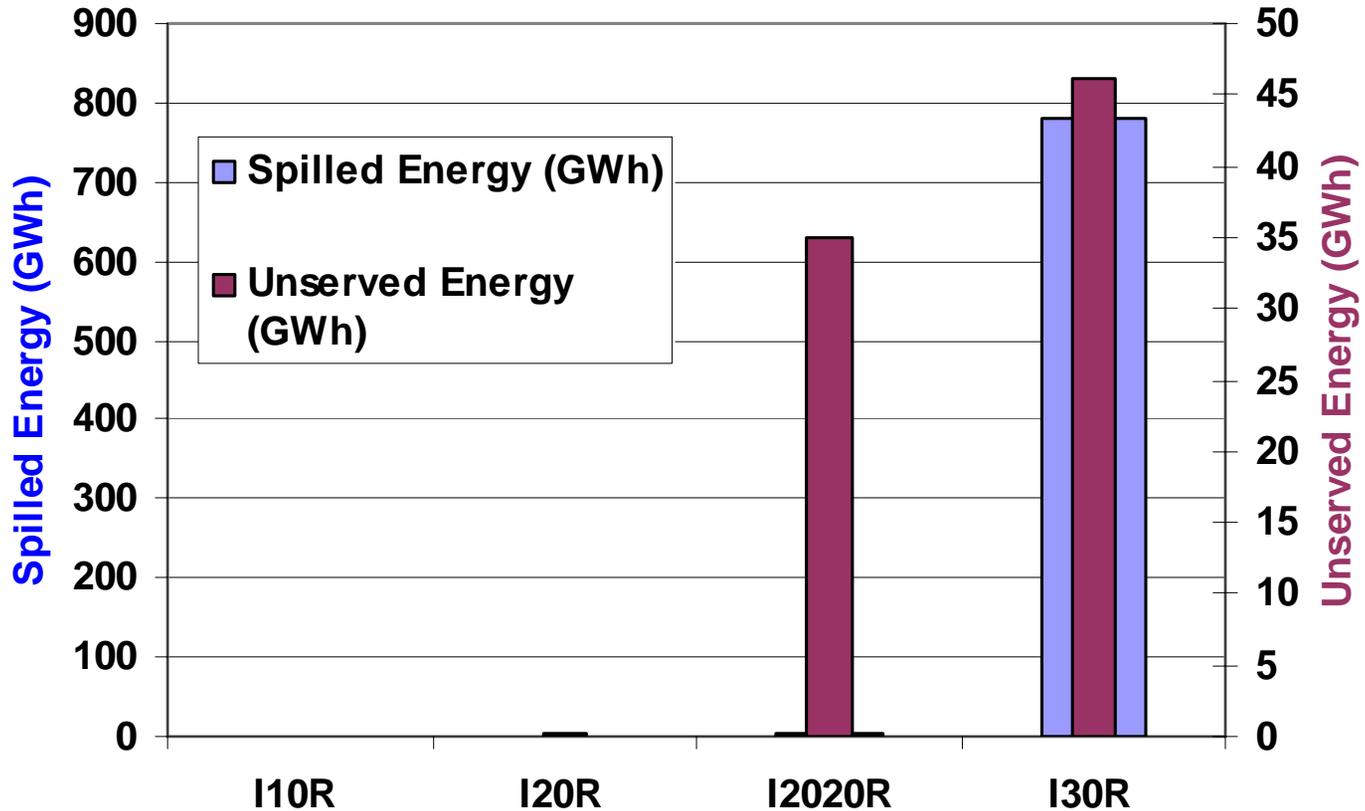
Interruptible loads
are easily cost
justified

Unserved Energy Value (\$/MWh)



Cost of reducing Unserved Energy by discounting wind generation forecasts. Costs are per MWh of energy reduced.

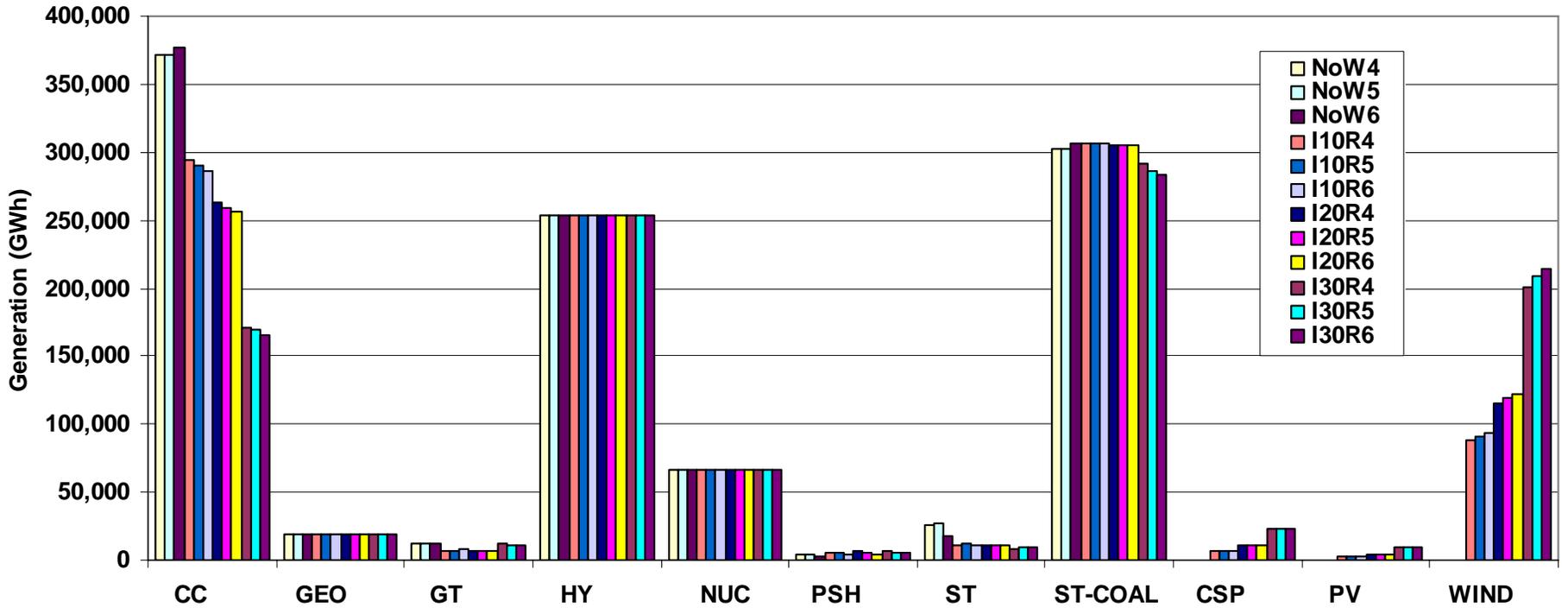
Impact of Renewables in Neighboring Areas



Year to Year Comparisons

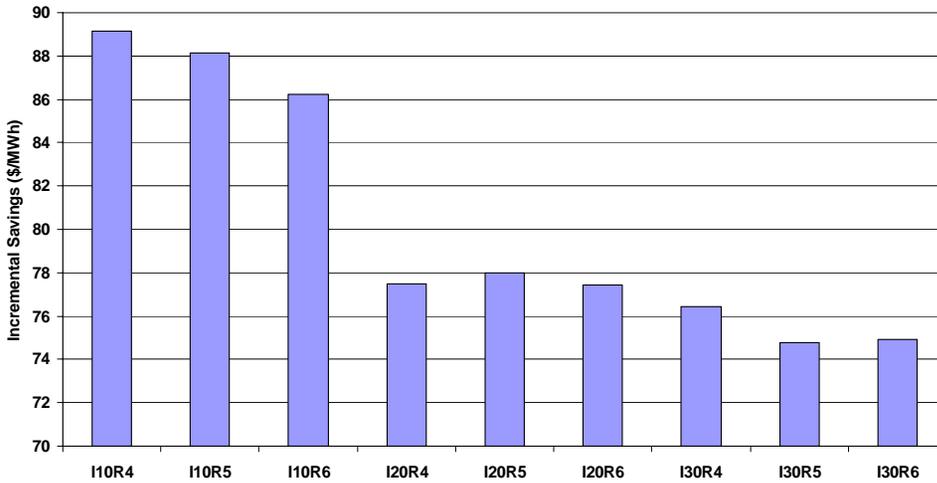
- Most of the operational results presented so far were using the 2006 load and renewable resource shapes.
- Renewable energy production varied slightly in other years.
- Results did not change drastically.

Generation by Type - WECC

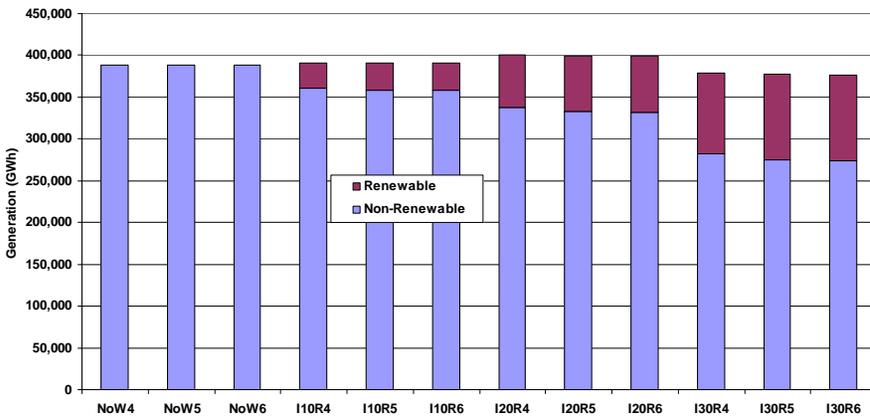


More Year to Year Comparisons

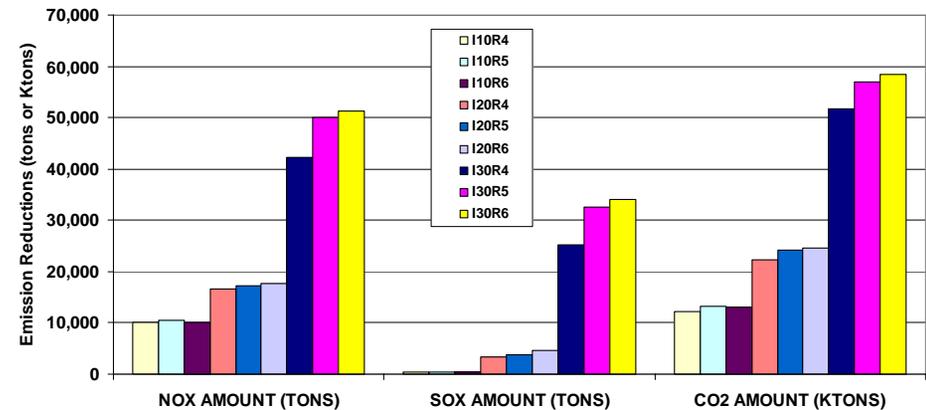
Incremental Savings per Incremental Renewable Energy (\$/MWh) - WECC



Total Generation - Study Area



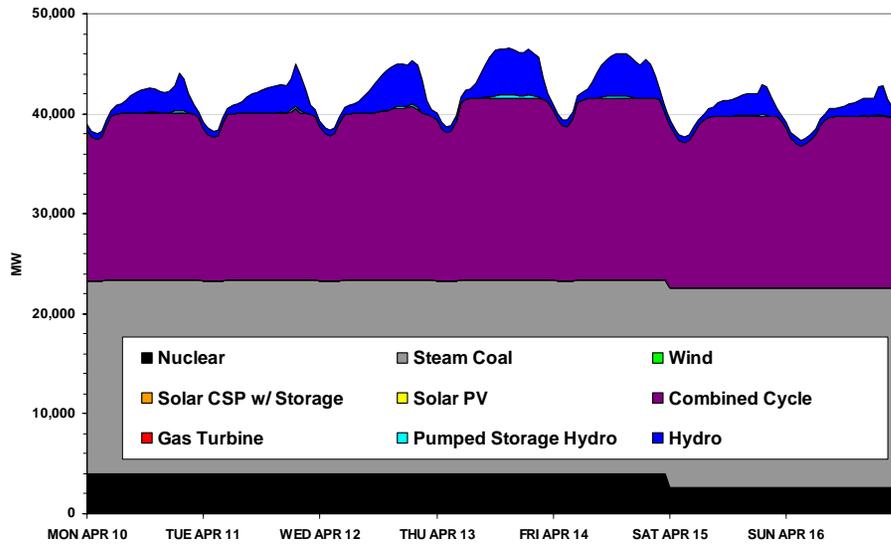
Emission Reductions - Study Area



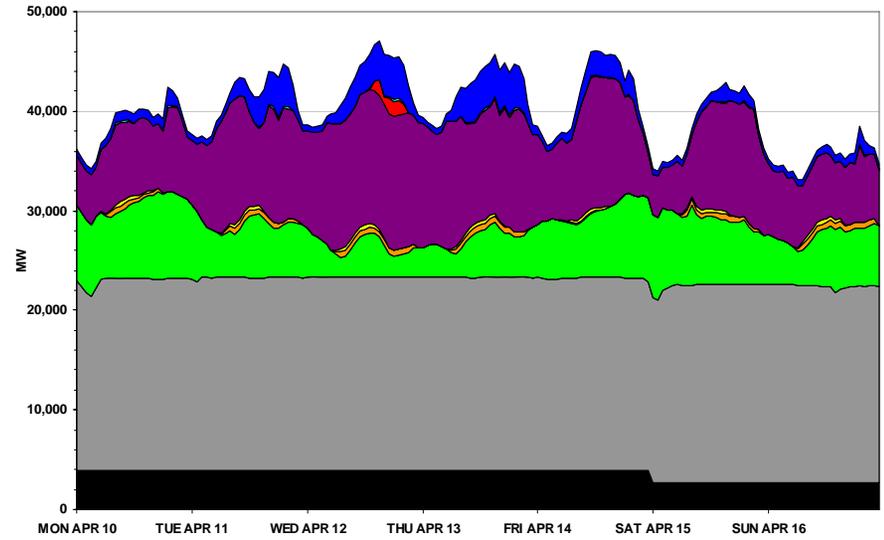
Weekly Operational Analysis

- Examined hourly operation for two specific weeks in mid-April and mid-July
- Results show hourly variation in generation by type as renewable penetration increases

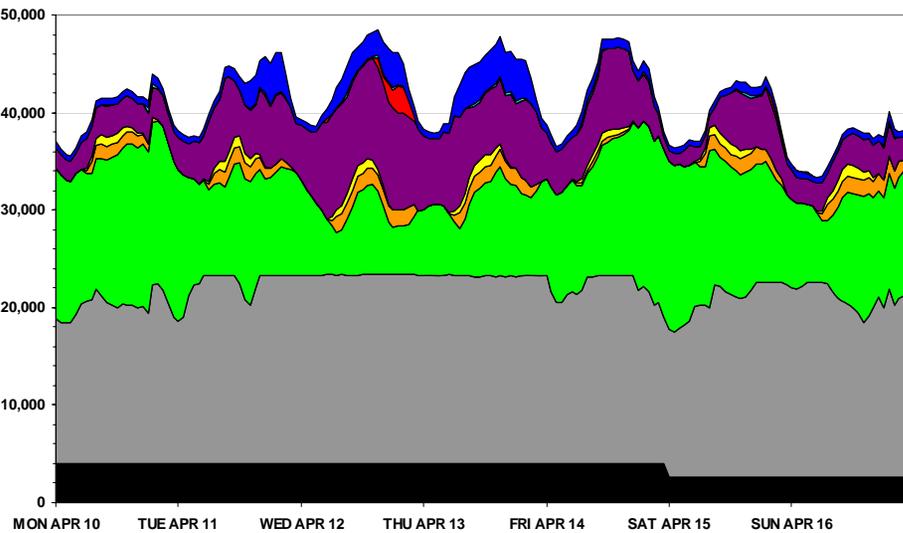
Study Area Dispatch - Week of April 10th - No Wind



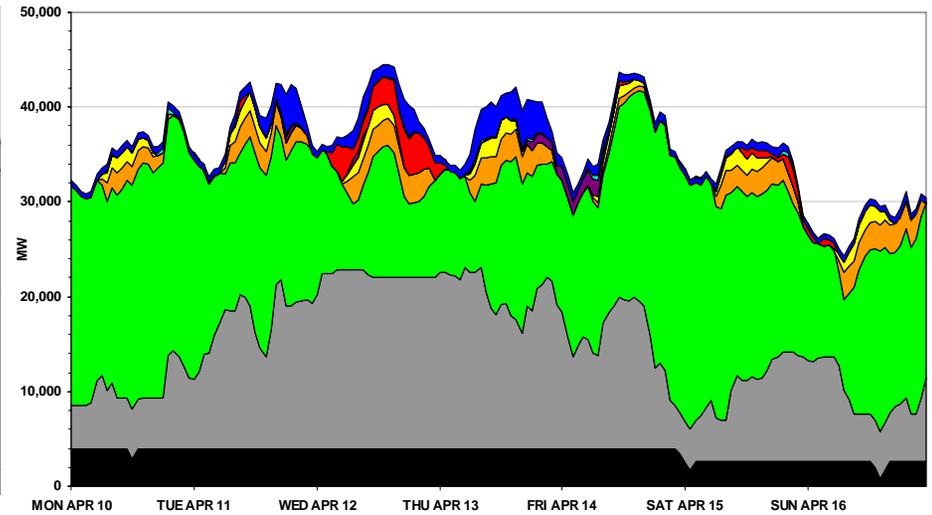
Study Area Dispatch - Week of April 10th - 10%R



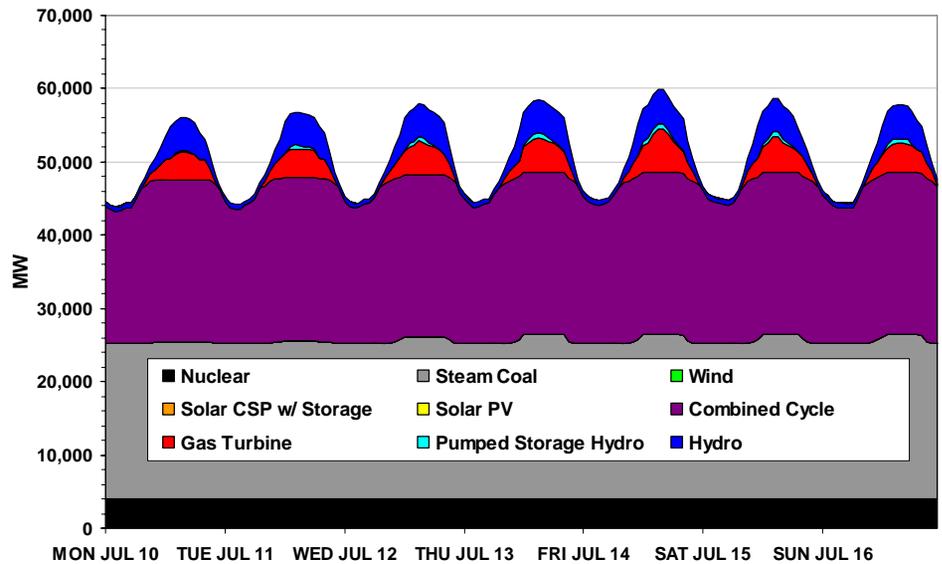
Study Area Dispatch - Week of April 10th - 20%R



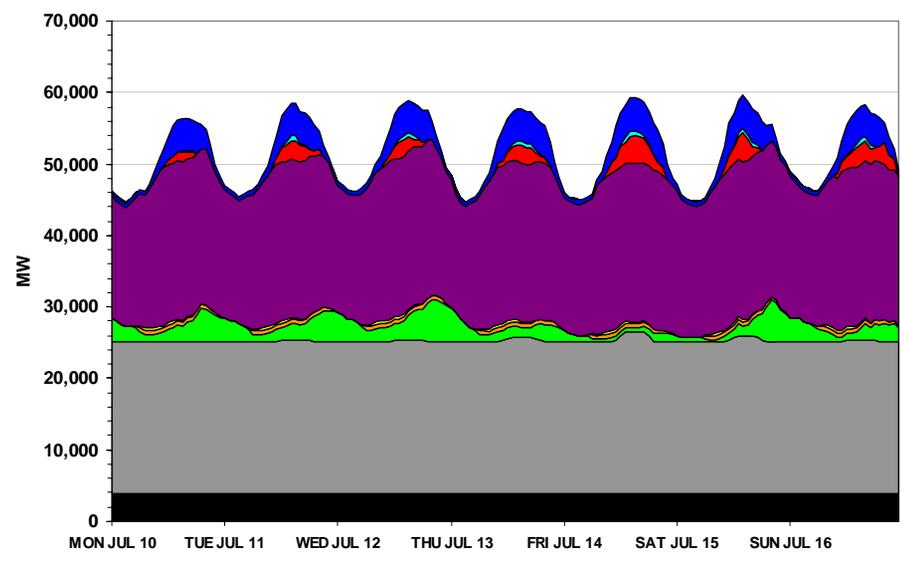
Study Area Dispatch - Week of April 10th - 30%R



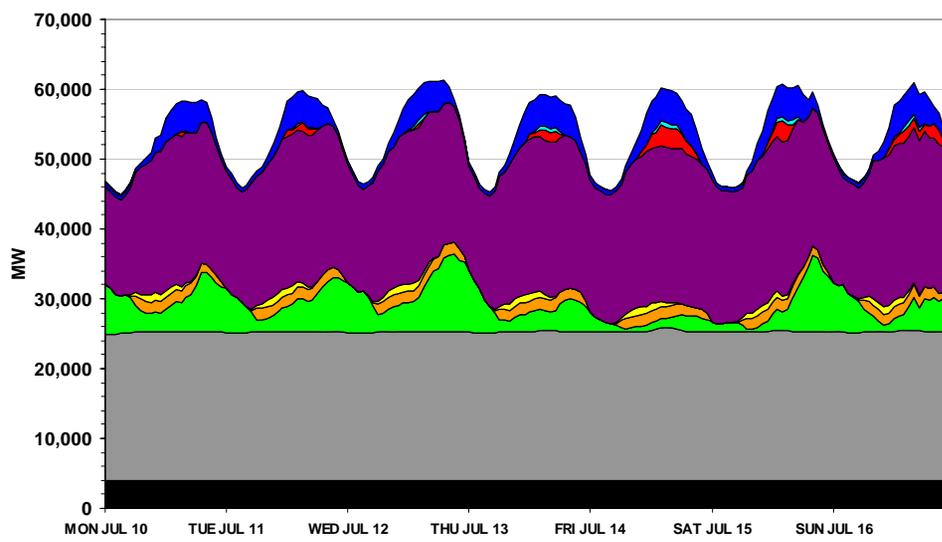
Study Area Dispatch - Week of July 10th - No Wind



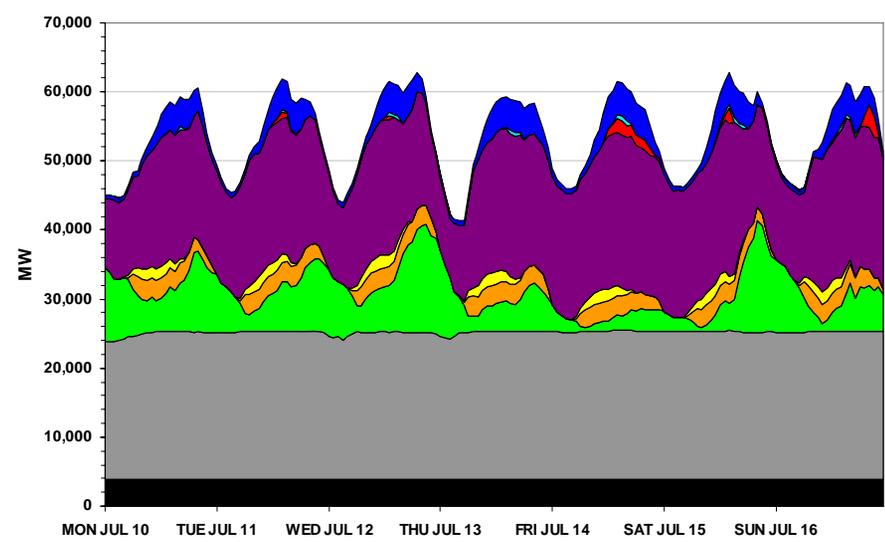
Study Area Dispatch - Week of July 10th - 10%R



Study Area Dispatch - Week of July 10th - 20%R

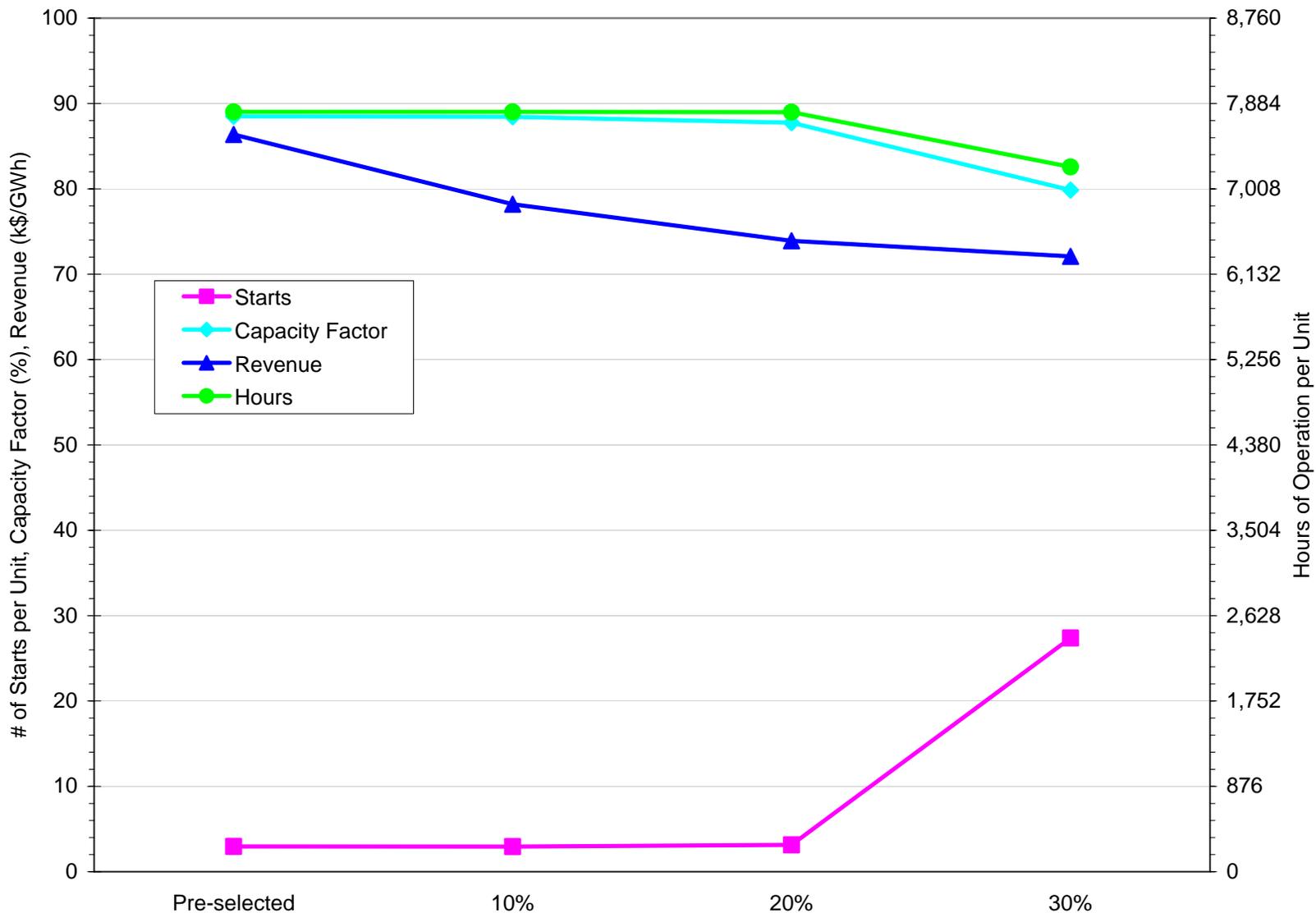


Study Area Dispatch - Week of July 10th - 30%R

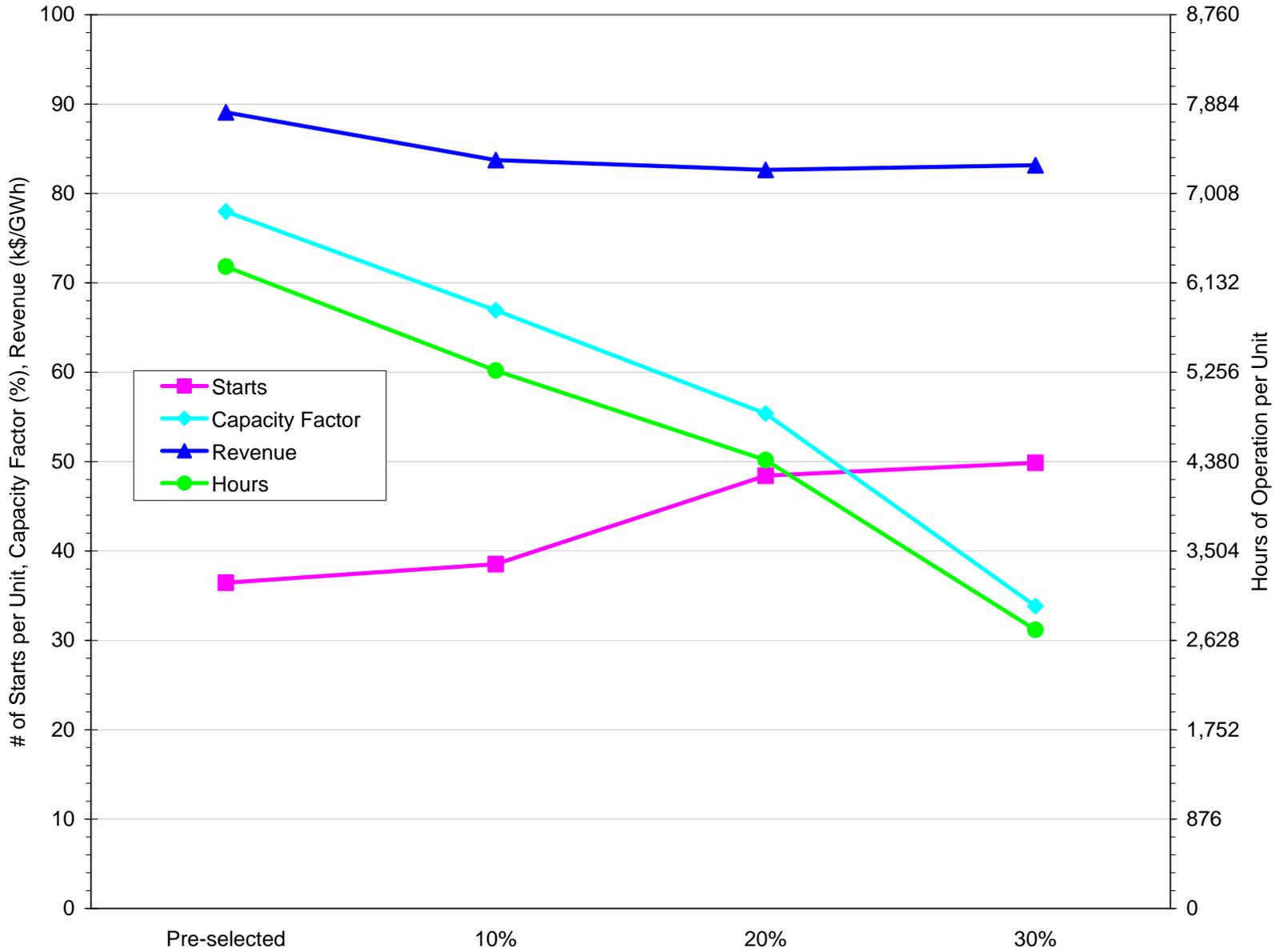


Unit Starts by Type, 2006

Coal Plants per Unit, Local-Priority Scenario



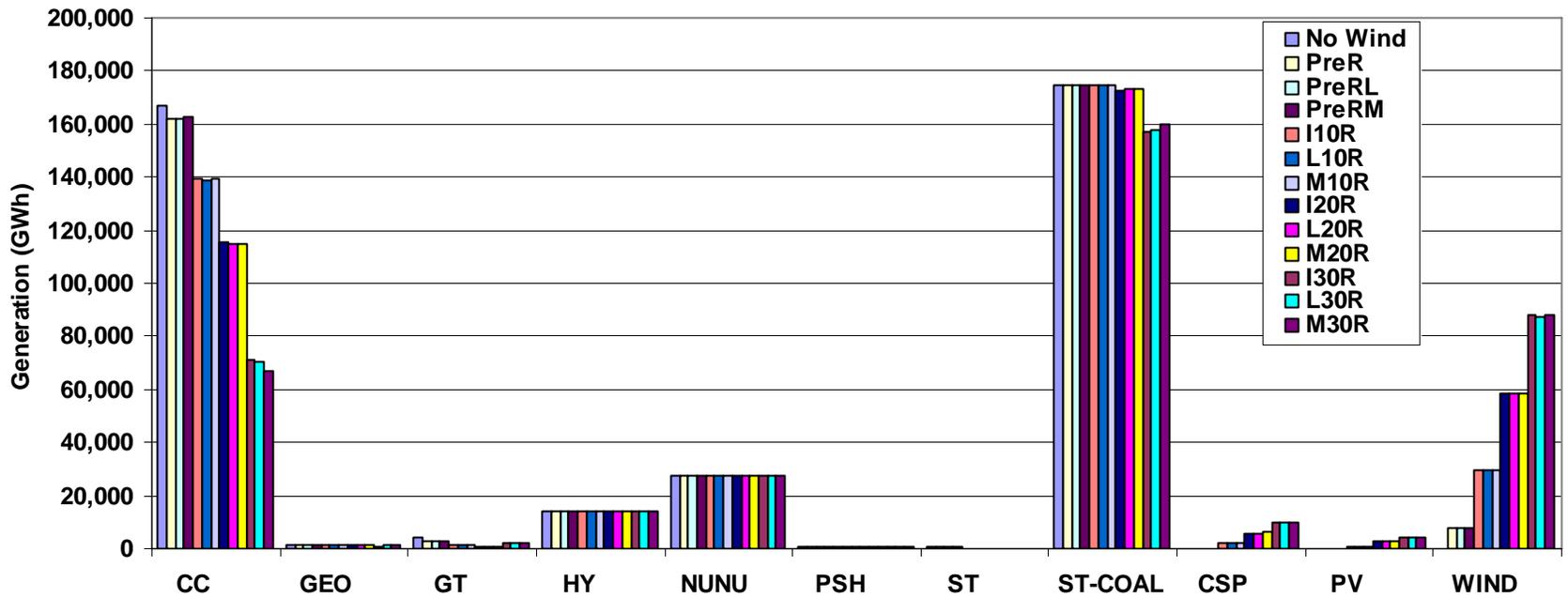
Combined Cycle Plants per Unit, Local-Priority Scenario



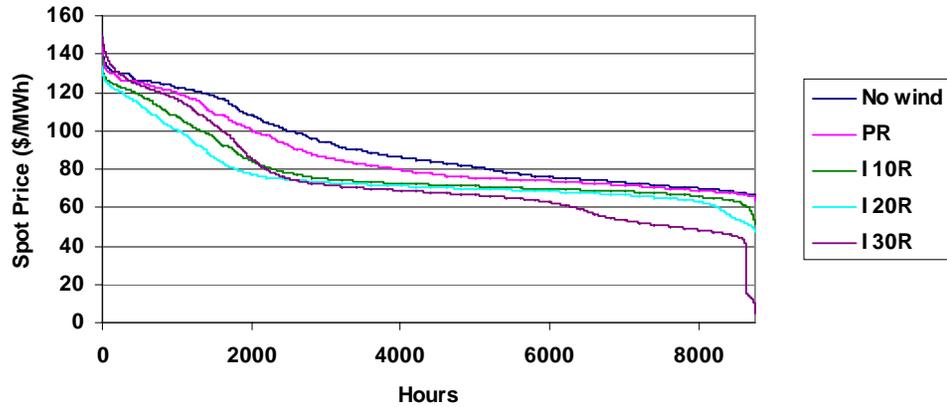
Impact of Scenarios

- Energy generation was held constant for the various scenarios but total installed capacity and location was varied.
- No significant variation in operational results between various scenarios.

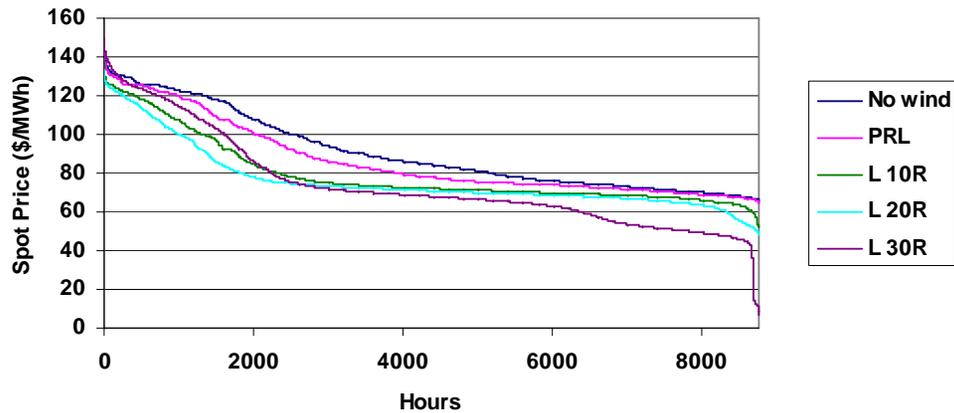
Generation by Type - Study Area - 2006



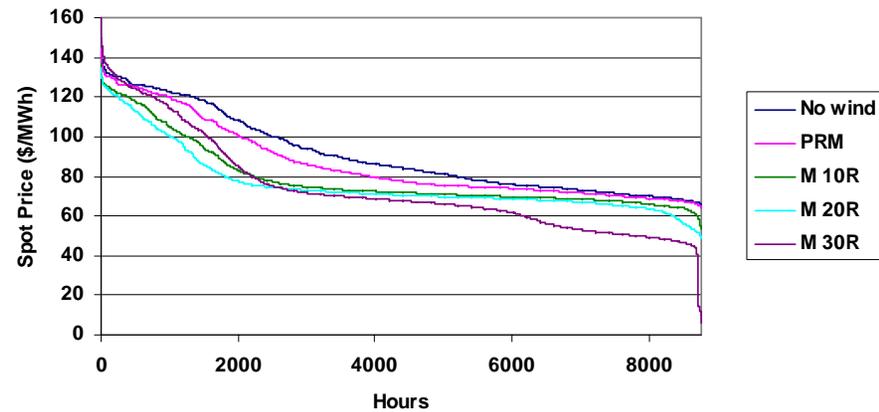
**Annual Spot Price Duration Curve
S-o-A Forecast, In-Area Scenarios**



**Annual Spot Price Duration Curve
S-o-A Forecast, Local Projects Scenario**

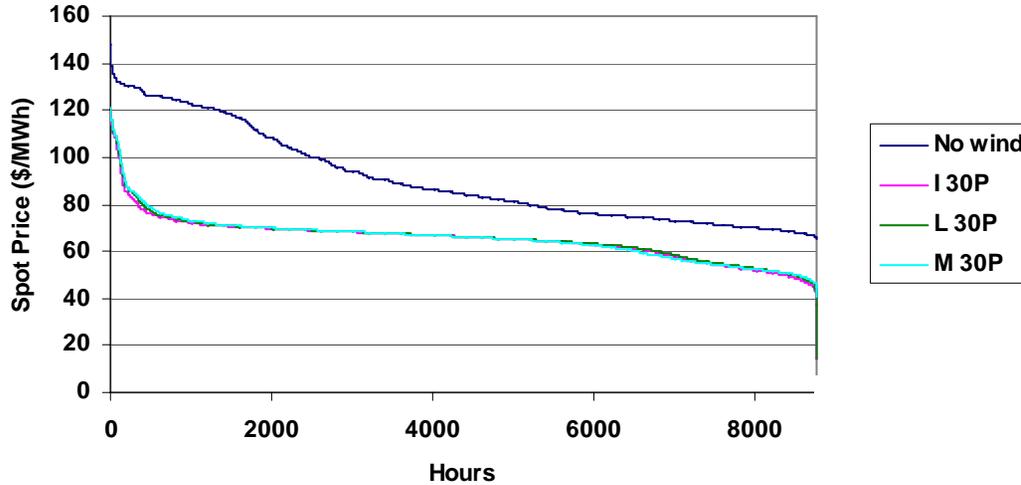


**Annual Spot Price Duration Curve
S-o-A Forecast, Mega Projects Scenarios**

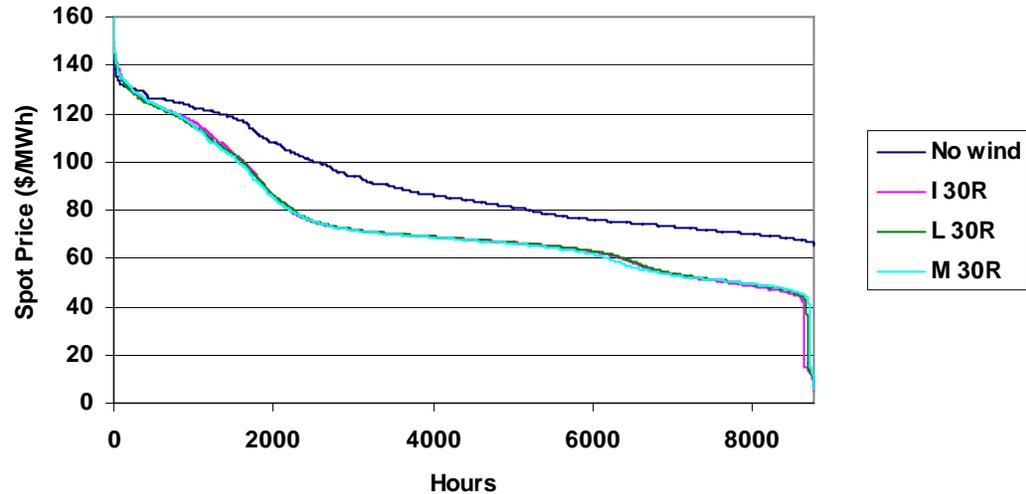


Scenario Comparison

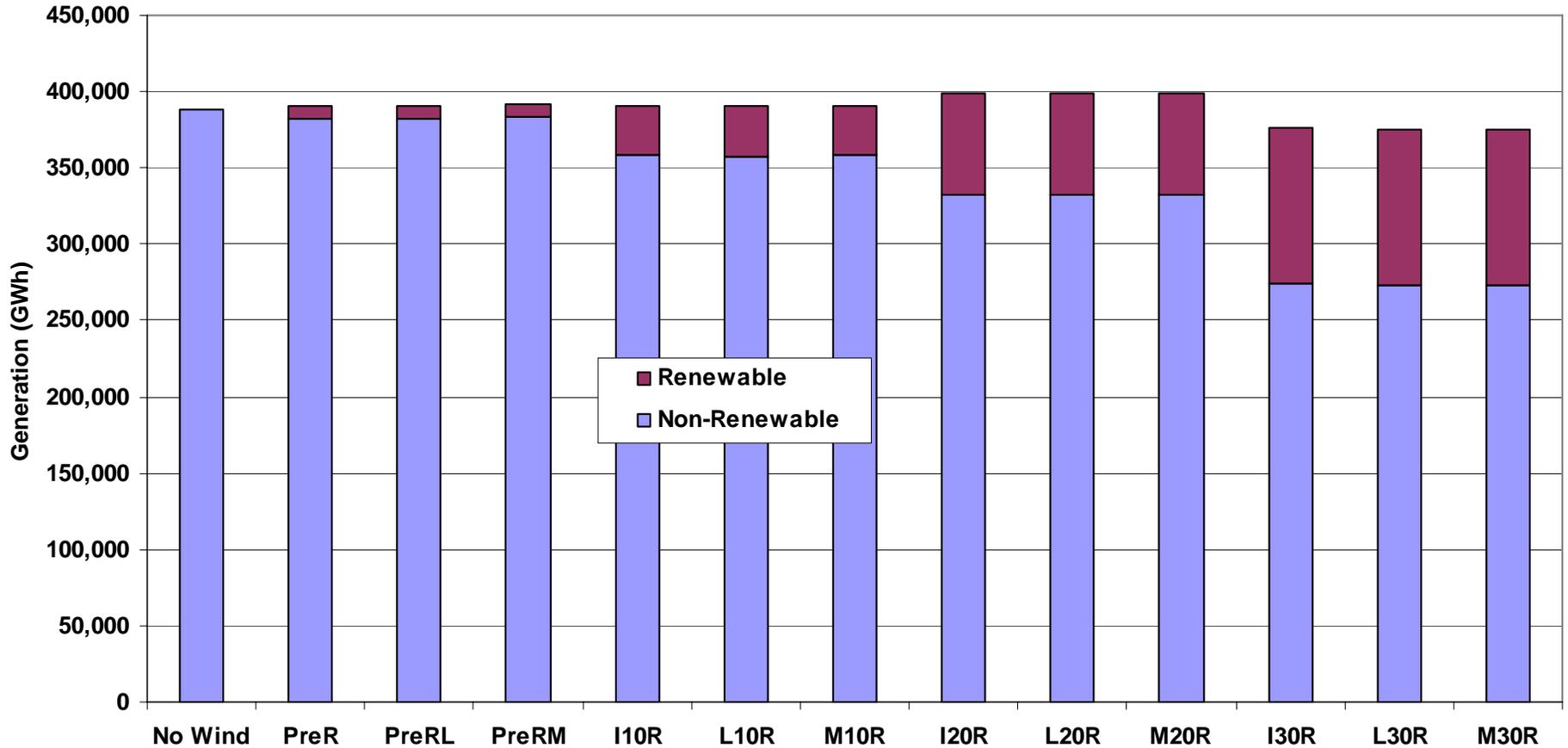
Annual Spot Price Duration Curve
Perfect Forecast, 30% Penetration



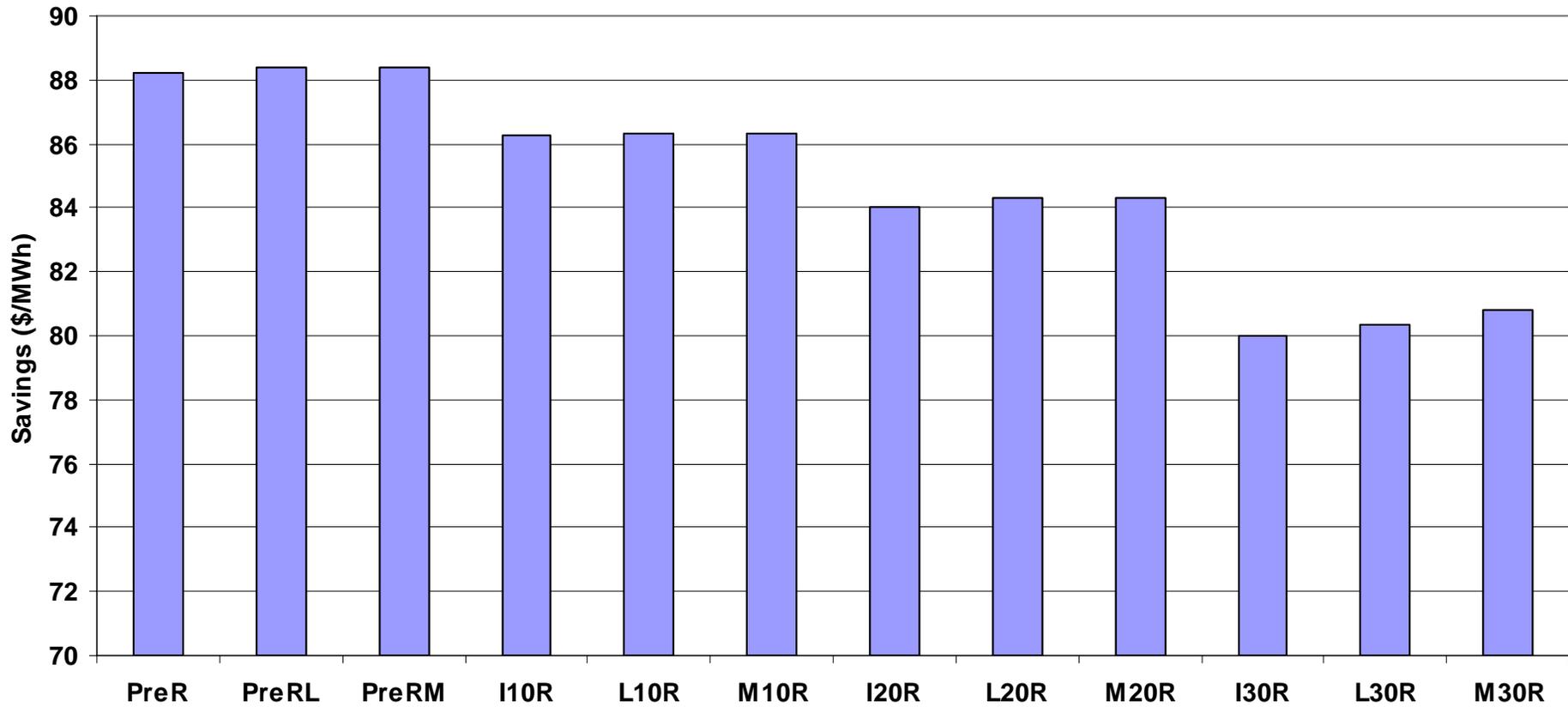
Annual Spot Price Duration Curve
S-o-A Forecast, 30% Penetration



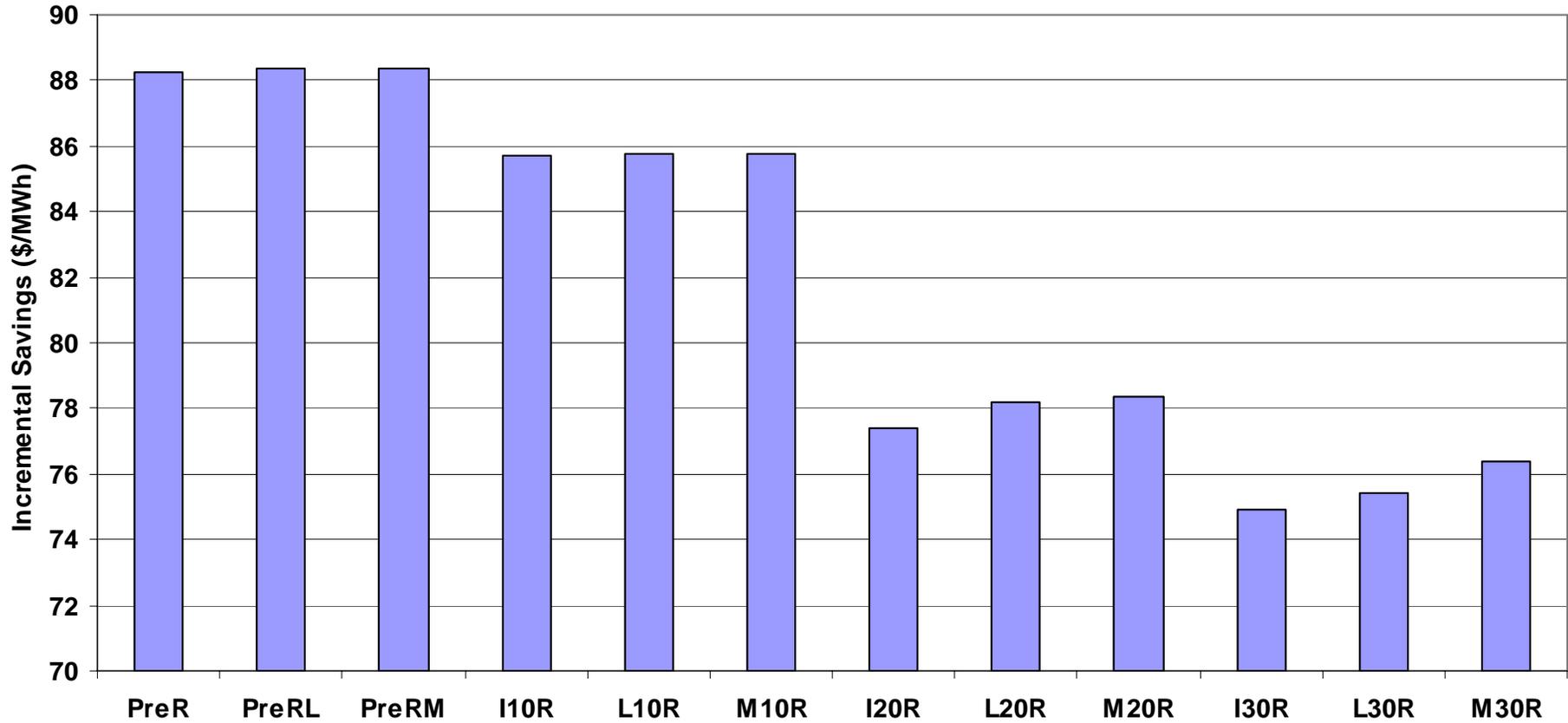
Total Generation - Study Area - 2006



Operating Cost Savings per MWh of Renewable Energy (\$/MWh) - WECC - 2006

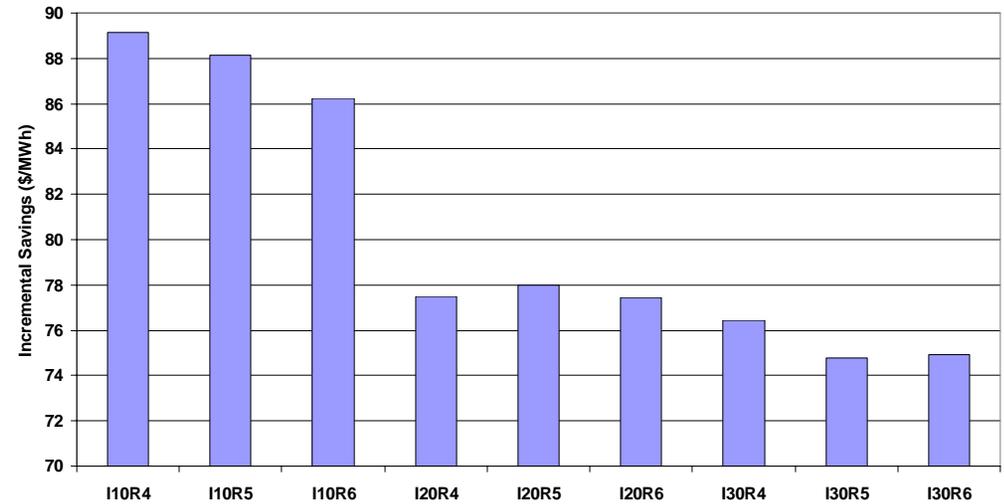


Incremental Savings per Incremental Renewable Energy (\$/MWh) - WECC - 2006

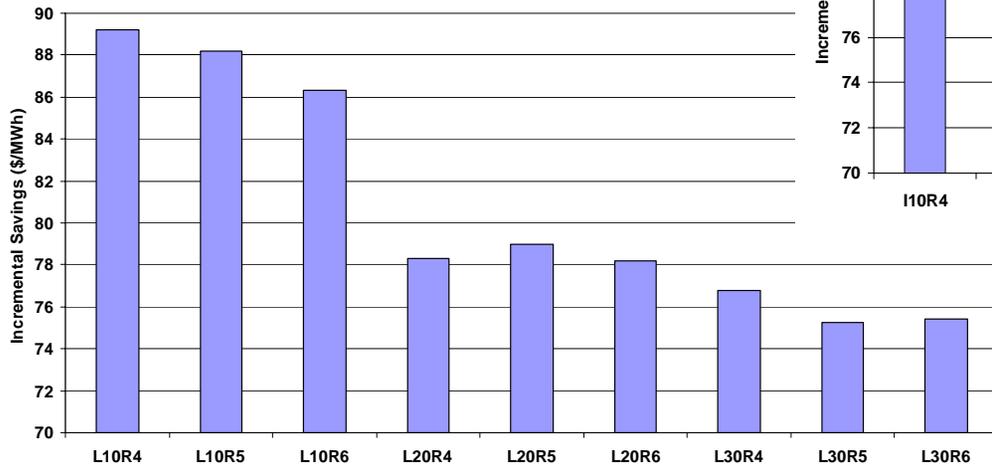


Multiple Years and Scenarios

Incremental Savings per Incremental Renewable Energy (\$/MWh) - WECC



Incremental Savings per Incremental Renewable Energy (\$/MWh) - WECC



Incremental Savings per Incremental Renewable Energy (\$/MWh) - WECC

