

Representing Wind and Solar Energy in GCAM: Current Issues

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August 4, 2010

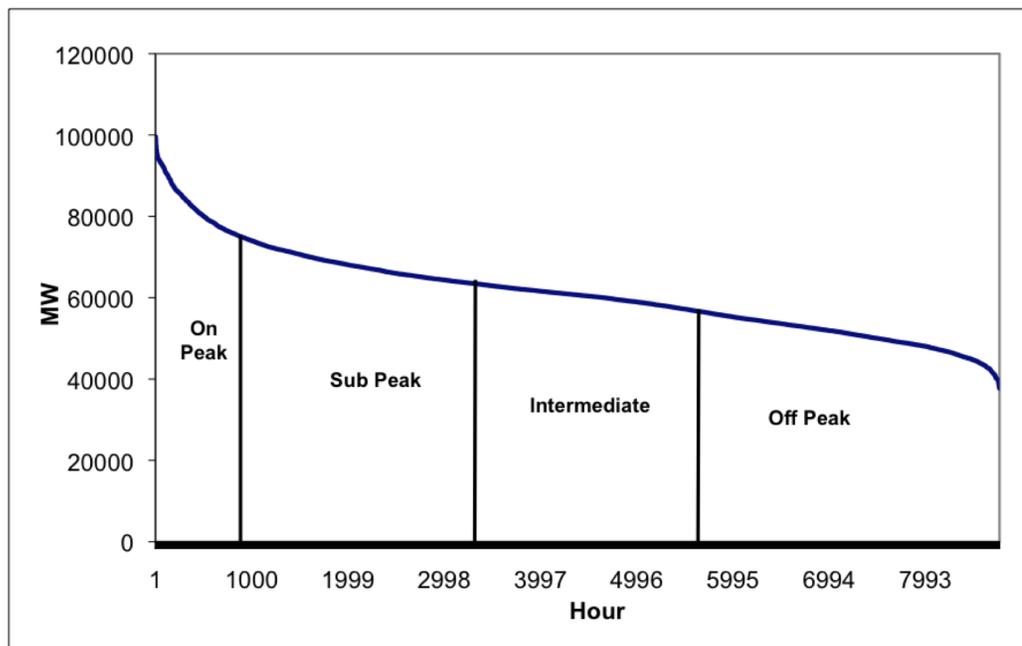
Overview of Talk

- ▶ Incorporating Solar and Wind Energy into Electricity
- ▶ Wind and Solar Resources in GCAM

Electricity in GCAM

For the U.S., GCAM splits the load duration curve into four segments.

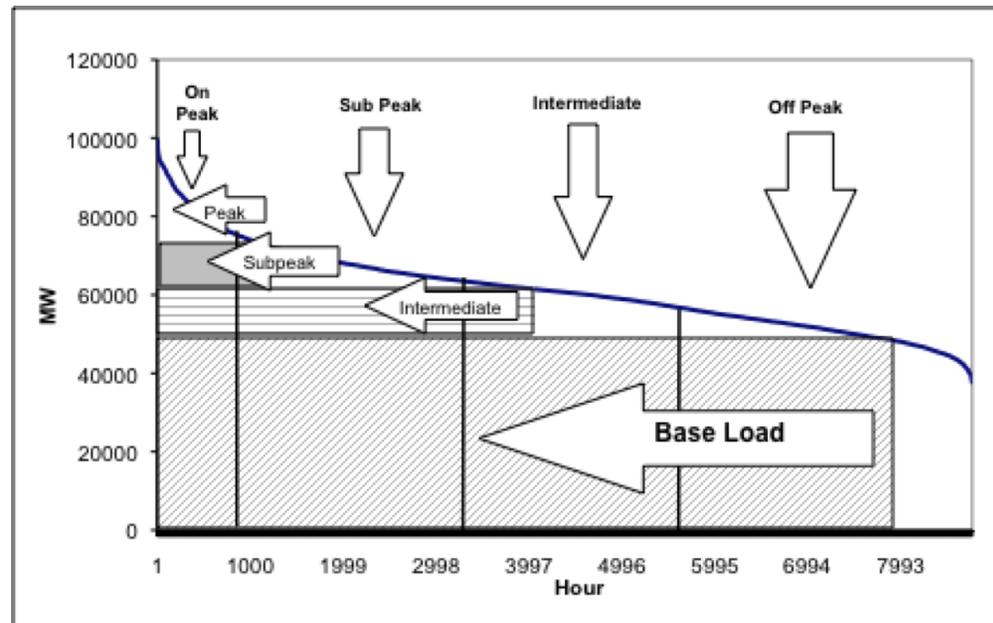
- ▶ The load duration curve divided into 4 segments: off-peak, intermediate, subpeak, and peak
- ▶ The load duration curve was based on a several sources
 - The BEopt program (Christensen et al. 2005) was used to develop hourly load curves for the residential sector and for heating and cooling in the commercial sector. Other sources were used to determine other hourly loads (e.g., industrial demands).
 - The remaining demands are from literature
 - Note that the load duration curve does not currently respond to changes in demand sectors.
- ▶ We are in the process of implementing this approach internationally.
 - One issue is how to think about load duration curves outside of the U.S.



Illustrative
conception
of load
duration
curve.

Electricity Generation Technologies Supply into “Horizontal” Segments.

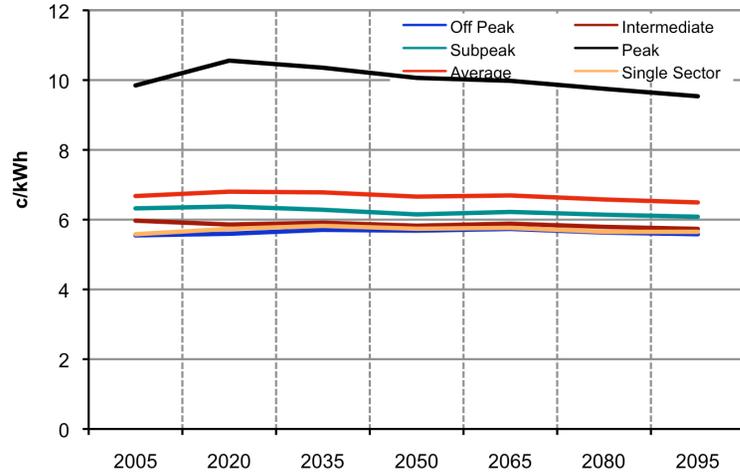
- ▶ Baseload generation supplies to all four sectors; intermediate to three, sub-peak to two, and peak to one.
- ▶ Each technology is assigned to a specific horizontal segment
 - For example, nuclear power supplies only to baseload; wind supplies baseload; solar PV w/o storage supplies subpeak, CSP w/ thermal storage is intermediate.
 - Some technologies (gas, coal) can supply more than one segment, but with different capacity factors.
- ▶ System storage (modeled as battery) buys from one vertical segment and sells to another.



Prices and Generation Mix

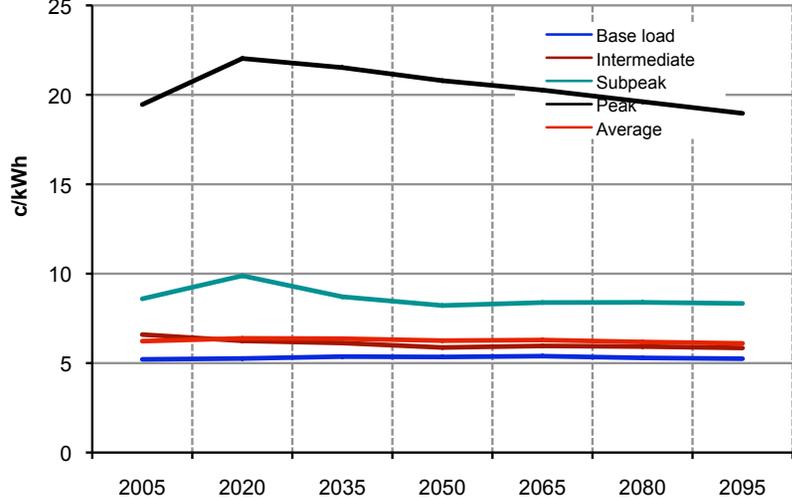
Electricity prices

(Vertical Segments) (Reference Scenario)

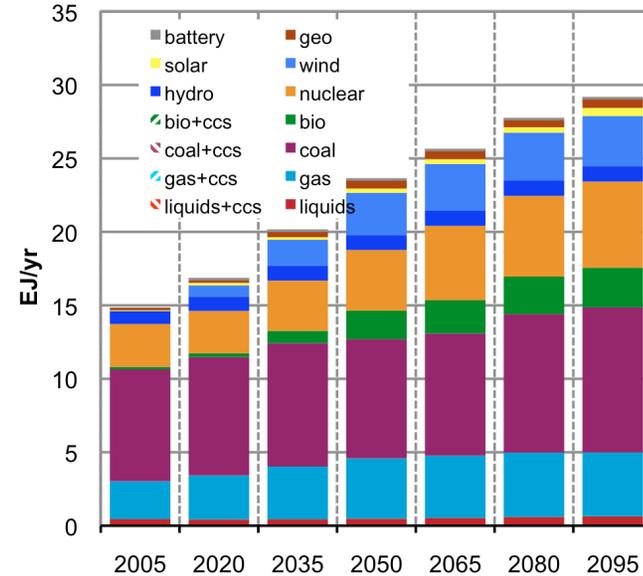


Electricity prices

(Horizontal Segments) (Reference Scenario)

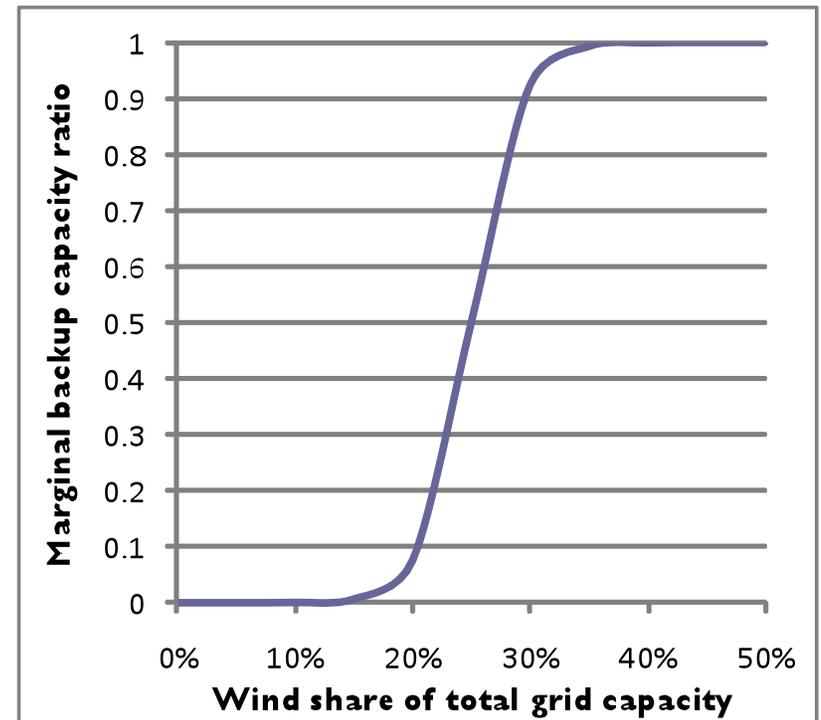


Generation Mix



Backup Requirements for Intermittent Renewables

- ▶ GCAM also includes an additional backup requirement to address variations in production within segments.
- ▶ Backup requirements are based on share of total intermittent renewable output to the grid.
 - Backup requirements increase with renewable energy penetration.
 - In the core version of GCAM, one-to-one backup is required at around 35% or total capacity.
 - The cost of a backup technology is modeled on a gas turbine with 5% capacity factor.
 - Generally, intermittent technologies also have a more capital intensive option with on-site storage that doesn't contribute to capacity limit.

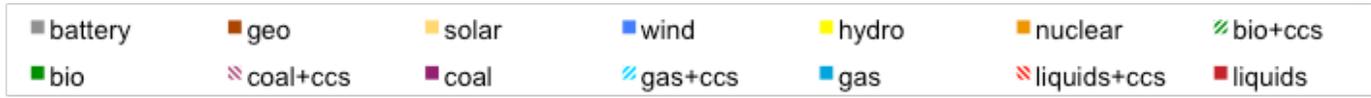
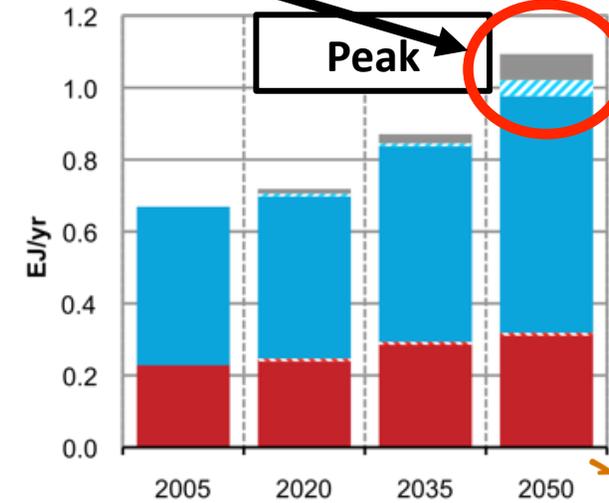
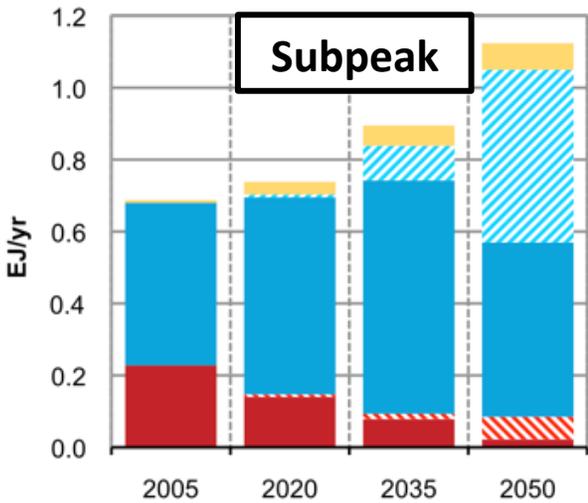
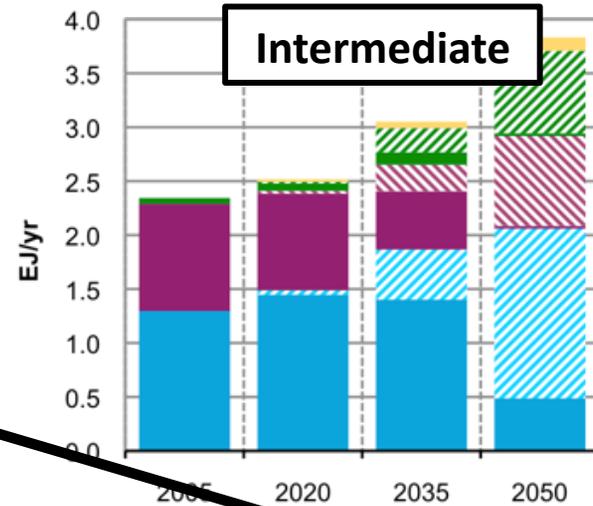
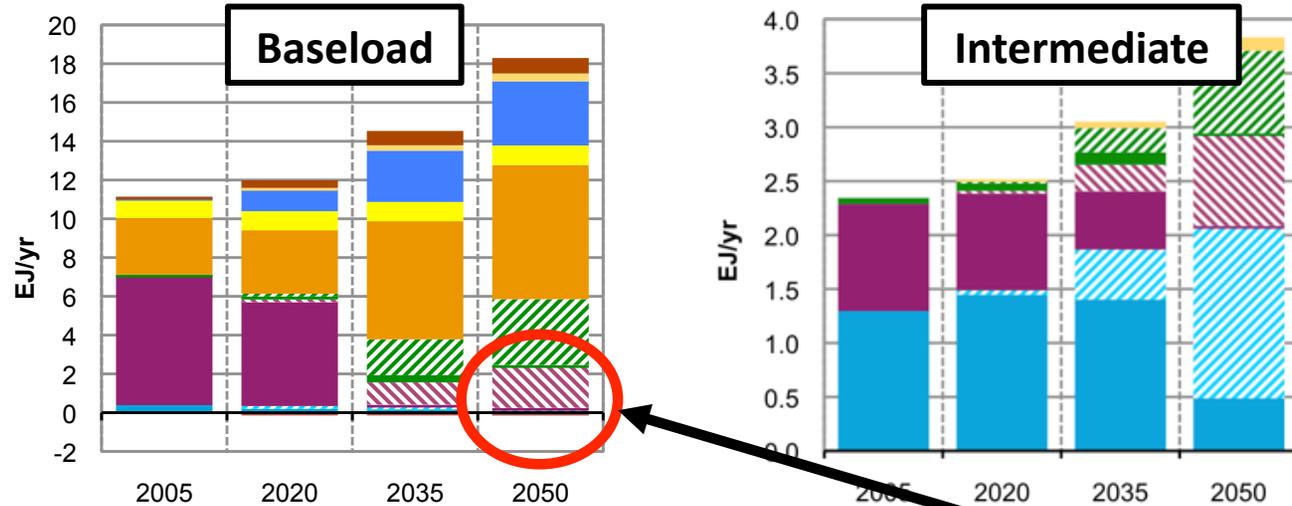


Policy case Results (80% reduction by 2050)

Deployment interacts with the availability of technologies by segment (e.g., nuclear only in baseload).

CCS is deployed across segments because of higher carbon prices.

Storage purchases energy from baseload and transfers it to peak generation



Wind and Solar Supplies in GCAM

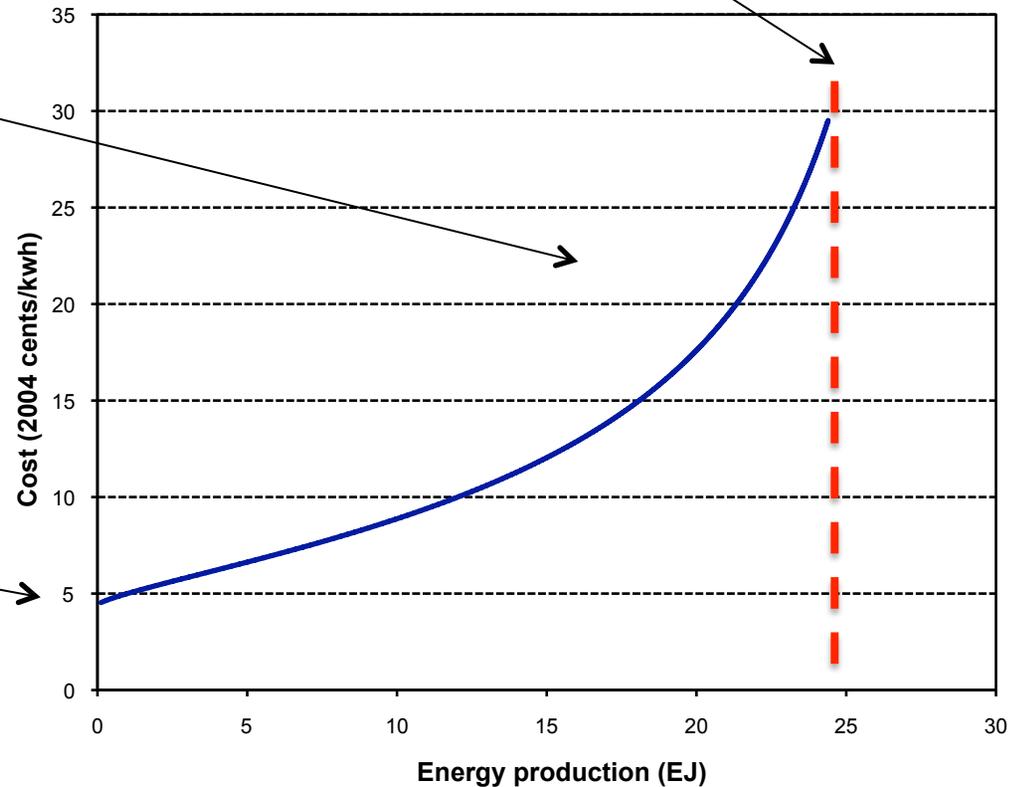
Representation of Wind Supplies in GCAM

Costs for additional capacity increase to represent both lower class wind and increasing transmission costs

Cost for the first unit of production

Maximum wind resource

2020 Input



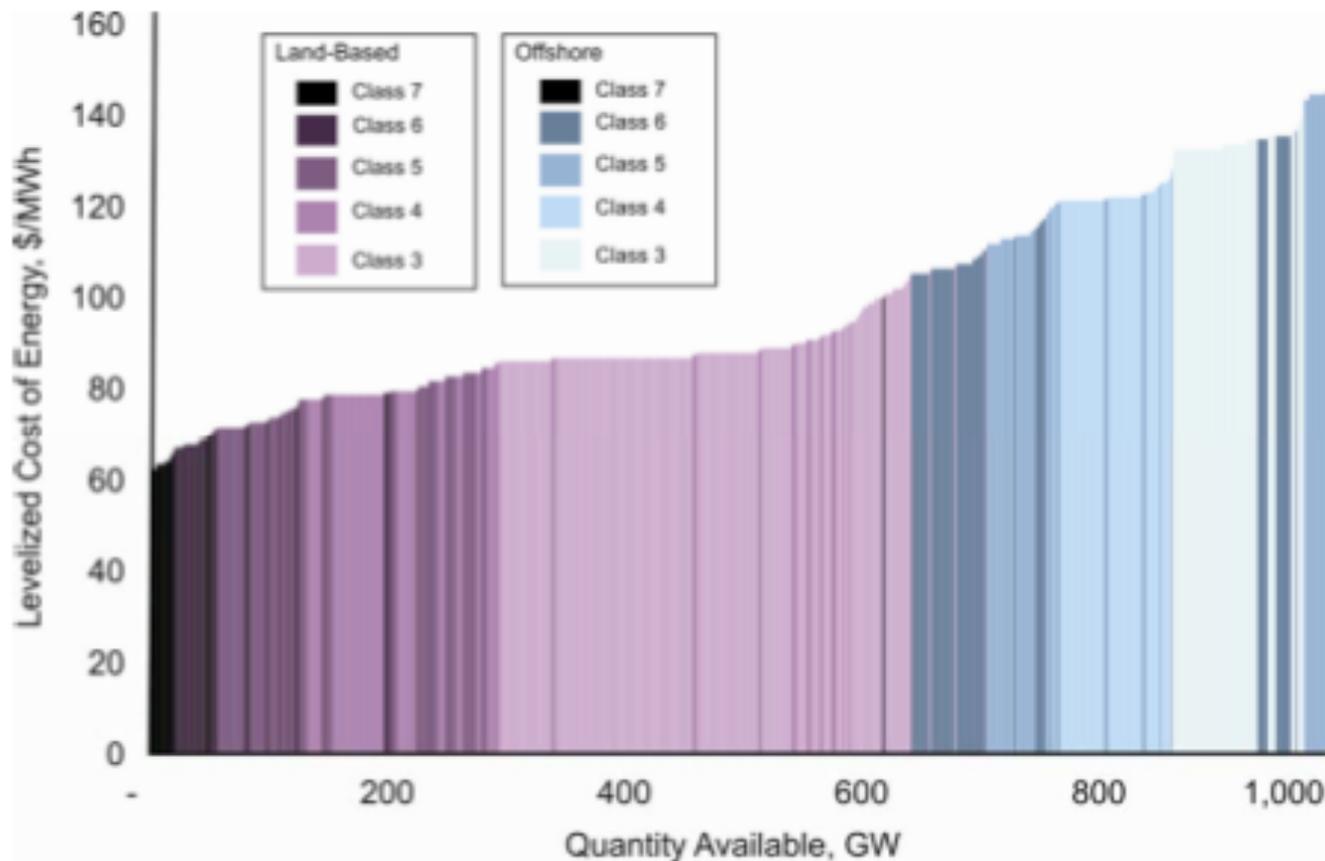
Where do the U.S. GCAM Wind Curves Come From?

- ▶ Costs for the first unit of production in GCAM are developed on a scenario-by-scenario basis, but are roughly based on a Class 4 site with no transmission costs.
- ▶ The additional costs for additional units (for decreasing quality and increasing transmission costs) are based on information from the NREL 20% by 2030 study**.
 - This applies only for projects that can enter existing grid (Includes exclusions for wind projects sufficiently distant from the existing grid)
 - The supply includes both onshore & offshore wind resources
- ▶ As a check, a detailed U.S. analysis was conducted based on GIS data to estimate available wind for classes 4+
 - Reasonably consistent with the NREL 20% numbers.

** US DOE. 2008. "20% Wind Energy by 2030 – Increasing Wind Energy's Contribution to U.S. Electricity Supply". Report No. DOE/GO-102008-2567. Available at: http://www1.eere.energy.gov/windandhydro/wind_2030.html

Material from NREL 20% by 2030 Study

Figure A-3. Supply curve for wind energy: energy costs including connection to 10% of existing transmission grid capacity



US DOE. 2008. "20% Wind Energy by 2030 – Increasing Wind Energy's Contribution to U.S. Electricity Supply". Report No. DOE/GO-102008-2567. Available at: http://www1.eere.energy.gov/windandhydro/wind_2030.html

Where do the Current International GCAM Wind Curves Come From?

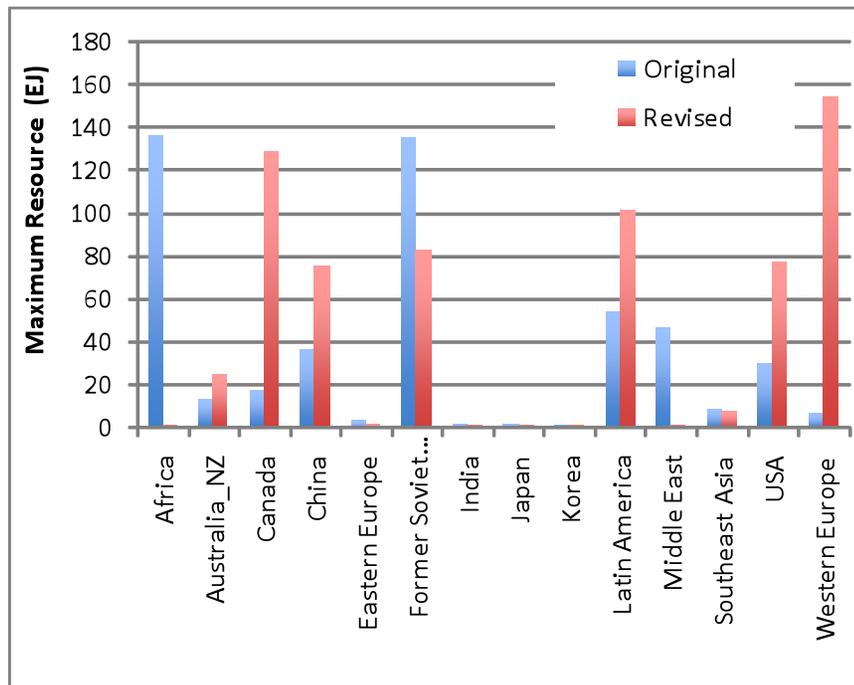
- ▶ IEA wind supply curves were used as a starting point for international supply curves**.
- ▶ The IEA curves were adjusted to reflect several adjustments, for example,
 - Assessments of land available
 - Density of turbines per land area. A detailed U.S. spreadsheet model was built to estimate available wind and compare to IEA-GHG results.
- ▶ We are formulating a more detailed, GIS-based approach.

** IEA-GHG. 2000. "The Potential of Wind Energy to Reduce CO2 Emissions". Report PH3/24. IEA Greenhouse Gas R&D Programme.

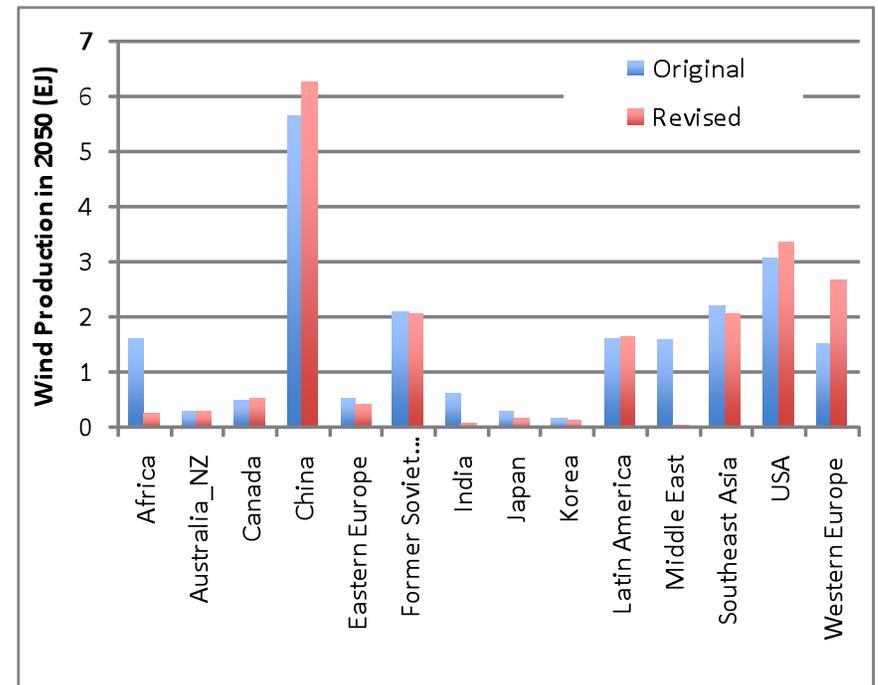
Changing wind supplies changes deployment, but supplies are not the only factor that influences results.

DRAFT Results: Not for Distribution

Maximum Wind Resource

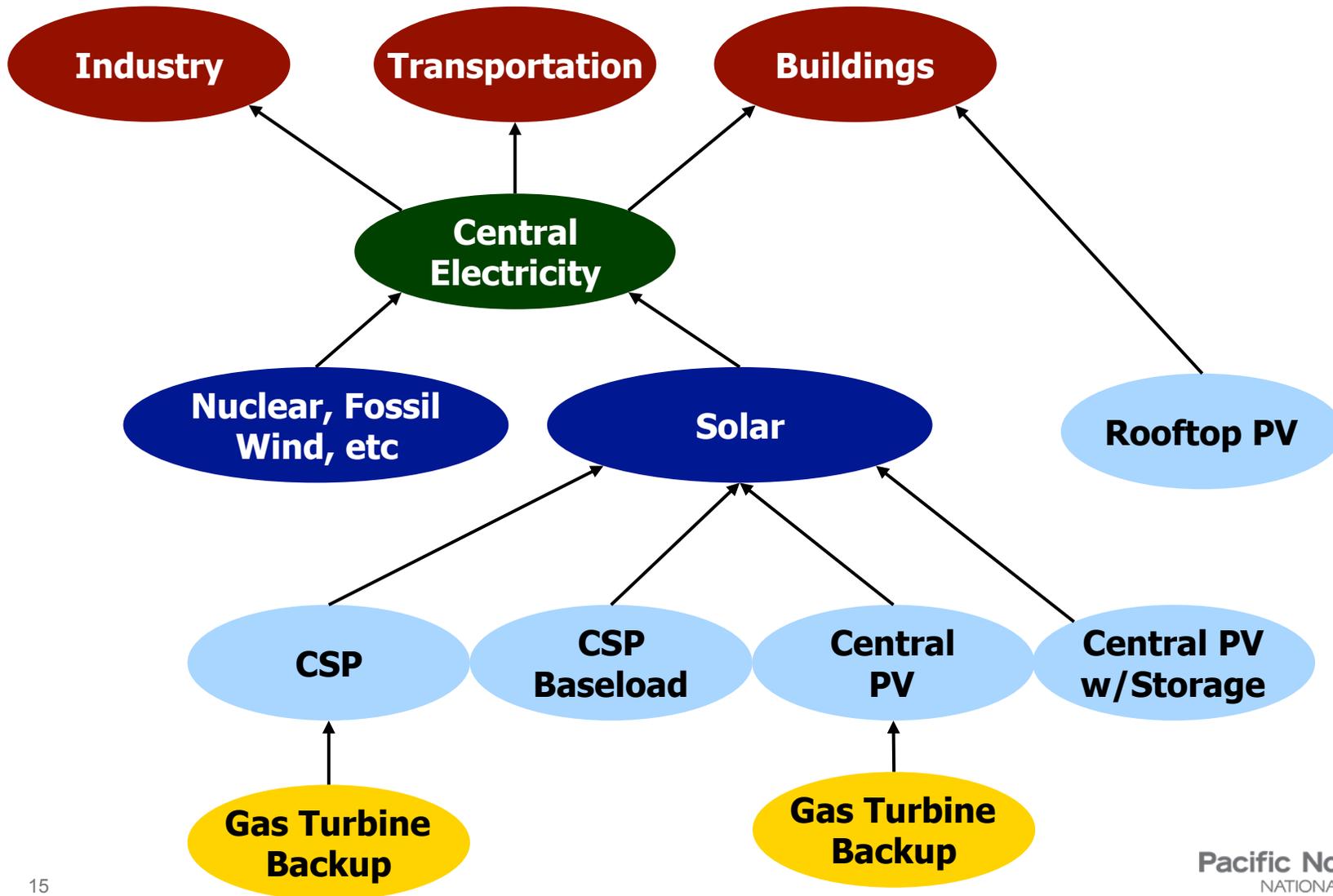


Wind Production in 2050



Results for an overshoot scenario reaching 450 ppmv CO2 in 2100

Solar Electricity Sources in GCAM



What do we need for a robust program to improve wind supplies in IAMs (or perhaps just GCAM)?

- ▶ ITEM 1: For input to the model: A matrix that takes into account exclusions and captures
 1. One axis: Representation of additional transmission requirements (probably some distance measure)
 2. One axis: Wind quality

- ▶ ITEM 2: To create inputs and sensitivities: GIS-based data
 1. Wind quality at the grid level
 2. Transmission grid or population density or other information that might inform transmission requirements
 3. Exclusions

- Different folks may work on these different issues.