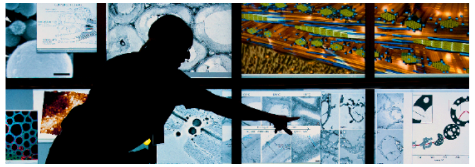
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Renewables Initiative: Resource Assessment

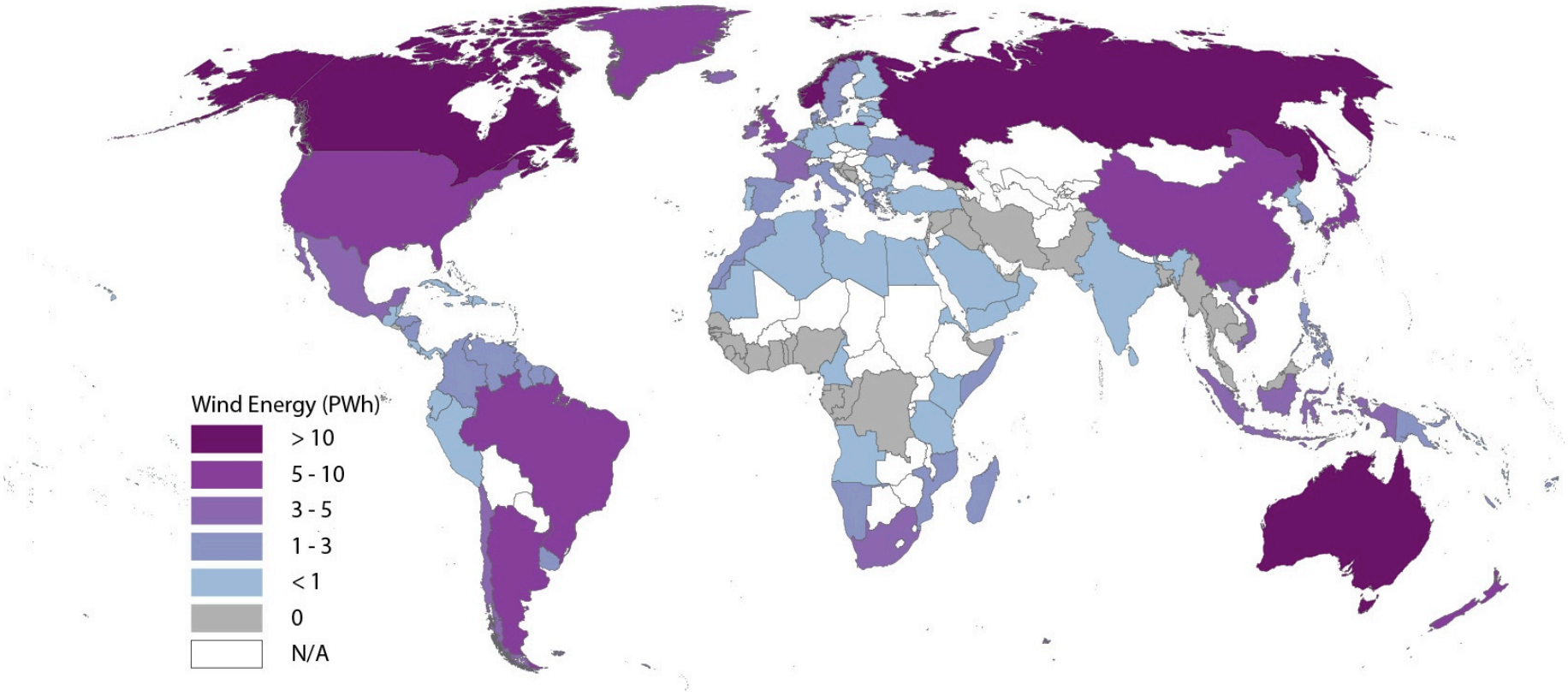
CCIA 2012

Patrick Sullivan

3 August, 2012

Global Wind Resource Assessment

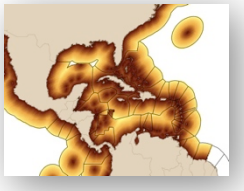
In 2011, first-pass offshore wind resource supply curves



Annual PWh of offshore wind potential, by country.

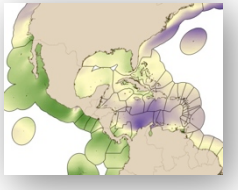
2011 Offshore Wind Database

Distance to Shore (meters)



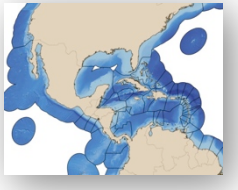
- Distance to shoreline
- Shoreline specific to EEZ

Wind Resource (meters/second)



- NOAA Blended Sea Winds
- Monthly wind speed
- 30km resolution
- 0.11 wind sheer used to extrapolate 10m-90m

Bathymetry (meters)



- NOAA ETOPO1
- 1.9km resolution

Protected Areas (status)

- Protected Planet

Shipping Lanes (ship tracks per km^2)

- National Center for Ecological Analysis and Synthesis

41 million records

PostgreSQL Database

EEZ Country

EEZ Sovereign

Jan-w/s-10m

Jan-w/s-90m

Feb-w/s-10m

Feb-w/s-90m

…

Annual Average-w/s-10m

Annual Average-w/s-90m

Distance to shore

Bathymetry

Protected Area (PA)

PA – Name

PA – Designation

PA – Type

-PA – IUCN

PA – Status and Rank

1. Formally Designated
2. Designated
3. Informally Designated
4. Adopted
5. Inscribed
6. Proposed
7. Recommended
8. Voluntary – Recognized
9. Voluntary – Unrecognized
10. “”

Ship tracks per km^2

1. 0 – 5 linear km per km^2

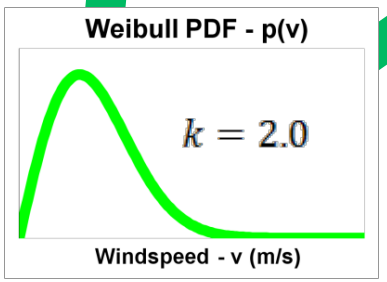
…

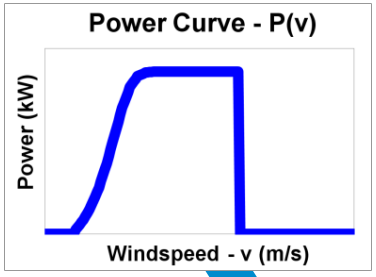
Supply Curve Algorithm

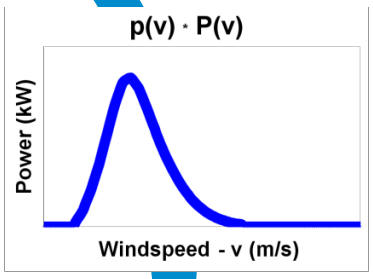
V_{hub}

Annual Average Windspeed

$$c = \frac{V_{hub}}{\Gamma(1+\frac{1}{k})}$$





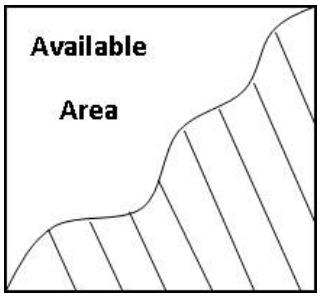


$$P_{gross}(MW/turb) = \sum_{v=0}^{V_{max}} p(v)P(v)$$

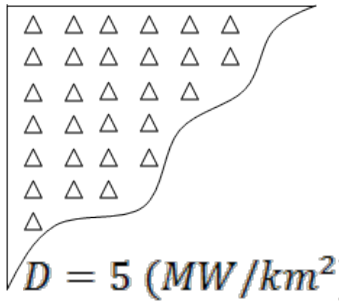
$$P_{net}(MW/turb) = P_{gross} * \eta_{array} * \eta_{avail}$$

$$CF = \frac{P_{net}}{P_{rated}}$$

Exclusions



Turbines



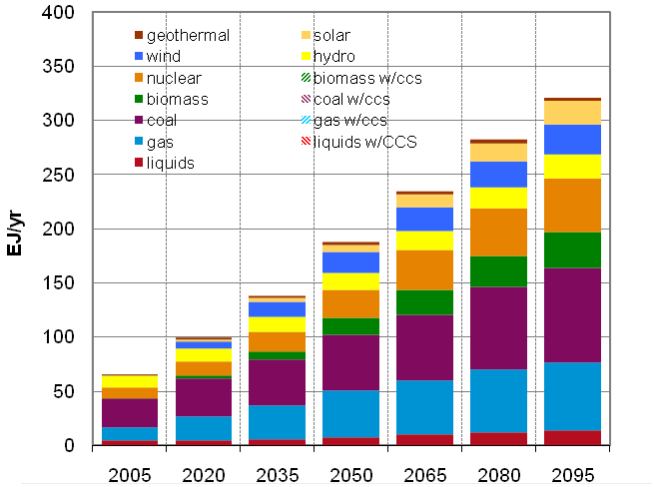
$D = 5\ (MW/km^2)$

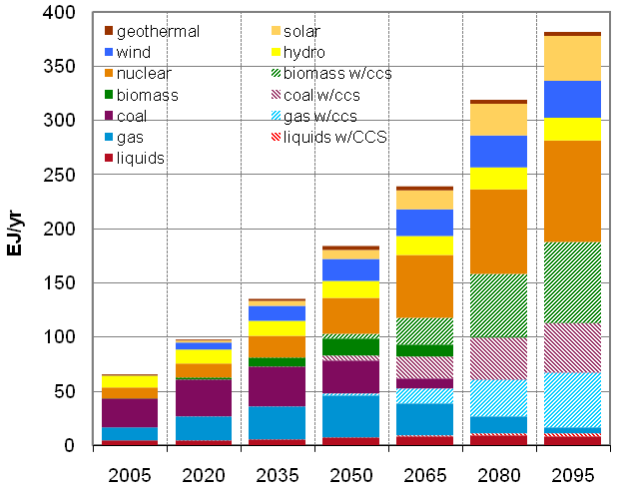
$$Potential\ (MW) = P_{net} * n_{turb}$$

Analysis is underway: GCAM

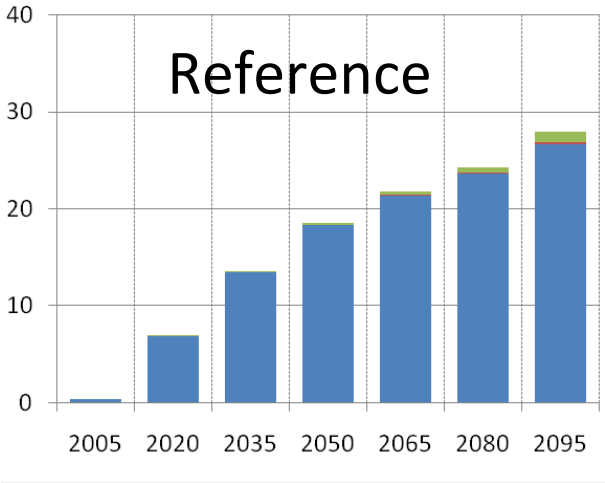
GCAM added offshore supply curves, has run scenarios to investigate its importance.

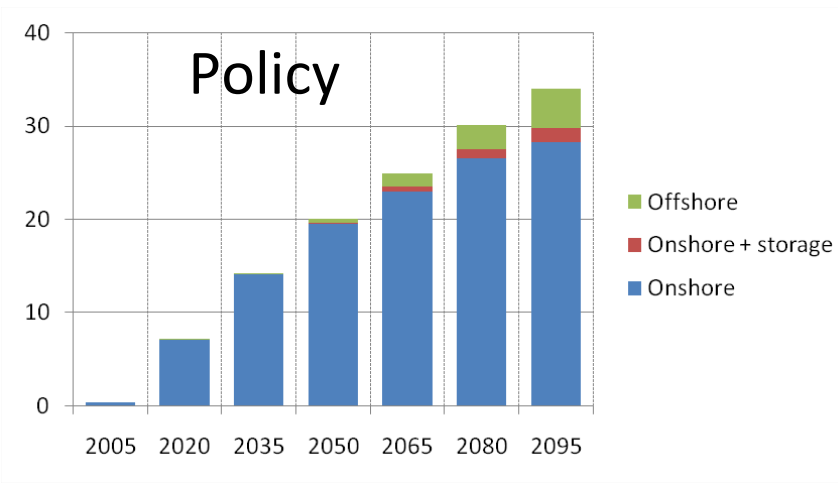
Global Electricity





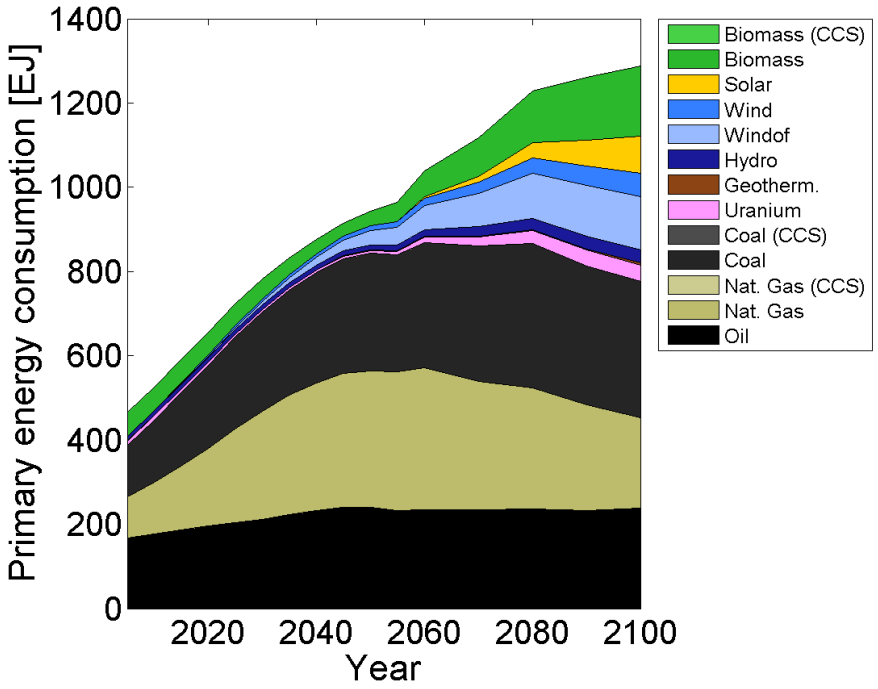
Global Wind Production



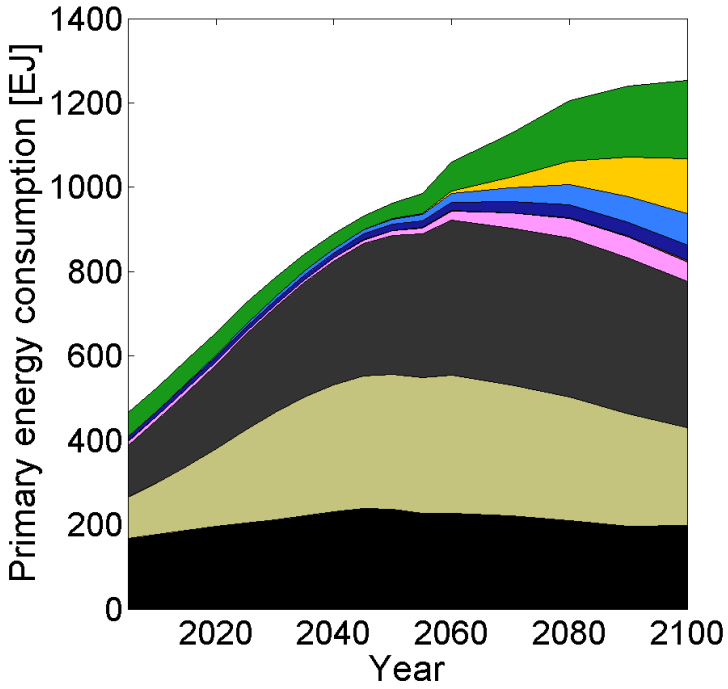


Analysis is underway: ReMIND

Business-as-usual, global primary energy equivalent.



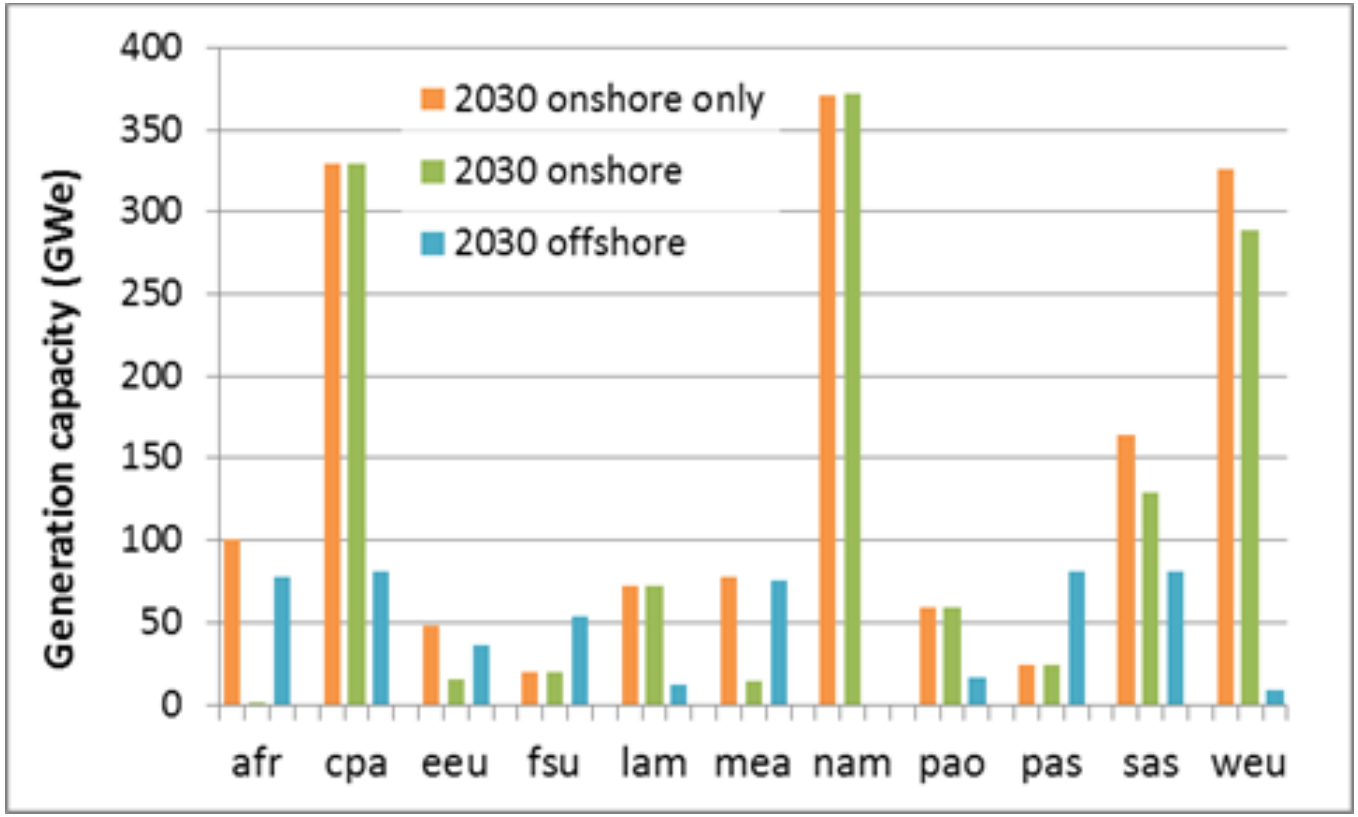
With new offshore wind



Without

Analysis is underway: MESSAGE

MESSAGE onshore is IMAGE (Hoogwijk).
Offshore is new, NREL supply curves.



Global Wind Resource Assessment

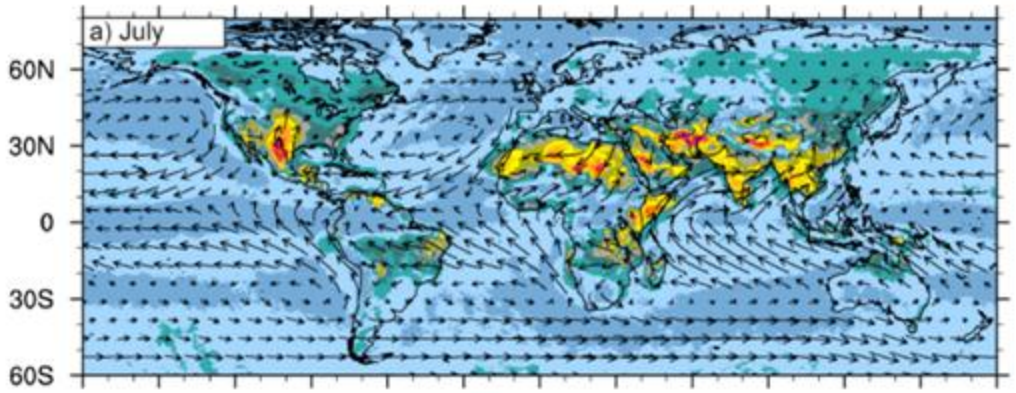
Shortcomings of 2011 analysis

- 10m wind, escalated to 90m hub-height.
- Monthly average wind speed, no time-series, no distribution.
  - Assumed Weibull-k of 2, naively.
  - Some missing months.
- Only offshore wind.

Global Wind Resource Assessment

For 2012, building supply curves from NCAR's CFDDA mesoscale reanalysis product:

- Modeled, but meshed with observations.
- Hourly time-series for 21 years: 1985-2005.
- Multiple heights AGL, including three between 70 and 150m.
- 40km spatial resolution.
- Insolation too.



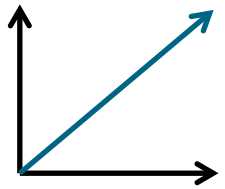
Raw CFDDA wind data

NCAR digested hourly time-series to monthly-hour (e.g. August 2pm) mean wind speed and distribution.

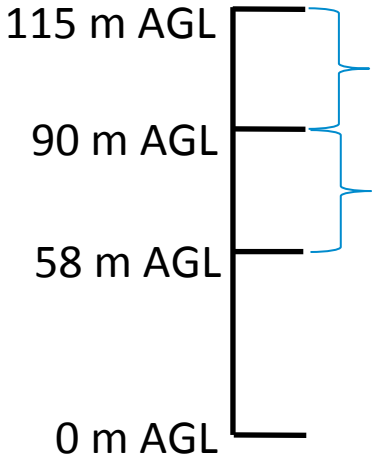
- *u* and *v* wind velocity vectors, directional variances, covariance.
- Focus on 58 and 115m AGL heights.

Processing wind speeds

Convert *u* and *v* to scalar speed & distribution



Interpolate between 58 and 115m to 90m hub height.

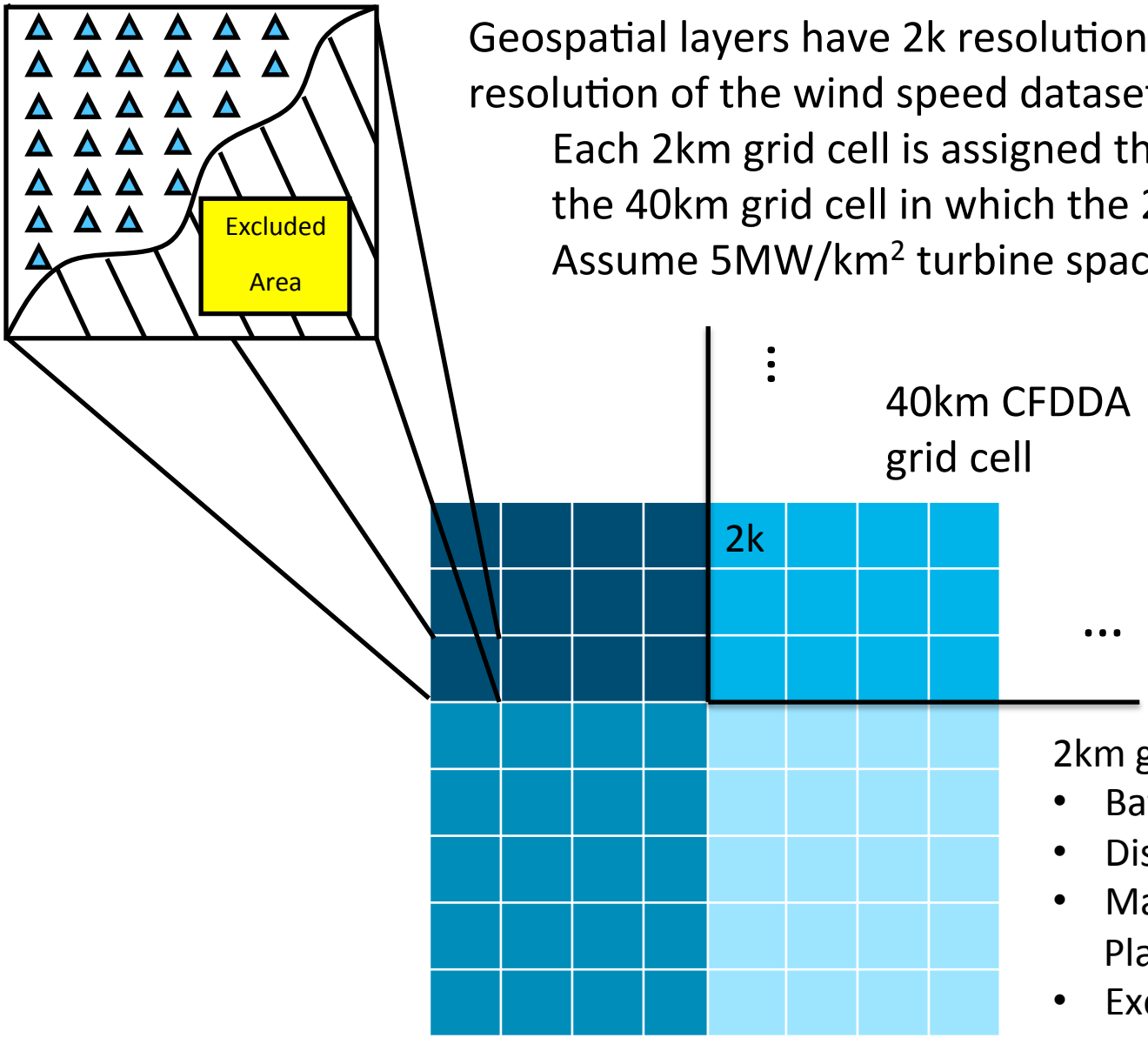


Approximate a Weibull distribution based on mean and variance*.

Convolve with power curve, adjust for losses, consolidate to annual CF.

*Justus et al., *Methods for Estimating Wind Speed Frequency Distributions*. Journal of Applied Meteorology, 17() 350-353, 1978.

Geospatial Assessment



Geospatial layers have 2k resolution compared to the 40k resolution of the wind speed dataset.

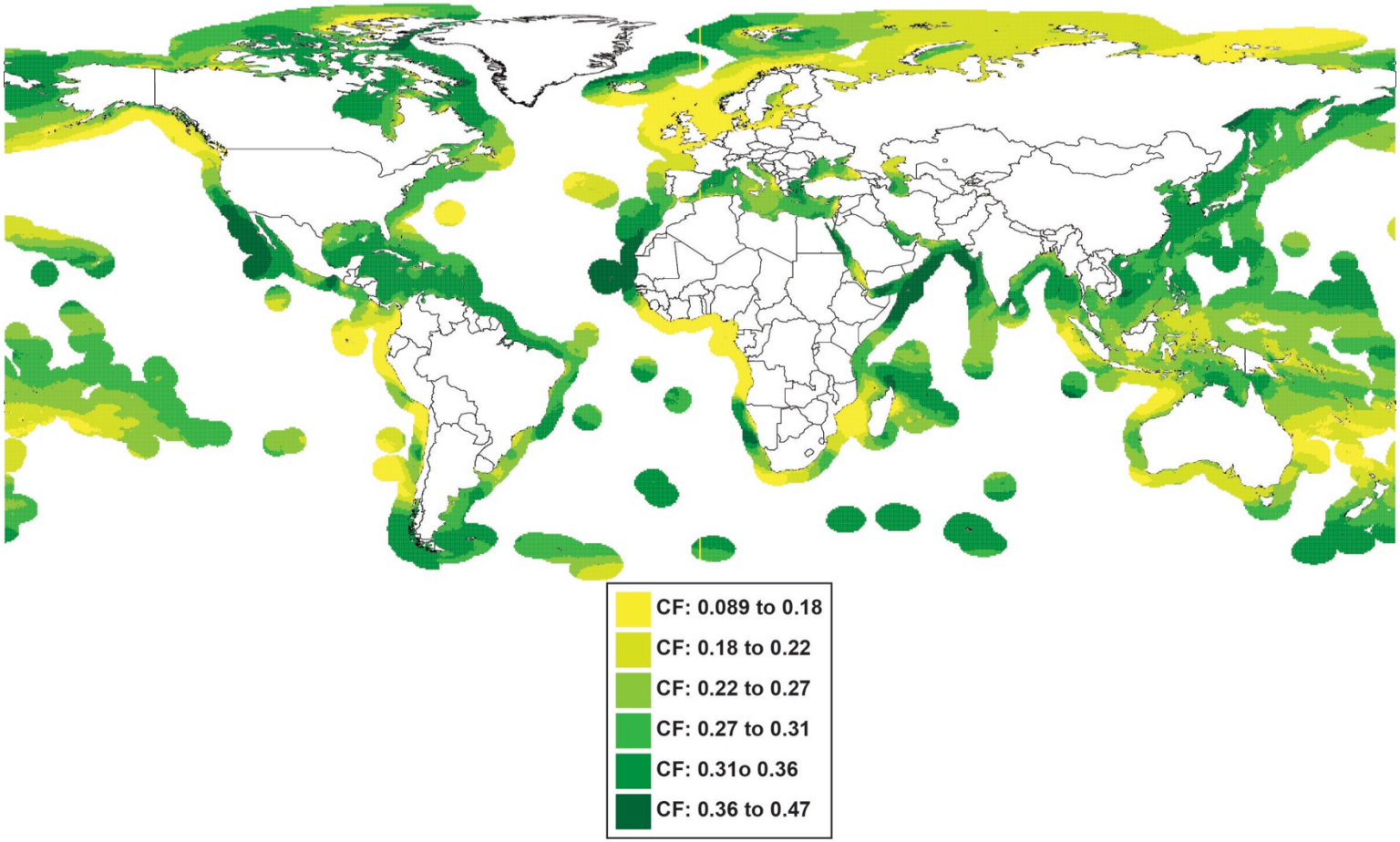
Each 2km grid cell is assigned the annual average CF for the 40km grid cell in which the 2km grid cell exists.

Assume 5MW/km^2 turbine spacing.

2km grid cell attributes:

- Bathymetry
- Distance to Shore
- Marine Status (Protected Planet)
- Exclusive Economic Zone

Processing wind speeds II



Processing wind speeds II

Onshore wind supply curves

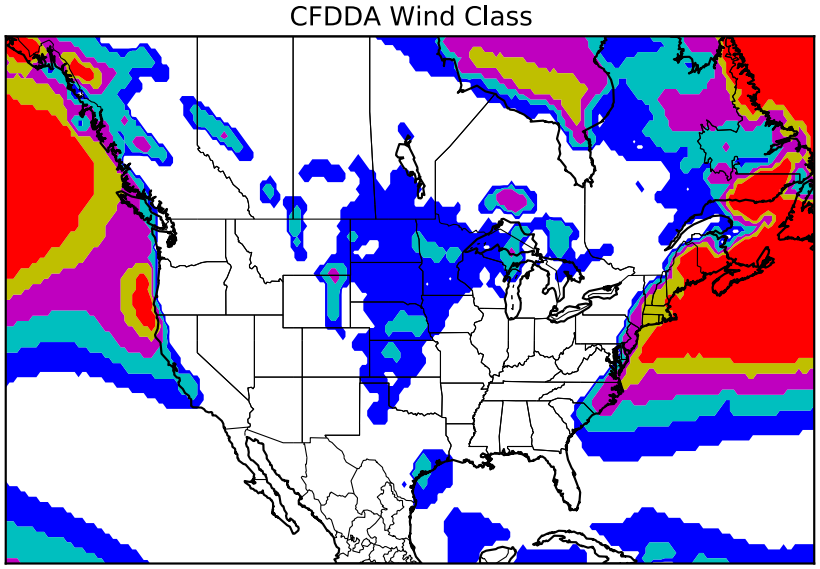
CFDDA again, considering land use (including protected areas) and elevation in place of marine protected areas and bathymetry.

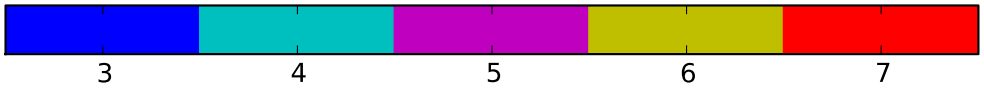
Testing methods for quantifying site-accessibility: proximity to loads, existing transmission corridors, etc.

- Synthetic transmission network
- Potential map

Onshore wind: terrain effects

Compared to the NREL high-resolution U.S. wind resource assessment, a straight-up assessment of the CFDDA dramatically underestimates resource.





CFDDA

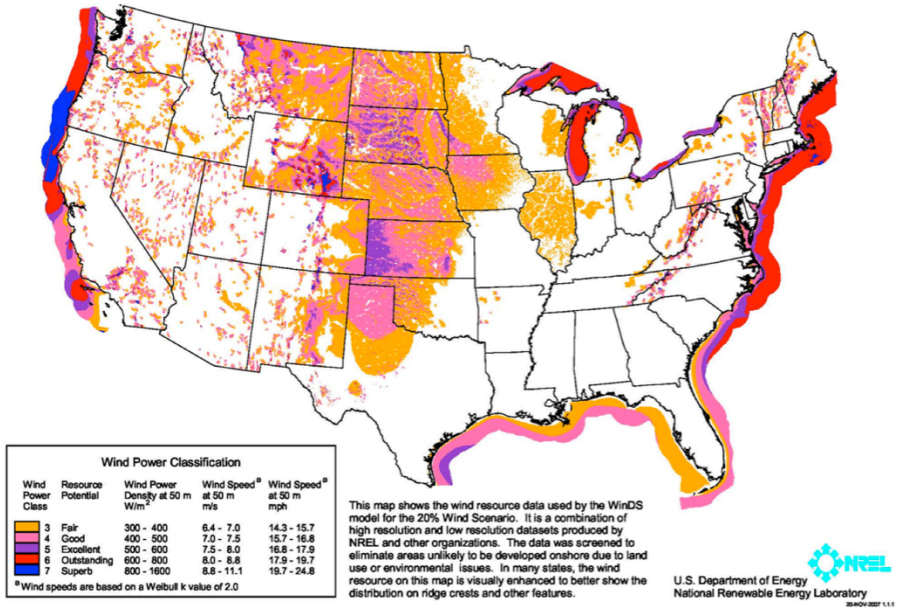
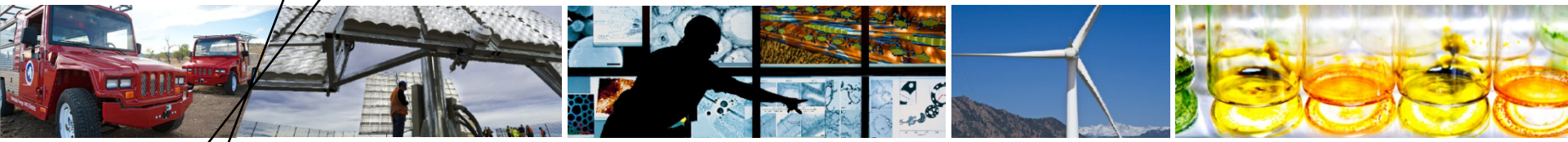


Figure 5: Wind Resource in ReEDS

NREL

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



patrick.sullivan@nrel.gov