# A Consistent Framework for Measuring Extra High Voltage Transmission Benefits and Costs

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# Introduction

- This paper describes a methodology to calculate the cost and benefits of Extra-High Voltage (“EHV”) transmission projects
- This paper *does not* describe a methodology for least-cost *simultaneous* transmission and generation planning
- We focus on EHV transmission intended to connect renewables to load centers
- CRA’s analysis of ITC’s Green Power Express *(Power Express LP, FERC Docket No.  ER09-681-000 )* follows the approach described herein

# The Need for New EHV Transmission

- New EHV transmission is needed for renewable projects, primarily wind. The highest quality onshore wind resources are in the Great Plains and the upper Midwest, which are distant from load centers
- The long-term need for renewable capacity is driven by carbon policy and/or renewable generation standards
  - Without these enabling policies only a limited amount of renewables are economic
  - The renewable additions that we have seen over the last decade have been driven by technological improvement, lower capital costs, production tax credits and state/regional renewable electricity standards

# EHV Transmission Enables Wind Development (1)

- New wind can be added in about two years, while EHV transmission, can take 10 years to receive regulatory approval and to construct
  - –The construction time for EHV transmission is not that great.  The bulk of the time is consumed in getting permits, right-of-way acquisition and public outreach
  - –Devers-Palo Verde 2 has been in planning stages for over 20 years
  - –It took AEP 16 years to build the Wyoming-Jackson's Ferry 765 kV line and 1.5 years to build
- Wind projects are almost always small (about 100 MW) relative to EHV transmission transfer capability (thousands of MW).

# EHV Transmission Enables Wind Development (2)

- EHV transmission is much less expensive than lower voltage transmission at moving large quantities of power

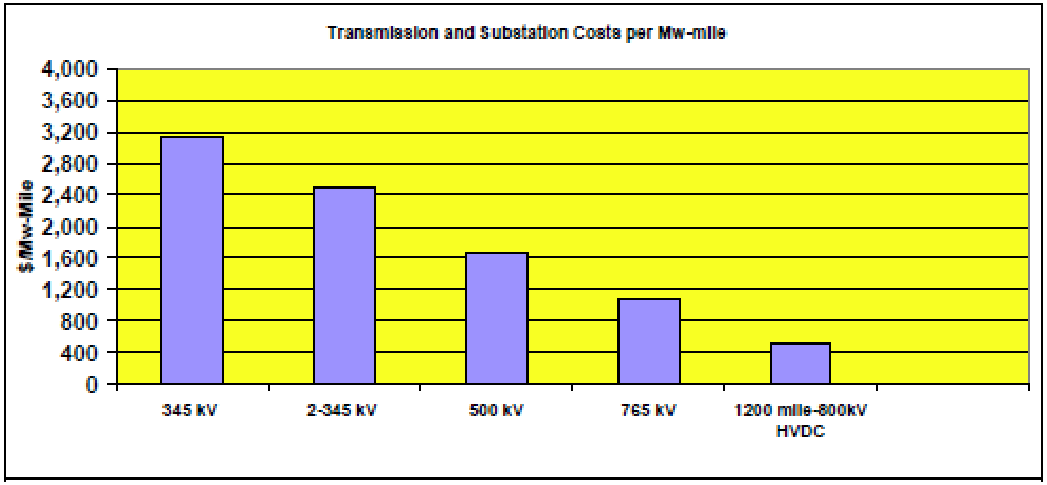



Figure A5-1: Transmission and Substation Costs per MW mile

**Source: Joint Coordinated System Plan 2008**

- The difference in lead times and the disparity in size between wind projects and EHV transmission make it important to plan EHV transmission prior to wind development

# A Careful Analysis of Generation Futures is Essential

- The challenge for EHV expansion is to support generation facilities where they best promote national policies:
  - Environmental/climate
  - Renewable electricity standards ("RES")

  while minimizing the overall cost of meeting those policy objectives
- To evaluate the benefits of a *specific* EHV project, one must take the transmission expansion as a given and consider the likely development of generation resources given the new EHV project
- In general EHV transmission will change the mix of generation resources
  - For example, EHV transmission that connects the Great Plains and the upper Midwest to eastern load centers would tap large wind resources that would be economic under a carbon policy or an RES
  - The wind would be expected to displace resources that would otherwise be added
- These changes can be complex: higher quality wind resources might replace lower quality or higher cost wind resources, additional wind might displace fossil generation or both might happen

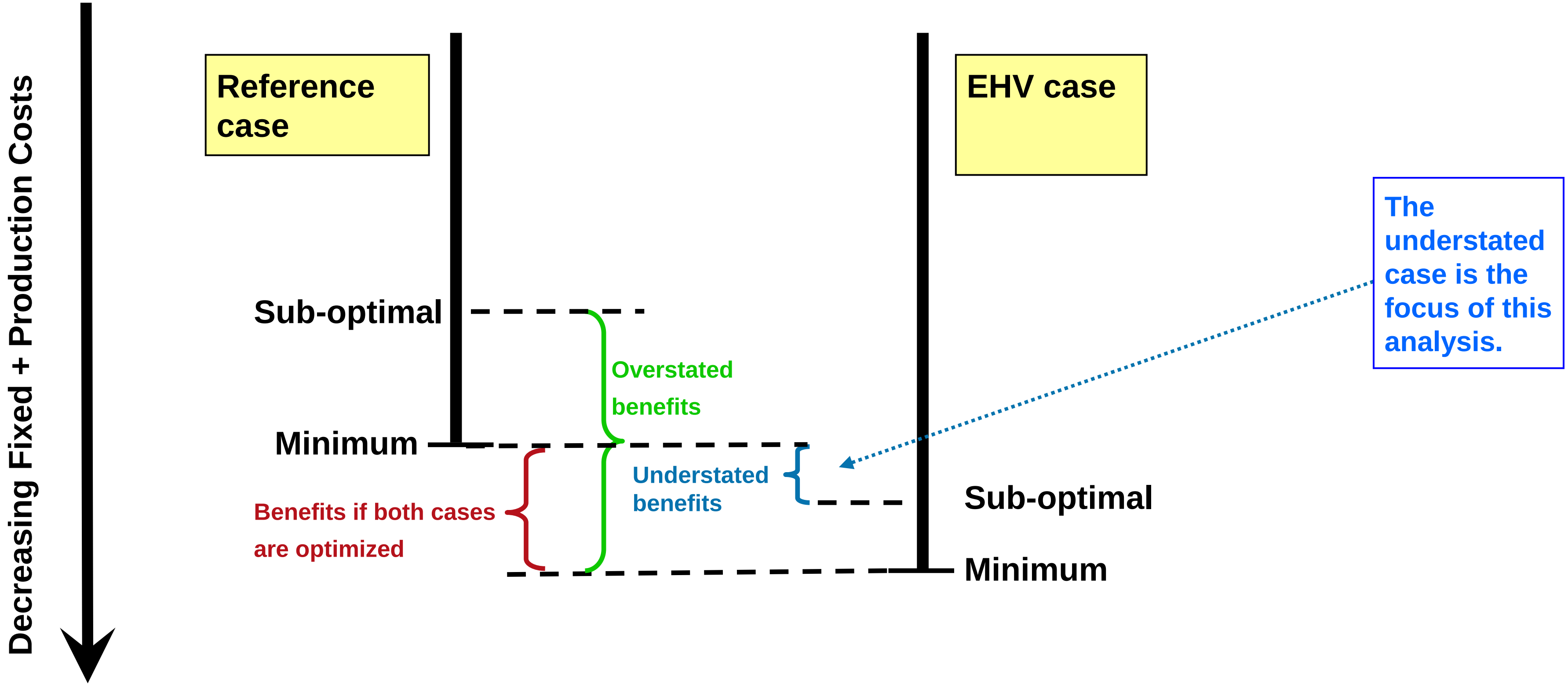
# Measuring Benefits and Costs (1)

- The proper way to evaluate an EHV expansion is to compare two cases:
  - –A Reference case (without the EHV expansion)
  - –An EHV case (with the EHV expansion)
- The generation cost for the two cases should be compared on:
  - –Adjusted production costs (or LMP changes)
  - –Generation fixed costs
- For each of the two cases, a long-term *optimal* generation expansion plan must be modeled to capture the benefits of long-lived EHV assets (at least 20-30 years of operation)
- Optimal Reference and EHV cases ensure internal consistency
- Ad hoc generation expansion plans can lead to incorrect results

# Measuring Benefits and Costs (2)

**Figure 1**

**Measuring Costs and Benefits**




**The minimized cost is lower in the EHV case than it is in the Reference case. If the Reference and EHV case expansion plans are not both optimal (e.g. least cost), generation benefits can be understated or overstated.**

# Measuring Benefits and Costs (3)

- The final step is to compare the changes in generation and fixed costs to the cost of the EHV project to calculate a benefit/cost ratio
- We do not do this in this paper since we have not estimated the cost of the EHV overlay

# The Analysis

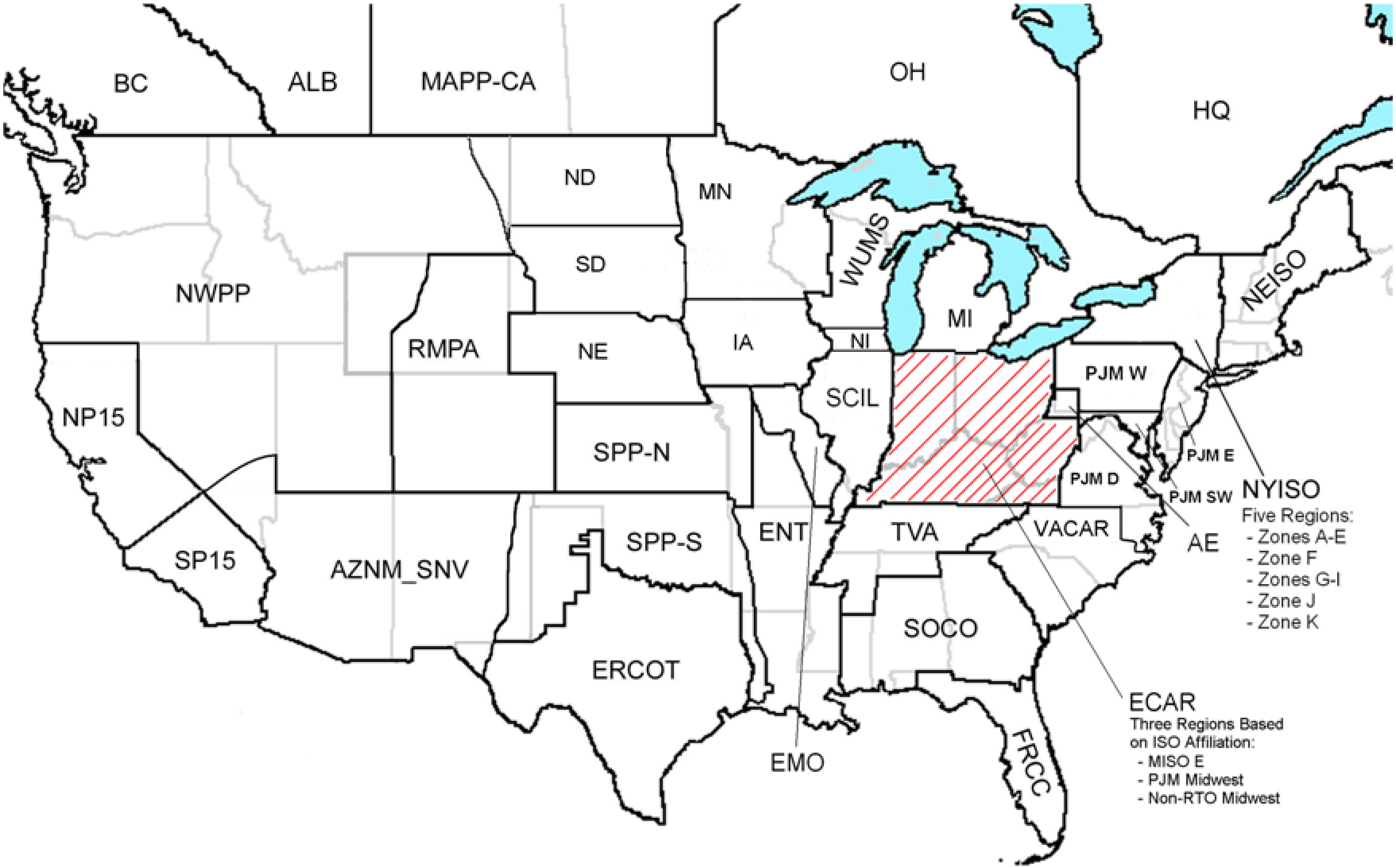
- To illustrate the principles, we developed optimized, long-term capacity plans for the Reference case and the EHV case
- To illustrate the importance of having optimized Reference and EHV case expansion plans, we analyze a third case in which the long-term capacity plan is the same as in the Reference case but we assume that the EHV case transmission is in place
  - The Reference case capacity additions are feasible with the EHV overlay, but are not optimal
  - This situation is like the “understated” example in Figure 1

# Modeling the Cases

- We used CRA's North American Electricity and Environment Model ("NEEM") for this analysis
- NEEM is a linear programming model that minimizes the present value over a 30-70 year time horizon of the cost of:
  - Constructing and maintaining new generating units
  - Installing and operating environmental retrofits
  - Maintaining existing generating units
  - Dispatching generating units

  Subject to constraints that:
  - Electricity demand is met
  - Reserve margin requirements are met
  - Environmental constraints are satisfied
  - Renewable Electricity Standards are met
  - Unit operational limits and energy limits are not exceeded
  - Limits on interregional power flows are not exceeded
  - Unit maintenance requirements are met
- We used the full NEEM data set for this analysis

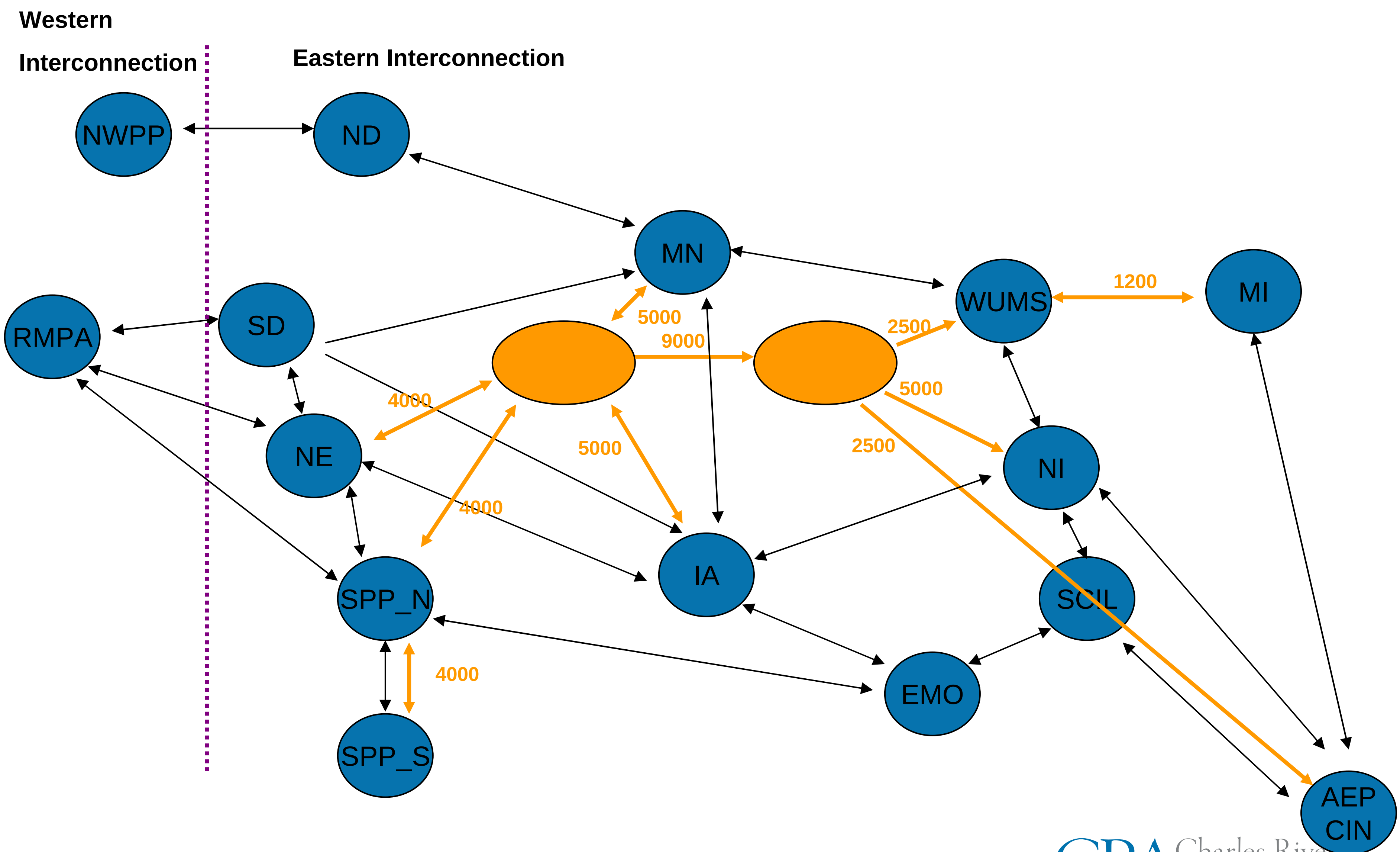
# NEEM Transmission Regions



# The EHV Overlay (1)

- For this analysis, we developed a synthetic EHV overlay that connects wind-rich regions in SPP, Minnesota and Iowa to load centers further east
- Although the overlay has elements in common with those in other studies, this overlay was developed only for the purpose of this paper
- This paper *does not* present an analysis of any proposed transmission project

# The EVH Overlay (2)

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# Major Inputs

- Natural gas:  AEO2010 early release
- Carbon policies:  $20/MTCO2 in 2013, rising at 5% real per year
- National Renewable Electricity Standard:  12% of US demand from 2020 on
  - Begins in 2013 at 3%
  - Has a $50/MWh (2009$) alternative compliance payment
- Region/State RPS modeled
- Eastern Interconnect load shape data:  2006 hourly load data
- Demand:  2008 FERC 714 load forecasts in eastern interconnect, except for PJM, NYISO and ISONE which use RTO projections.
  - Demand has been adjusted downward to account for customer response to higher electricity prices due to the carbon policy
  - Regional demand reductions were estimated using CRA's MRN-NEEM macro/bottoms-up modeling system

# Wind Data (1)

- 2006 NREL EWITS data are used for wind output patterns in the eastern interconnect
- 2004-2006 NREL EWITS capacity factors were applied to 2006 wind patterns
- Eastern offshore sites are characterized using the same approach as eastern onshore sites
- Western onshore sites were sampled within each NEEM region from the Western Wind and Solar Integration Study


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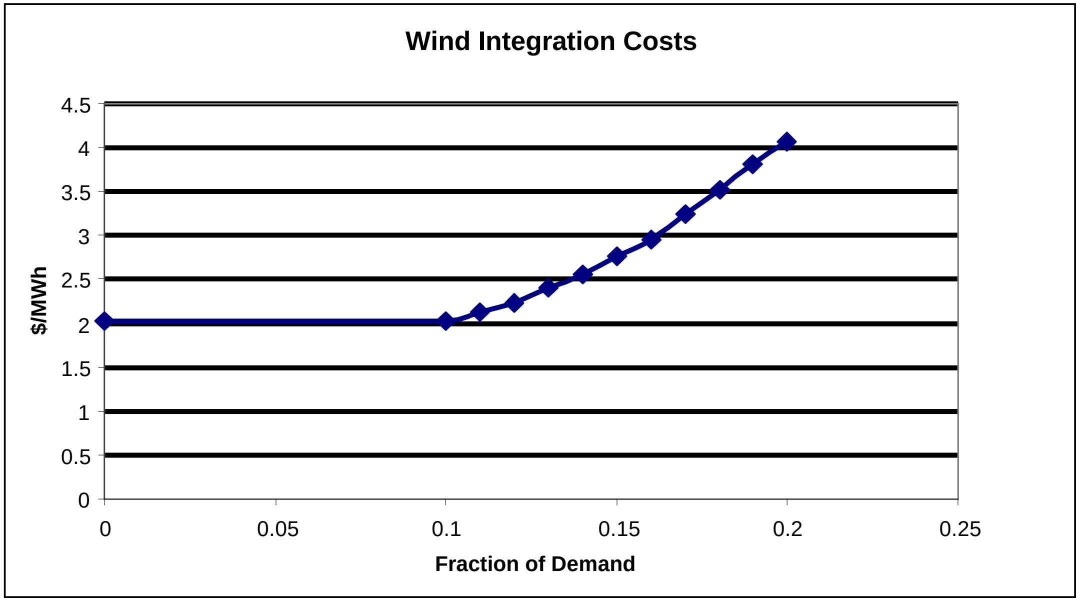
# Wind Data (2)

| NEEM Transmission Region | Maximum Capacity Factor | Capacity Credit |
|---|---|---|
| SCIL, NI | 35% - 36% | 13-15% (13% in PJM / NI) |
| IA | 38% - 39% | 15% |
| SPP-N and SPP-S | 39% | 6% |
| ISO-NE (Onshore / Offshore) | 22% - 34% / 35% - 46% | 15% / 20% |
| MI (Onshore / Offshore) | 31% / 36% | 15% / 20% |
| MN | 38% - 41% | 15% |
| ND | 40% | 15% |
| NE | 41% | 6% (SPP) |
| SD | 40% | 15% |
| WUMS | 33% | 15% |
| AE | 27% | 13% |
| ECAR | 32% | 13-15% (13% in PJM) |
| ENT | 34% | 15% |
| NP15 and SP15 | 30% | 25% |
| NWPP | 26% | 15% |
| ERCOT | 33% | NA |
| NYISO | 33% - 34% | 10% |
| PJM-Classic (Onshore / Offshore) | 23% - 29% / 37% - 41% | 13% / 20% |

**We did not alter the capacity credit of the wind between the Reference and EHV cases.**

# Intermittent Penetration Limits & Integration Costs (1)

- Wind integration costs are incremental costs associated with frequency regulation, spinning reserves, load following, and unit commitment required to accommodate wind energy
- For this analysis we modeled each region having a maximum of 20% variable energy as part of the resources that meet load
- We assumed an increasing cost for integrating variable generation (wind, solar) starting at $2.00/MWh for up to 10% and rising to $4.15/MWh at 20% (2009$)
- These are the average costs per MWh of variable generation for a given level of penetration.



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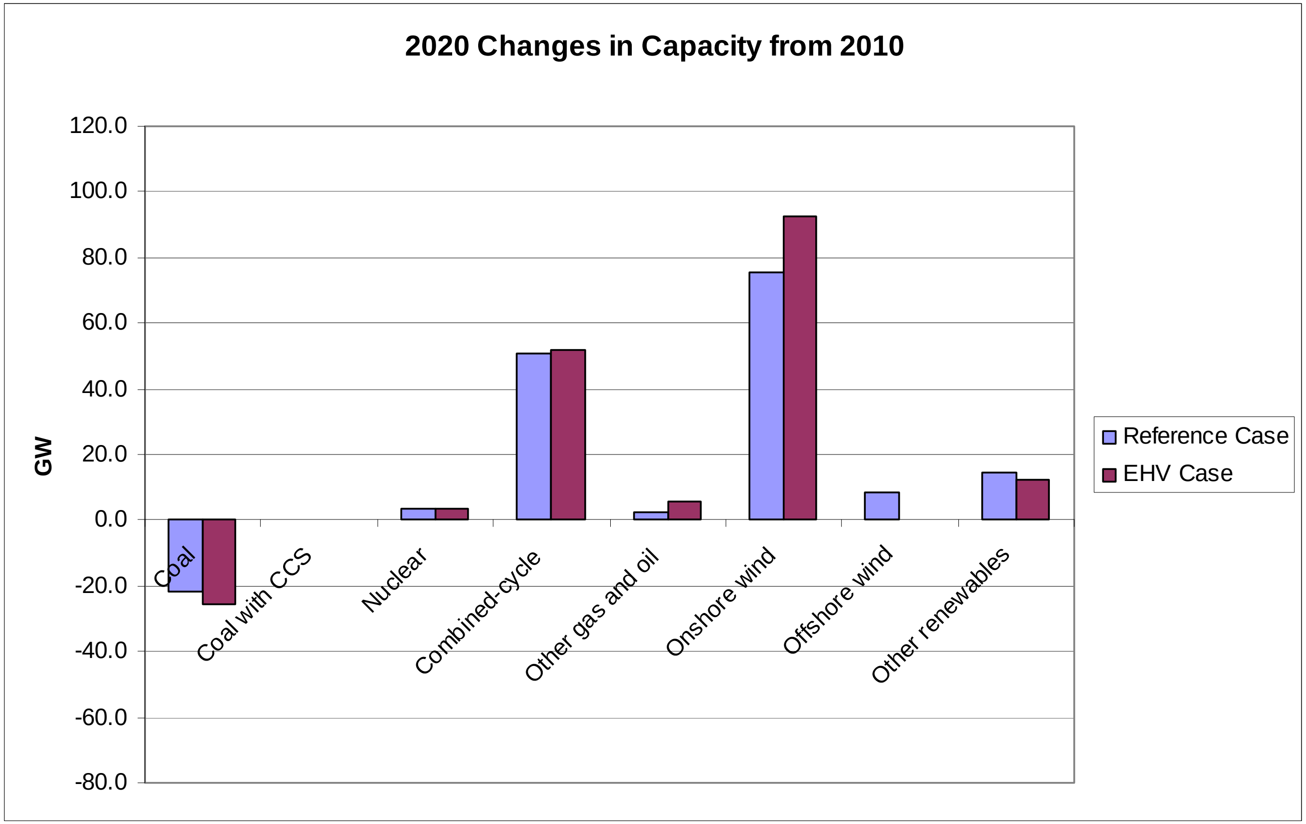
# Intermittent Penetration Limits & Integration Costs (2)

- We developed the cost curve from studies performed for XCEL, We Energies, PacifiCorp and MISO (see *20% Wind by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply,* US DOE 2008, Table 4.1)
- The effect of the EHV overlay is to expand the effective balancing area for wind integration
- This allows more wind to be built at a lower cost of wind integration

# Key Outputs

- Mix and timing of new capacity additions
- Dispatch of generation units to meet demand
- Interregional transfers of energy
- Retrofits of existing generation units with pollution control equipment
- Retirement or continued operation of existing units
- Fuel switching between types/grades of coal
- Emission allowance sales, purchases, and banking
- Scheduling of maintenance for generation units

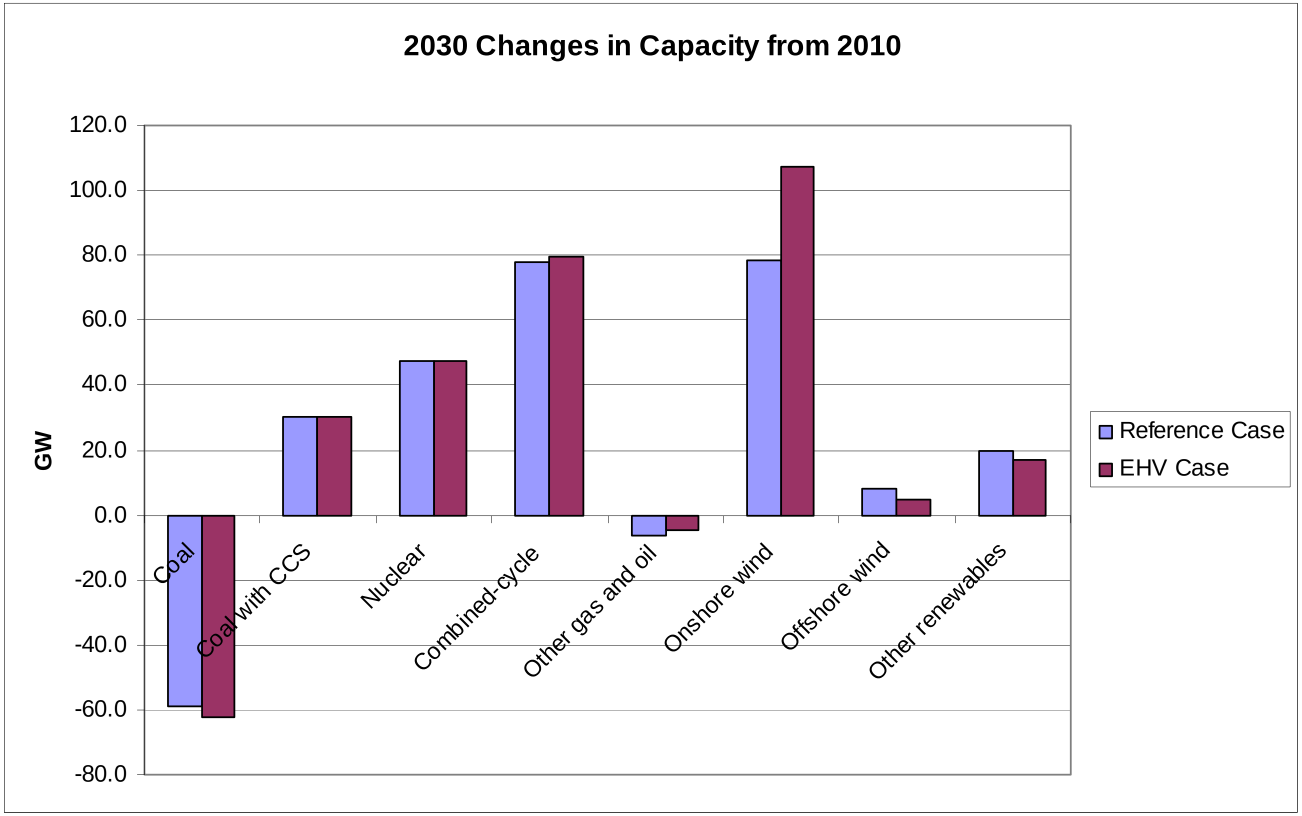
# Results – US 2020 Capacity




**Note: Coal consists of 16 GW of planned additions followed by model-selected retirements**

**By 2020, the EHV overlay supports 17 GW of additional onshore wind, displacing 8 GW of offshore wind and 2 GW of other renewables (relative to the Reference case).**

# Results – US 2030 Capacity




**Note: Coal consists of 16 GW of planned additions followed by model-selected retirements**

**By 2030, the EHV overlay supports 29 GW of additional onshore wind, displacing only 3 GW of offshore wind and 2.5 GW of other renewables (relative to the Reference case). By 2030, the EHV overlay allows substantially more U.S. renewables generation than Reference case transmission.**

# Annual US Generation Benefits & Costs – EHV

**Benefits of EHV Overlay (2009$, Millions)**

| | Adjusted Production Cost Savings (2009$) | Generation Fixed Cost Increases (2009$) | Wind Integration Cost Increases (2009$) | Total Benefits (2009$) |
|---|---|---|---|---|
| 2020 | $ 2,125 | $ (2,716) | $ 188 | $ 4,653 |
| 2025 | $ 1,652 | $ (3,838) | $ 161 | $ 5,329 |
| 2030 | $ 6,591 | $ 2,905 | $ 381 | $ 3,305 |

- The EHV overlay reduces production cost in all years and generation fixed cost in 2020 and 2025 when lower capital cost renewable resources are used to meet the US RES requirement
- In 2030 in the EHV case, renewables become economic without the RES requirement because the carbon price has risen to a level that renewables are added to replace coal-fired generation
- Wind integration costs increase since the volume of wind increases sharply compared with the Reference case
- The wind capacity credit likely would be higher with the EHV network. In addition, the EHV overlay provides reliability benefits (reducing the need for reserve capacity). We have not addressed these benefits here.

# Annual US Generation Benefits & Costs – EHV with Reference Case Additions

**Benefits of EHV Overlay if Builds are Restricted to Reference Case (2009$, Millions)**

| | Adjusted Production Cost Savings (2009$) | Generation Fixed Cost Increases (2009$) | Wind Integration Cost Increases (2009$) | Total Benefits (2009$) |
|---|---|---|---|---|
| 2020 | $ 170 | $ - | $ (94) | $ 272 |
| 2025 | $ 61 | $ - | $ (90) | $ 147 |
| 2030 | $ 90 | $ - | $ (76) | $ 161 |

- Keeping Reference case additions fixed and adding the EHV overlay, reduces production cost only modestly
  - This is not surprising since the capacity mix is the same in both cases
- Wind integration costs are lower with the large balancing area (the level of renewables is the same in the reference and restricted build cases)

# Conclusions (1)

- In this paper we have outlined a framework for evaluating the generation benefits of an EHV transmission expansion and illustrated the principles with a synthetic EHV overlay using the full NEEM model
- The results demonstrate that with optimized resource plans for the Reference and the EHV cases overlay benefits are significant, but when the resource plan is assumed not to change in response to the presence of the EHV transmission, generation benefits are small and understated. This is the primary conclusion of our analysis
- On the other hand, if we performed the evaluation with the EHV case and compared that with the Reference case using a sub-optimal expansion plan (e.g., the expansion plan from the EHV case), we would expect to find larger but overstated benefits (please see Figure 1). Here, the Reference case would be burdened with generation capital that the transmission system could not adequately utilize – windpower would be wasted and wind integration costs would be high
- Although the results presented here are for the US, regional analysis can also be done

# Conclusions (2)

- At a regional level, cost allocation issues arise:
  - For purpose of calculating generation costs and benefits (but not to allocate the cost of the EHV transmission), how should one split costs and benefits between the regions that have the wind resources and the consuming regions?
  - If net benefits are positive, are they distributed widely enough to socialize most of the cost of the EHV transmission?
- One possible approach for splitting generation costs and benefits is to assume that load serving entities ("LSEs") contract for the output of new wind farms
- Under the contracts between the LSE's (consumers) and the new wind generators (producers), one might assume that there will be a 50/50 economic sharing of the net margins of the new wind farms
- Of course, the market would ultimately determine how generation costs and benefits are allocated

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