NREL
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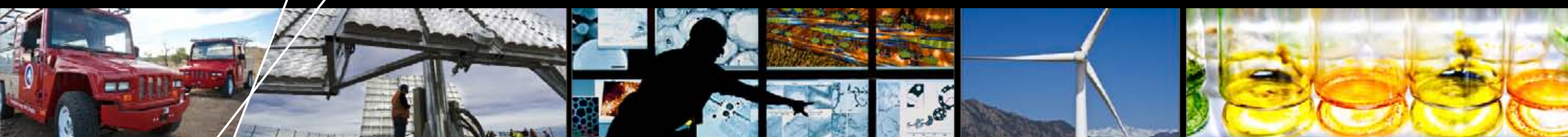
A Reliability-Based Assessment of Transmission Impacts in Systems With Wind Energy



AWEA WINDPOWER 2012: Expanding the Science Behind Wind Integration

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Building transmission can reduce the need for generation.

We describe a LOLE model to demonstrate the ability of new transmission to offset needed generation.

Generation cost is much larger than transmission (but transmission is hard to build because of institutional impediments).

Outline

- **Objective**
- **Modeling tool**
- **Application to the U.S. Western Interconnection**

Objective

- **Develop tool that allows comparison of alternative reliability metrics**
  - Expand analysis of sliding window (Milligan, 2001) with multiyear data
- **Further analysis of results from the *Eastern Wind Integration and Transmission Study* that show the capacity value of transmission**
- **Implication: Building transmission can reduce the need for generation and, therefore, improve resource adequacy**

Tool: REPRA

- **Renewable Energy Probabilistic Resource Assessment tool (REPRA)**
- **Tool objectives**
    - o Include variable generation in traditional probabilistic-based methods
    - o Allow comparison of alternative targets, metrics (LOLE, ENS, LOLH, etc.)
- **First use: Assess the effect of transmission on resource adequacy**

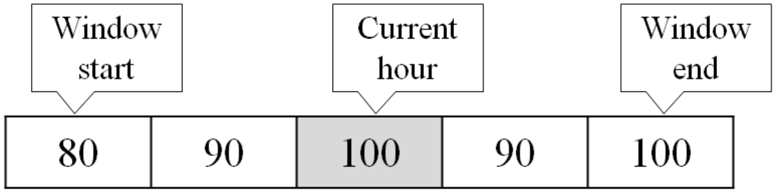
REPRA – Conventional Generators

- **A convolution is performed for conventional generations.**
- **For example, six 50-MW units with 8% EFOR result in the following convolution table.**

MW-OUT	MW-IN	Probability	LOLP
0	300	0.6064	1.0000
50	250	0.3164	0.3936
100	200	0.0688	0.0773
150	150	0.0080	0.0085
200	100	5.20E-04	5.38E-04
250	50	1.81E-05	1.84E-05
300	0	2.62E-07	2.62E-07

REPRA – Renewables

- **Renewables are represented using a sliding window approach.**



100 MW with probability 2/5
90 MW with probability 2/5
80 MW with probability 1/5

MW-OUT	MW-IN	Probability	LOLP
0	100	0.4	1.0
10	90	0.4	0.6
20	80	0.2	0.2

REPRA – Combining Both

MW-OUT	MW-IN	Probability	LOLP
0	300	0.6064	1.0000
50	250	0.3164	0.3936
100	200	0.0688	0.0773
150	150	0.0080	0.0085
200	100	5.20E-04	5.38E-04
250	50	1.81E-05	1.84E-05
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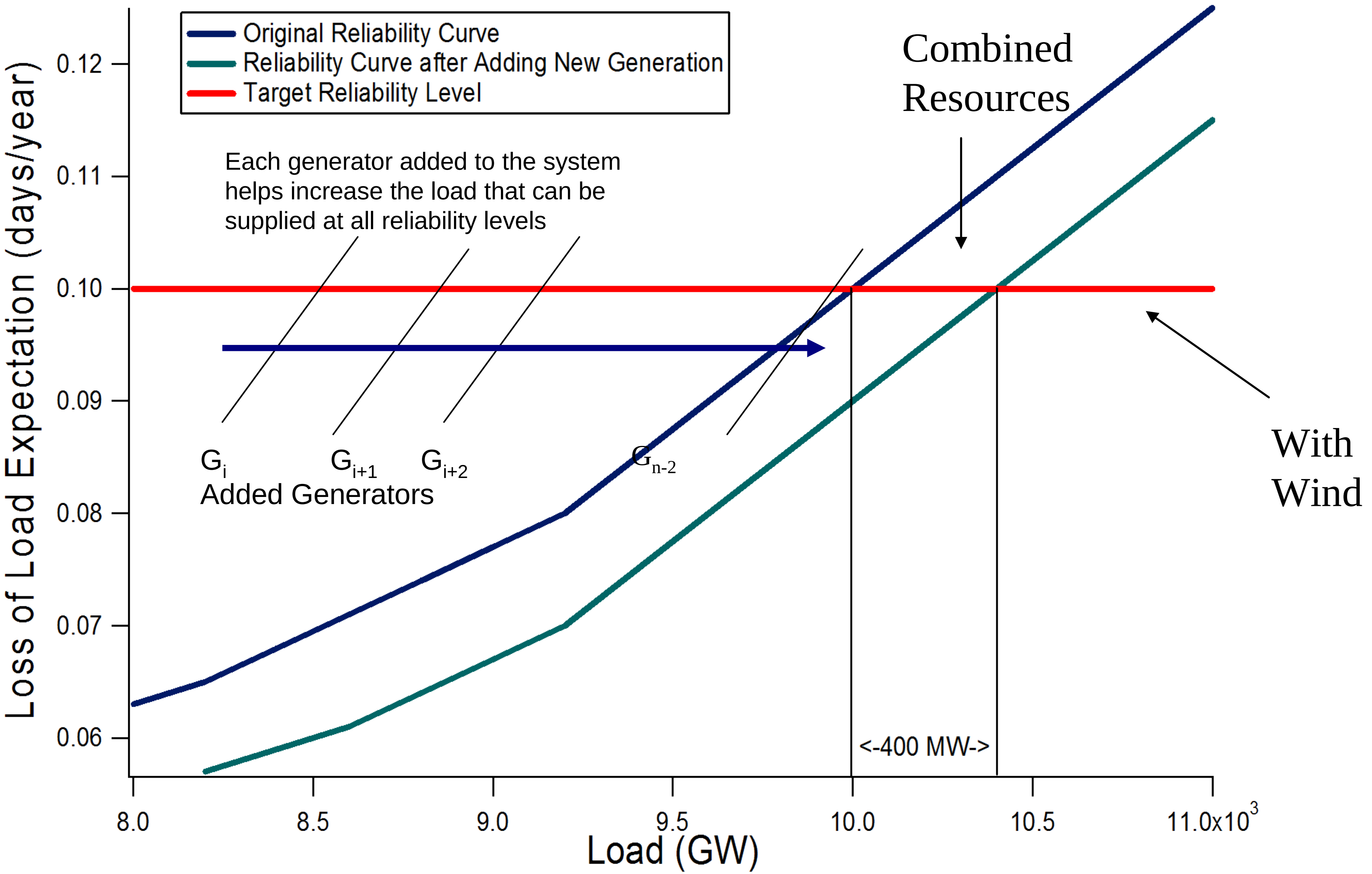
MW-OUT	MW-IN	Probability	LOLP
0	100	0.4	1.0
10	90	0.4	0.6
20	80	0.2	0.2

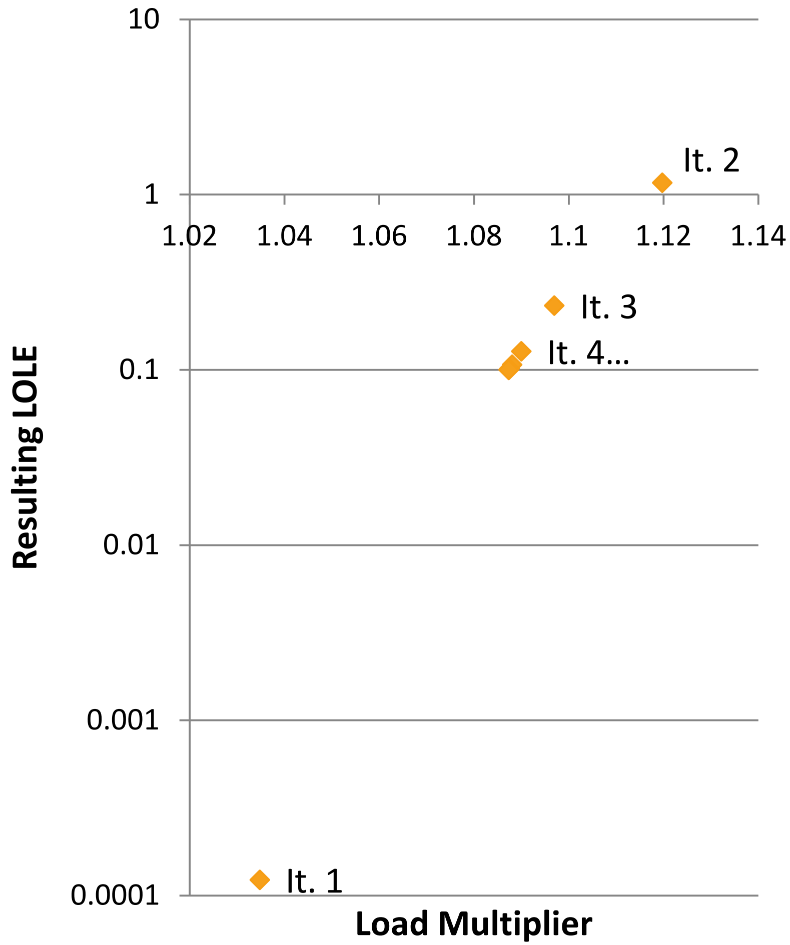
MW-OUT	MW-IN	Probability	LOLP
0	400	0.243	1.000
10	390	0.243	0.757
20	380	0.121	0.515
50	350	0.127	0.394
60	340	0.127	0.267
70	330	0.0633	0.141
100	300	0.0275	0.077
110	290	0.0275	0.050
120	280	0.0138	0.022
150	250	0.0032	0.008
160	240	0.0032	0.005
170	230	0.0016	0.002

ELCC: Measure Contribution of Generator to Resource Adequacy



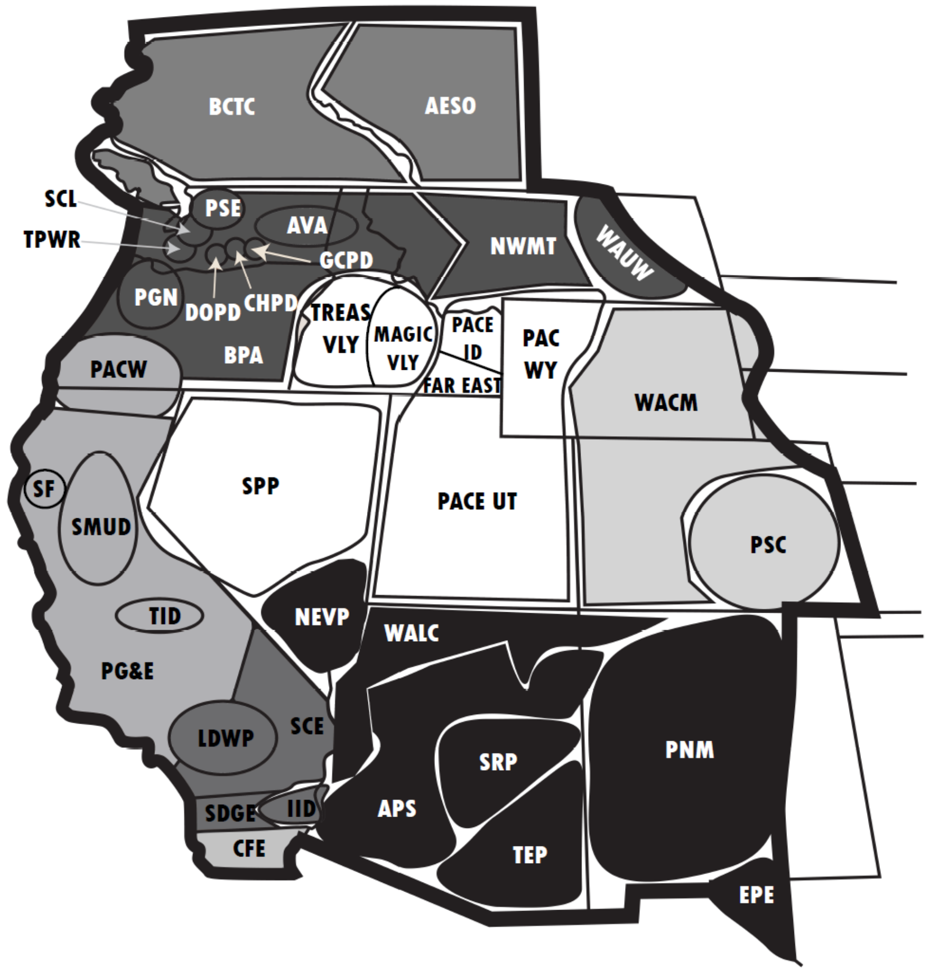
Area Reliability

- **To calculate the ELCC in an area, load is scaled to meet a predefined criteria.**
  - E.g., 1 day/10 yrs LOLE
  - We will explore other values and metrics
- **Example, interpolation steps to reach 1d/10y for the Western Electricity Coordinating Council**



Approx. Transmission ELCC

- **LOLE is calculated for**
  - The entire system
  - Subregions (Eight shaded areas)
  - Individual balancing authority areas (38).
- **One can then compare the LOLE for different levels of aggregation.**
- **Differences are the ELCC of a perfect transmission system.**

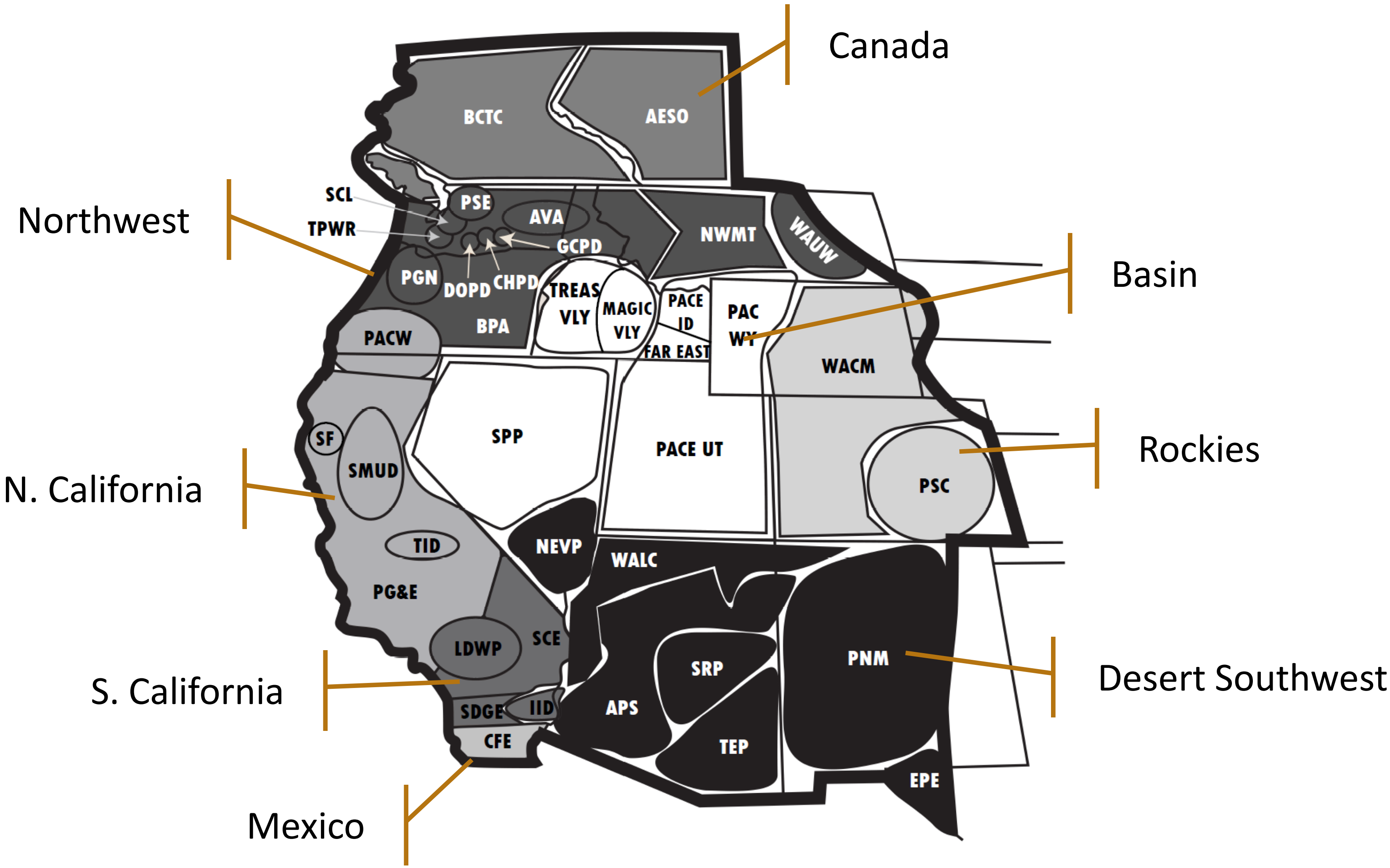


Numerical Example

- **The tool is applied to NREL's *Western Wind and Solar Integration Study* (WWSIS) Phase 2.**
  - Three 33%-penetration scenarios plus reference

Case Name	Wind Penetration	Solar Penetration
Reference	8%	3%
High Wind	25%	8%
High Mix	16.5%	16.5%
High Solar	8%	25%

Numerical Example: Subregions



Example: Transmission ELCC

- **Max peak load (GW) served for each case**

	Reference	High Wind	High Mix	High Solar
Interconnection	240.6	256.5	263.3	260.7
Subregion	228.9	239.6	239.7	236.6
BAA	206.2	213.1	213.3	212.1

- **The difference between levels of aggregation correspond to ELCC of perfect transmission**

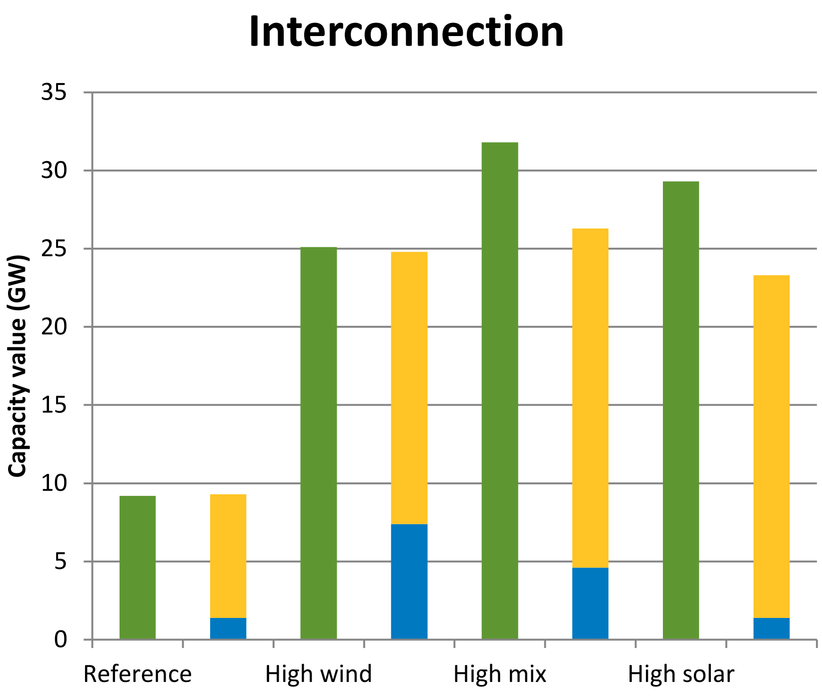
	Reference	High Wind	High Mix	High Solar
Interconnection	34.4 (17%)	43.5 (20%)	49.9 (23%)	48.6 (22.9%)
Subregion	22.6 (11%)	26.6 (13%)	26.4 (12%)	24.4 (12%)

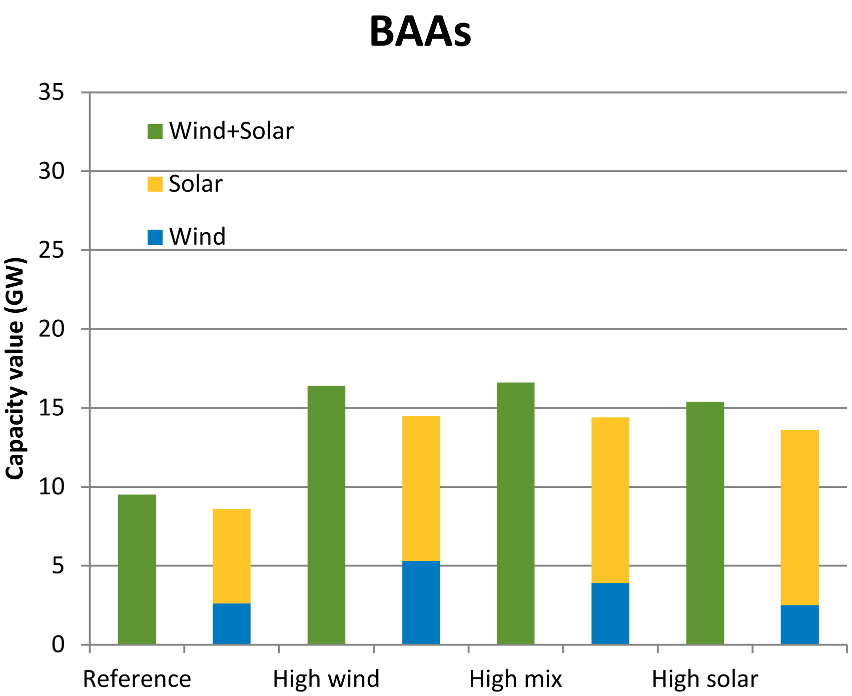
Implications

- **Perfect transmission in the West could support about 35–50 GW of load growth with no need for additional generation.**
- **Alternatively, approximately 35–50 GW of generation are not needed to meet resource adequacy requirements with perfect transmission.**
- **This is an upper bound because perfect transmission is unattainable, but it provides insight and suggests further work to refine analysis with transmission data.**

Example: Variable Generation Capacity Value

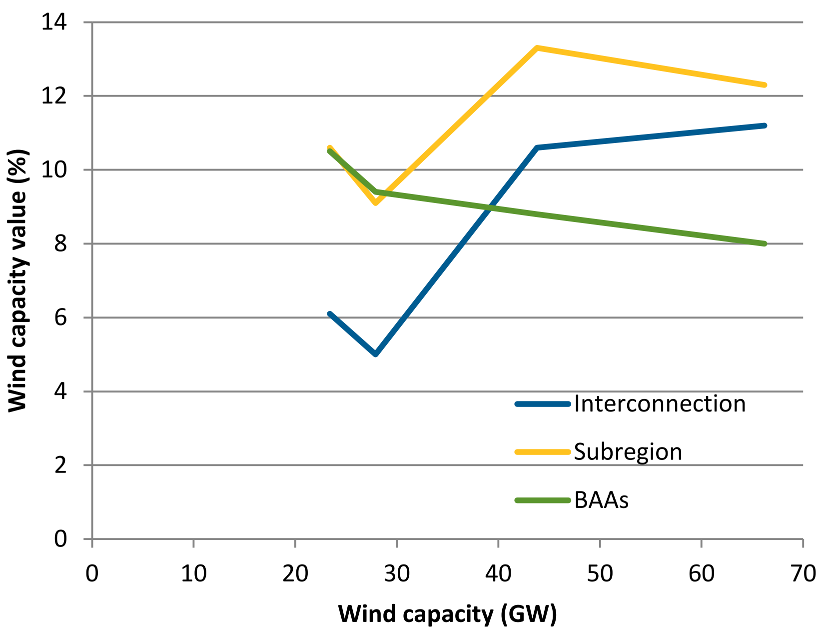
- **We can compare the contribution of renewables combined and independently.**
  - Generally, capacity value increases with additional transmission.

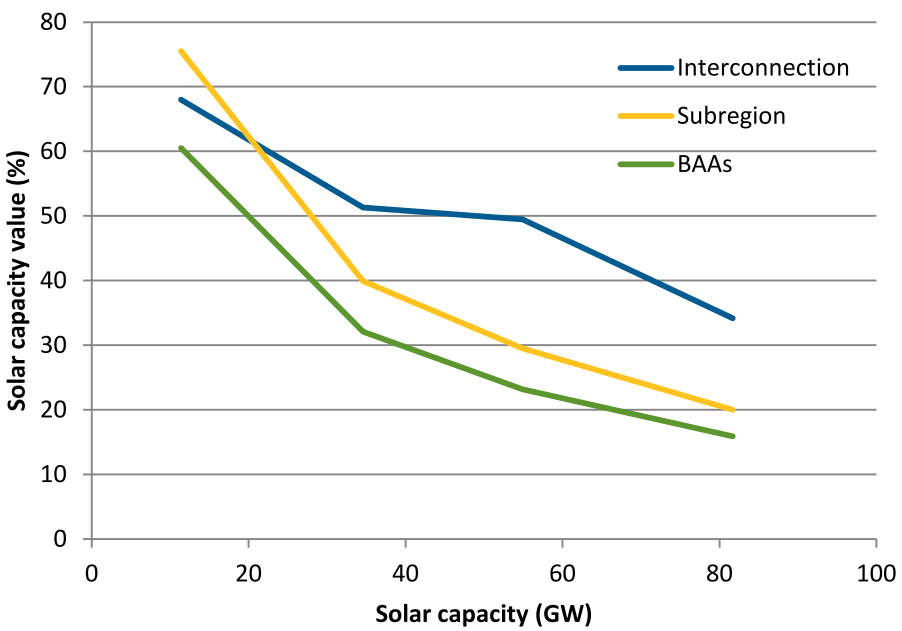




Example: Variable Generation Capacity Value

- **Relative capacity value presents complex behavior.**
  - Very sensitive to location and quality of resource, correlation to load, etc.





Conclusions

- Transmission build-out can reduce the need for additional generation.
- Result appears to be significant in the West.
- Additional work is needed to better quantify feasible transmission solutions.
- Synergies present between wind and solar resources when calculating capacity value.
- Data for more years are necessary to analyze trends.

Next Steps

- **More information:**
  - Ibanez, Milligan “Impact of Transmission on Resource Adequacy in Systems with Wind and Solar Power” http://www.nrel.gov/docs/fy12osti/53482.pdf
  - Paper expanding this presentation
- **Better representation of actual limits of the transmission system**
- **Compare benefits of adding new transmission versus adding new generation**
- **Impact on variable generation**
- **Study robustness of different metrics**