GE Energy

Asia Development Bank
Wind Energy Grid Integration Workshop:

Issues and Challenges
for systems with high penetration of Wind Power

Nicholas W. Miller

GE Energy Consulting

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Large Scale Integration – an introduction

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GE's Integration of Renewables Experience

Studies commissioned by utilities, commissions, ISOs…
- **Examine feasibility of 100+ GW of new renewables**
- **Consider operability, costs, emissions, transmission**

2004 New York
3 GW Wind
10% Peak Load
4% Energy

2005 Ontario
15 GW Wind
50% Peak Load
30% Energy

2006 California
13 GW Wind
3 GW Solar
26% Peak Load
15% Energy

2007 Texas
15 GW Wind
25% Peak Load
17% Energy

2008 Maui
70 MW Wind
39% Peak Load
25% Energy

2009 Western U.S.
72 GW Wind
15 GW Solar
50% Peak Load
27% Energy

2010 Oahu
500 MW Wind
100 MW Solar
55% Peak Load
25% Energy

2010 New England
12 GW Wind
39% Peak Load
24% Energy

PJM Study (underway)
96GW Wind
22GW Solar
30% Energy

Need for fleet flexibility, new operating strategies and markets, transmission reinforcement, grid friendly renewables

Major Study Results :

- **Large interconnected power systems can accommodate variable generation (Wind + Solar) penetration levels exceeding 30% of peak loads**
- **But not by doing more of the same…..**

To reach higher levels of wind generation and other renewables:

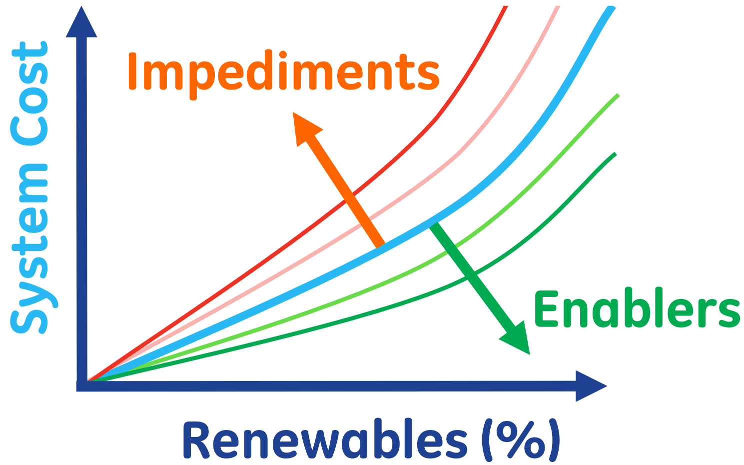
- Get the infrastructure right
- And use it better

The debate has changed:
No longer: "Is it possible?"
Now: "How do we get there?"

Lessons Learned

System Cost

Unserved Energy
Missing Wind/Solar Target
Higher Cost of Electricity



Impediments

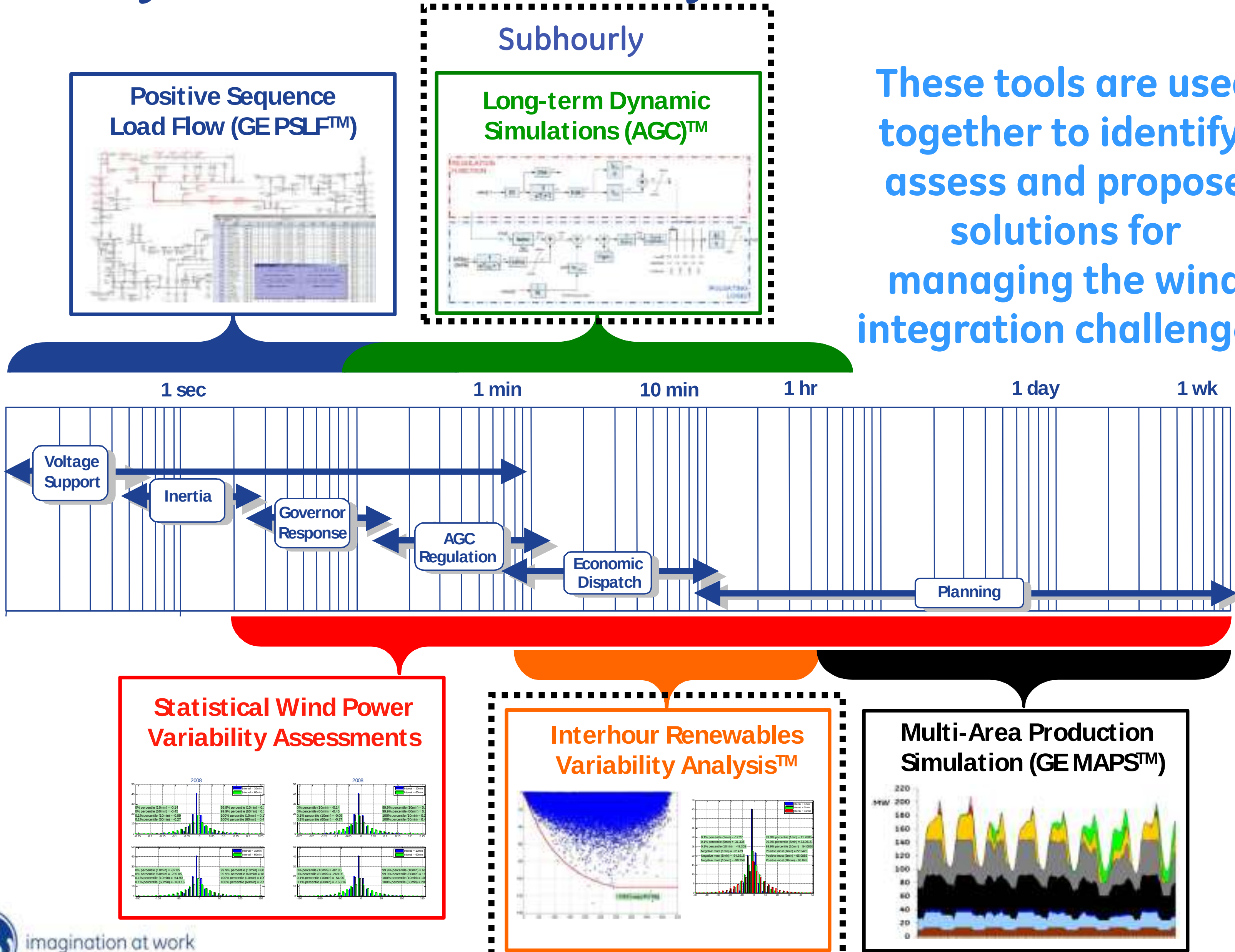
- Lack of transmission
- Lack of control area cooperation
- Market rules / contracts constraints
- Unobservable DG – "behind the fence"
- Inflexible operation strategies during light load & high risk periods

Enablers

- Wind Forecasting
- Flexible Thermal fleet
  - Faster quick starts
  - Deeper turn-down
  - Faster ramps
- More spatial diversity of wind/solar
- Grid-friendly wind and solar
- Demand response ancillary services

All grid can accommodate substantial levels of wind and solar power ... There is never a hard limit

A variety of tools across many timescales…



These tools are used together to identify, assess and propose solutions for managing the wind integration challenges

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Nicholas W. Miller, GE Energy Consulting
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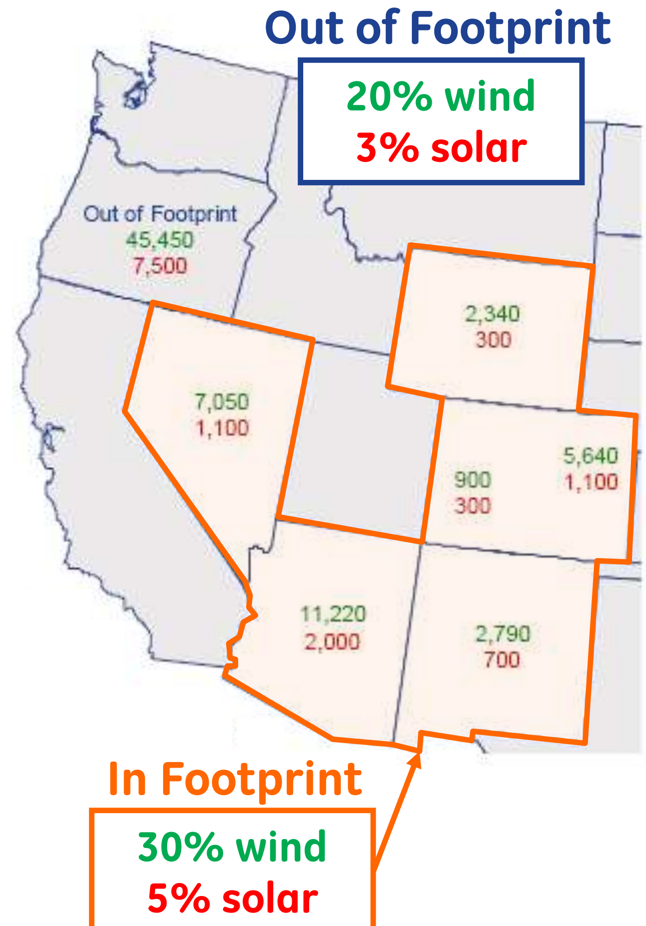
Western Wind & Solar Study

Can 35% wind and solar, by energy be integrated into the western United States?

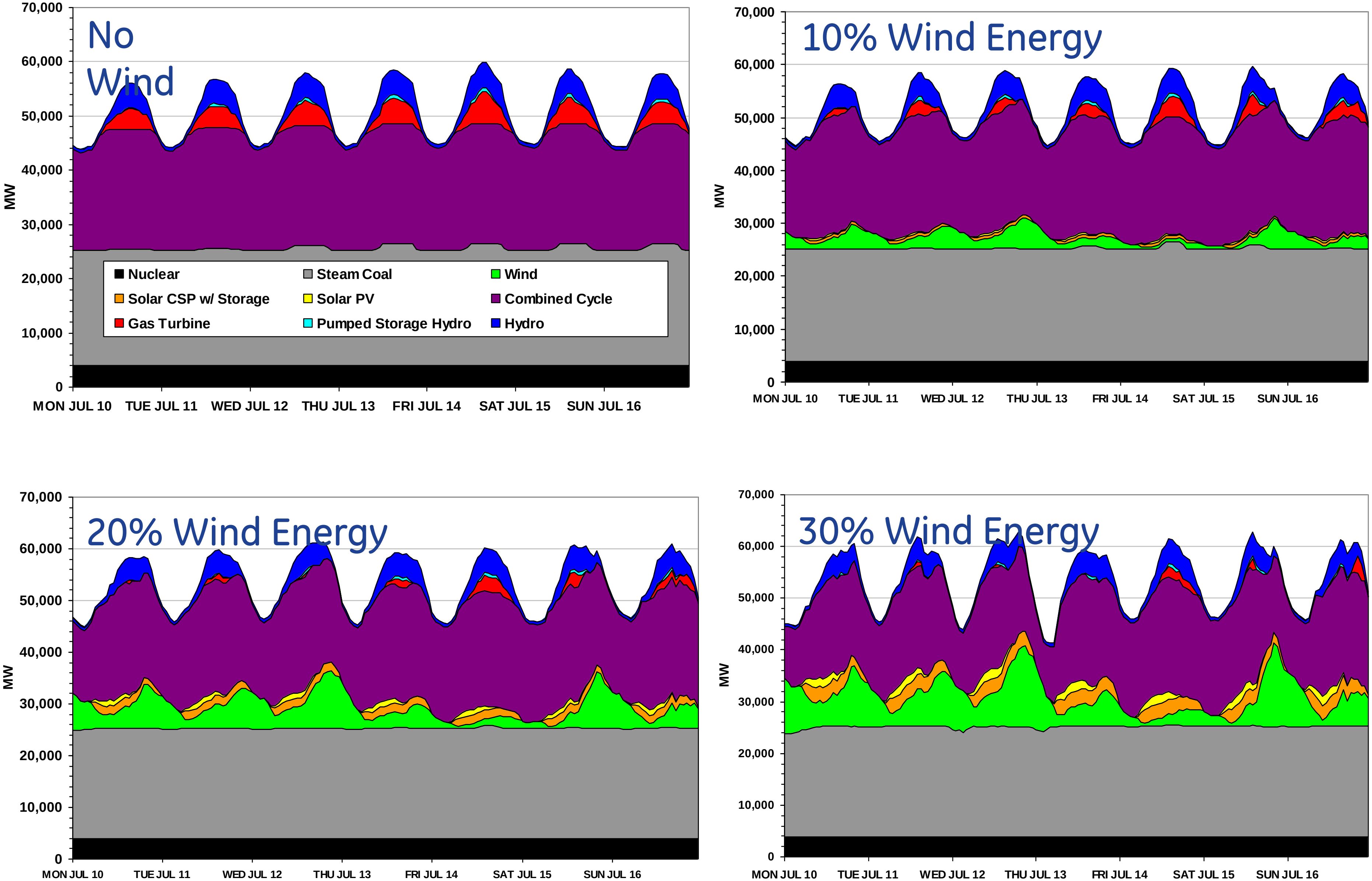
Goal: Assess the operating impacts and economics of wind and solar

- How do local resources compare to remote, higher quality resources delivered by long distance transmission?
- Can balancing area cooperation help manage variability?
- Do we need more reserves?
- Do we need more storage?
- How does geographic diversity help?
- What is the value of forecasting?

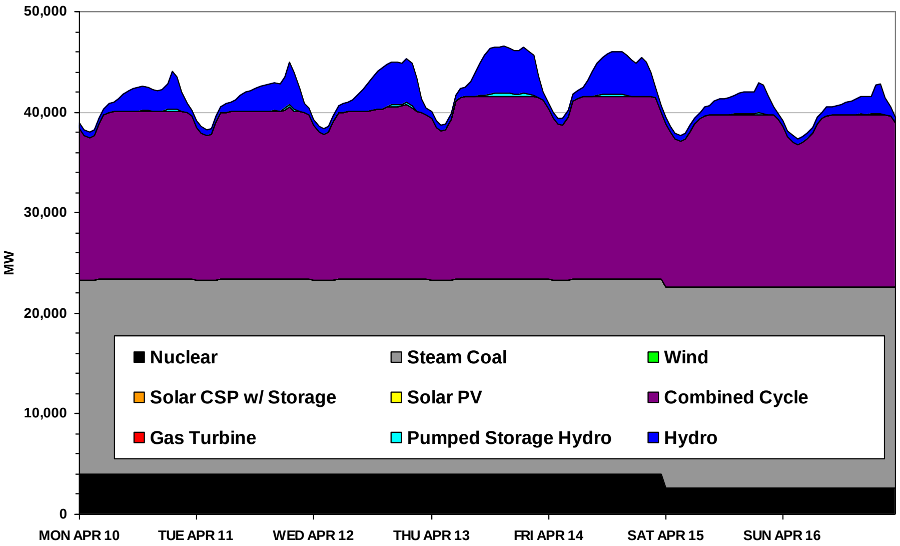


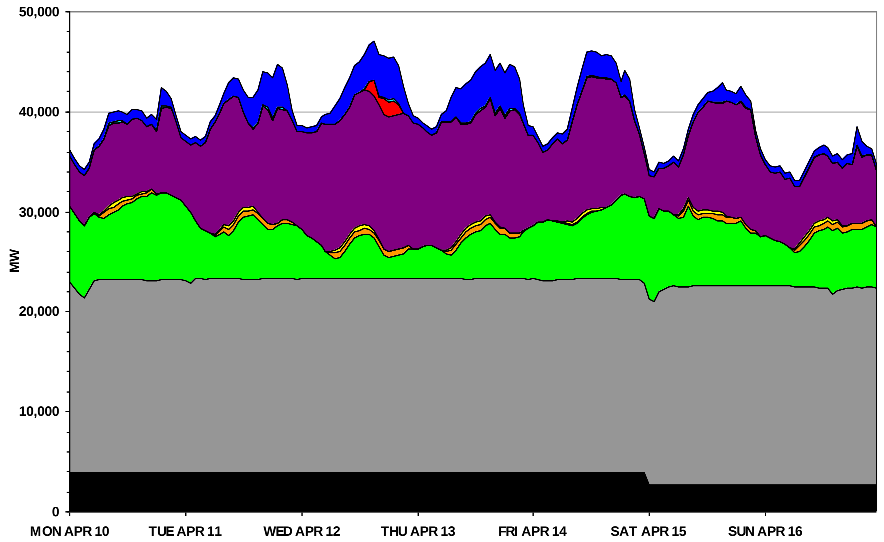
Source: NREL Western Wind & Solar Integration Study
Final report http://www.nrel.gov/docs/fy10osti/47434.pdf
Executive summary http://www.nrel.gov/docs/fy10osti/47781.pdf

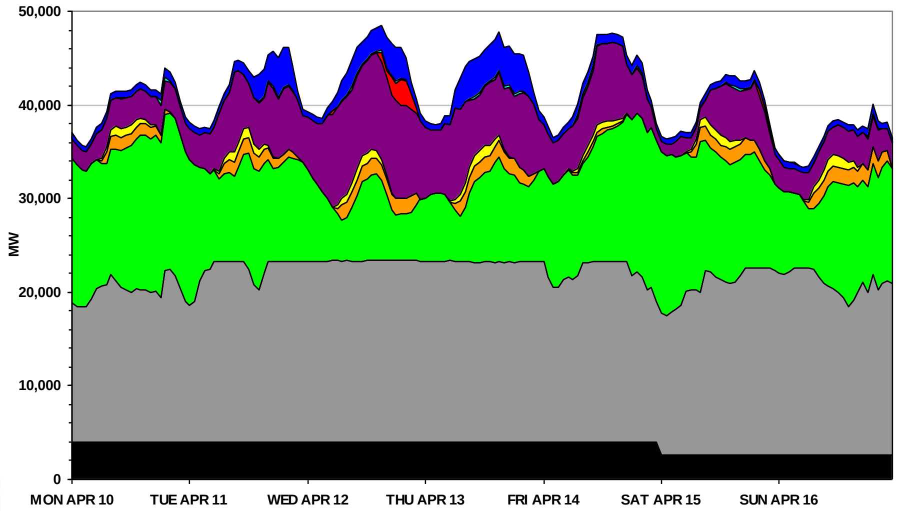
Week of July 10th *(Peak-Load Season)*

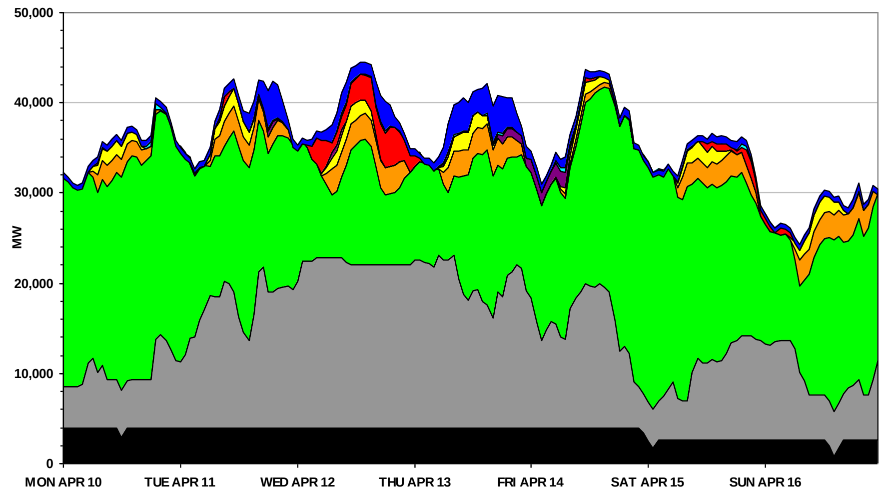


Week of April 10th *(Loads are lower, winds are higher)*









Operating Cost

- As the penetration of wind increases, the system operating cost (production cost) decreases.
- The savings is not proportional to the penetration level of wind
  - Diminishing returns with increased penetration
- Wind forecast accuracy is important to capture all operating cost savings from increased wind penetration.
  - Forecast has substantial and increasing impact as penetration level increases

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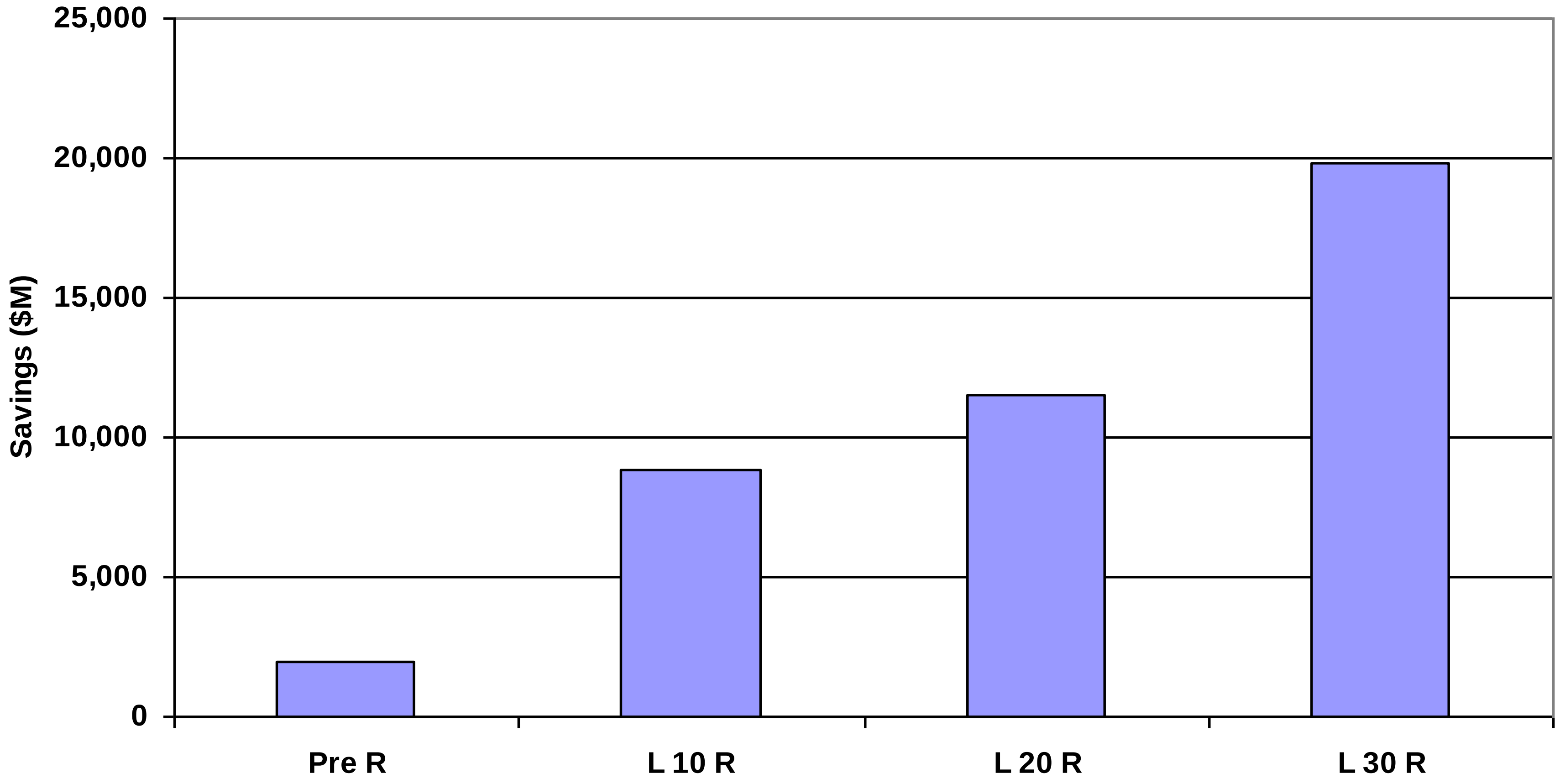
Operating Cost Savings ($M)



Locational Marginal Price (LMP)

- Wind is assumed to enter the market as a "zero cost" price taker.
  - Wind generation revenues are assumed to equal their LMP market value
- As the penetration of wind increases, the LMP decreases.
  - The highest priced hours see the largest impact.
  - With perfect forecast of wind, LMP decreases for all hours
  - With State of Art forecast, LMP may increase at times due to forecast errors

LMP is a good way to look at operational economic, even without full locational power markets

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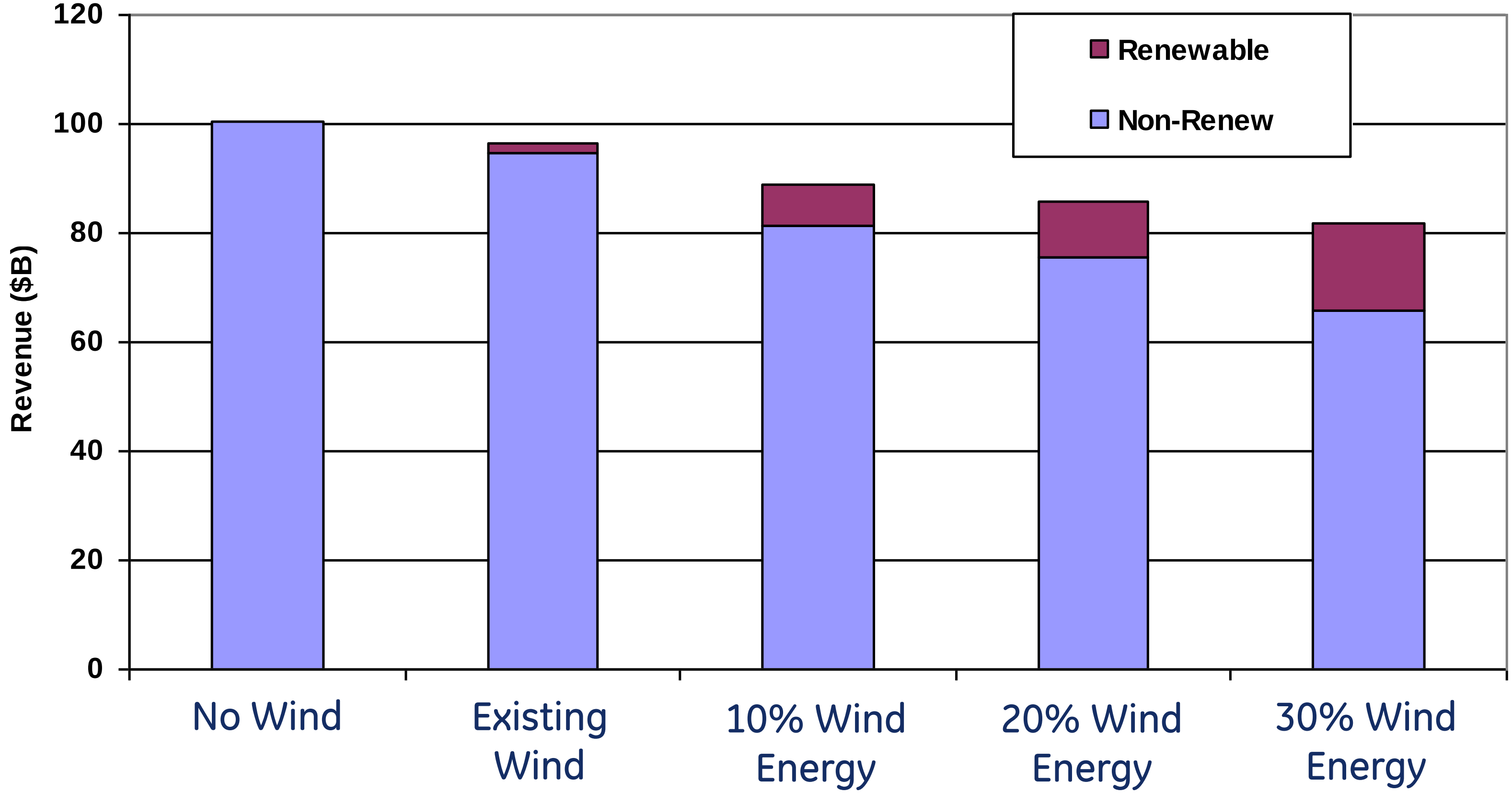
Generator Revenues for All of WECC ($B)



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Impact on other resources

Thermal (especially coal) cycling

Hydro operation

Inter-area cooperation

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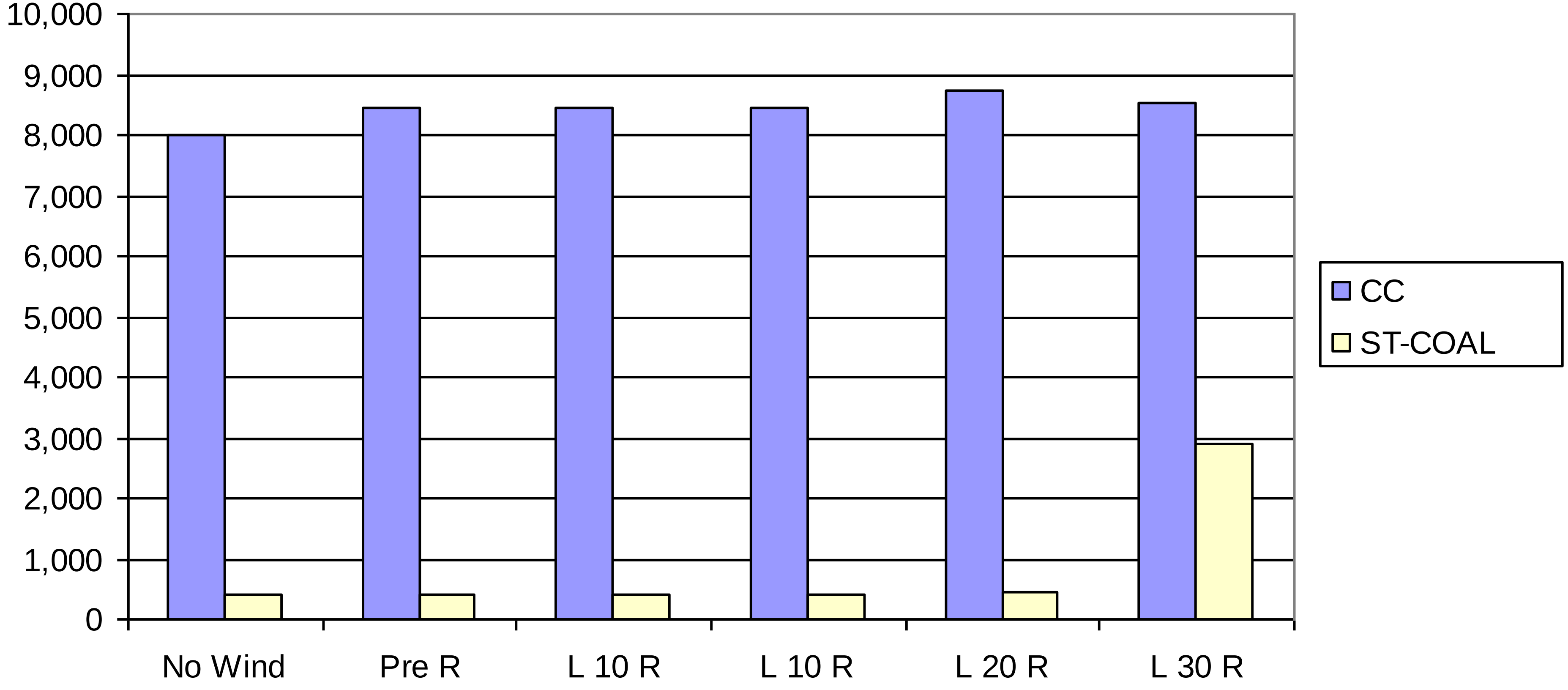
Total Number of Generator Starts for Combined Cycle and Coal Plants



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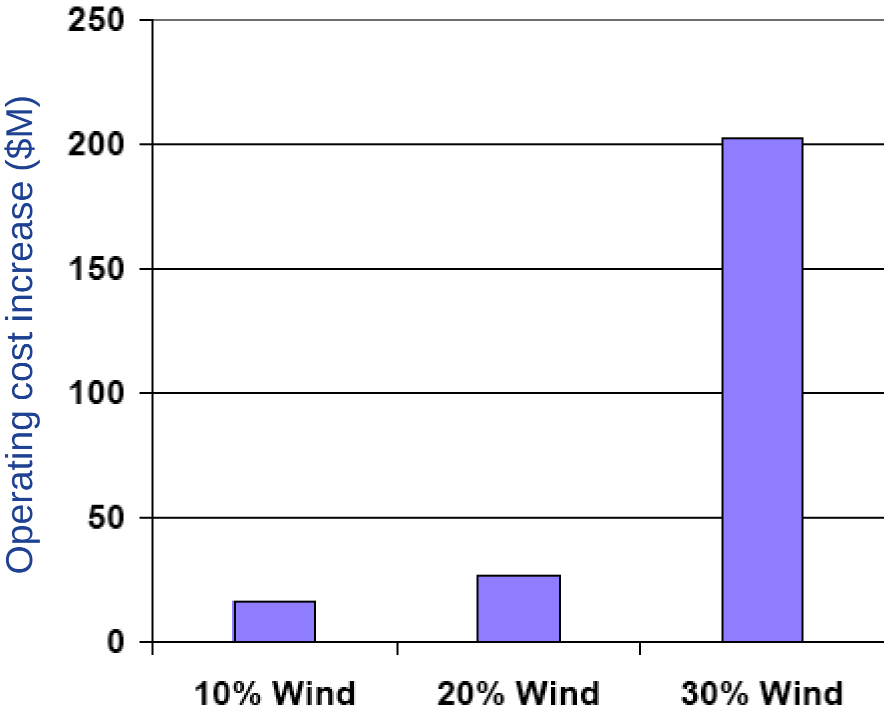
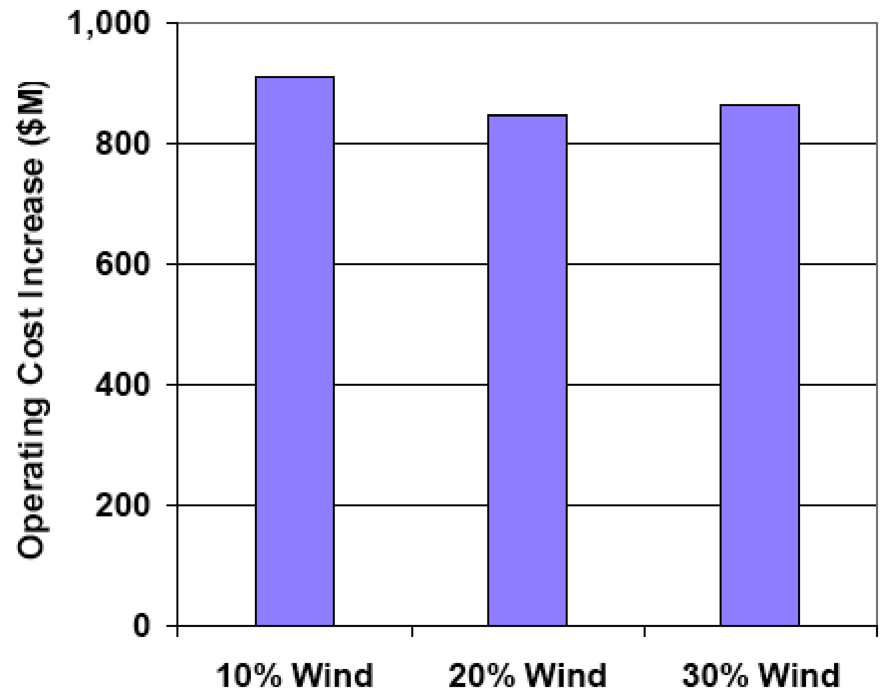
How do hydro constraints affect these results?

Cost if you dispatch hydro to load only, not net load



Cost increase if hydro output kept flat over the year



Scheduling and dispatch of hydro AFTER wind saves operating costs

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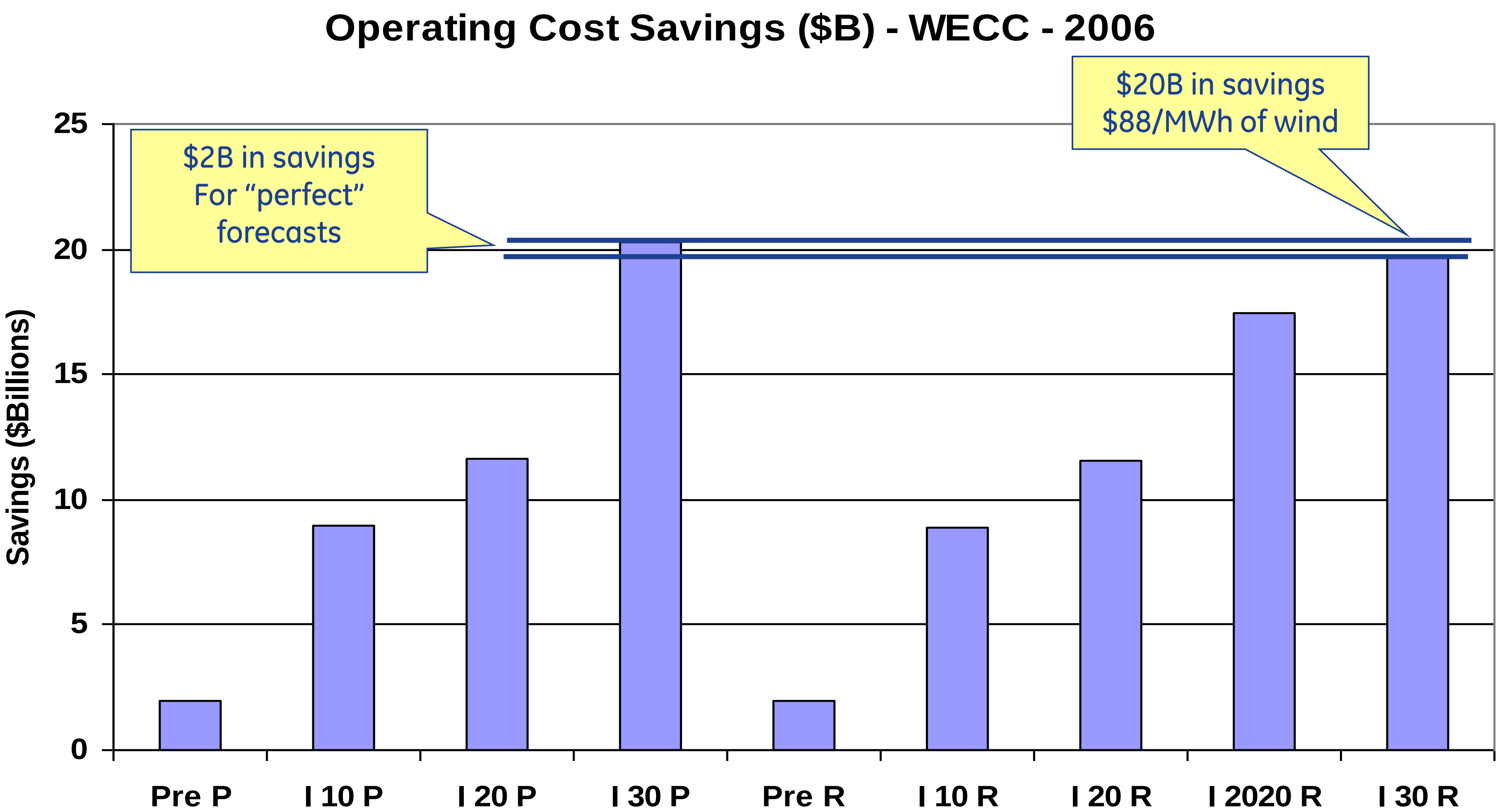
Operating Cost Savings due to Wind Forecasts



P = perfect wind forecast   R = state-of-art wind forecast

At 30% renewable energy penetration, this system CAN NOT operate without forecasts

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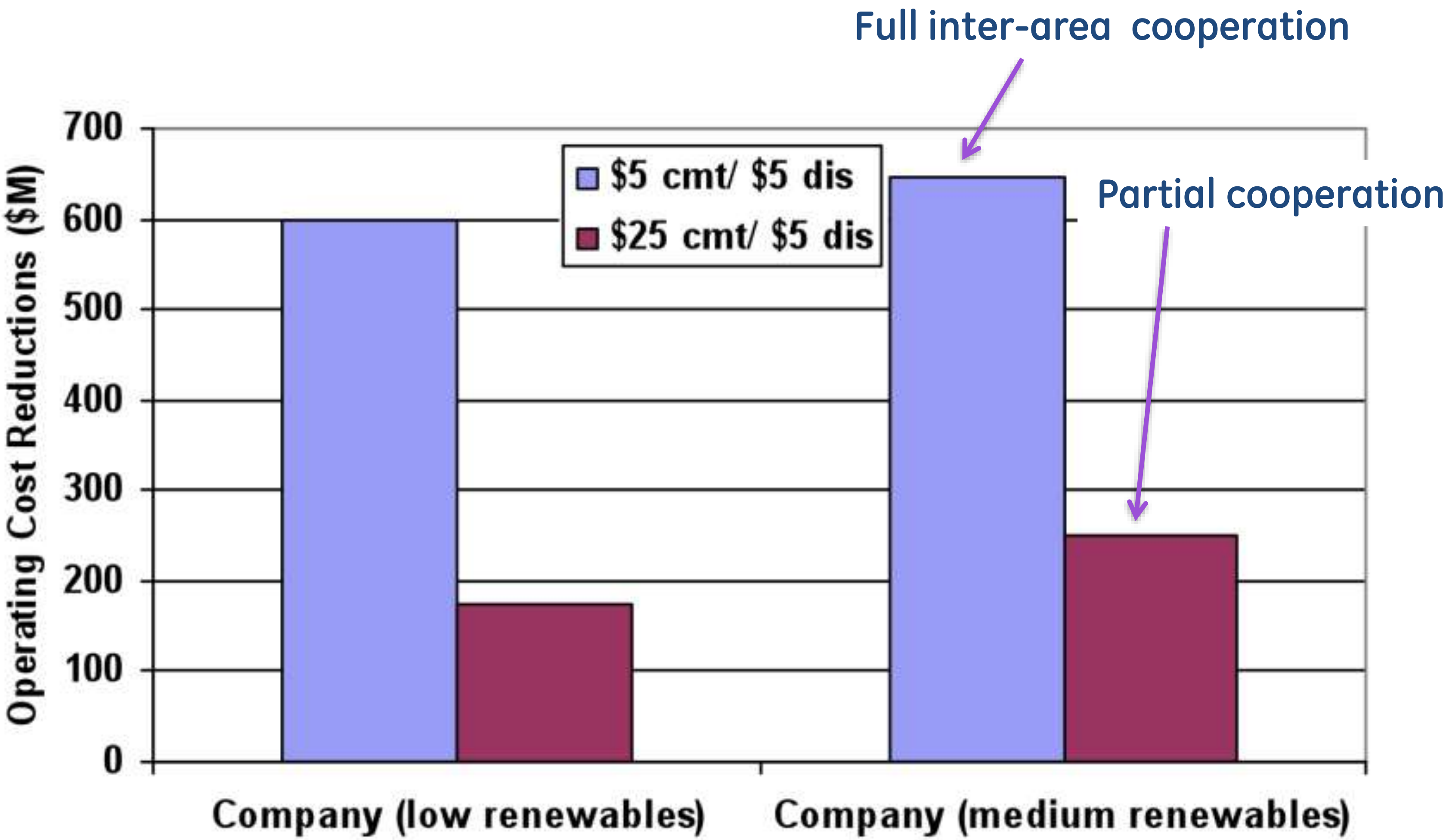
Savings from better inter-area cooperation



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Wind Curtailment is reduced by cooperation