The effect of microscale spatial variability of wind on estimation of technical and economic wind potential

Olexandr Balyk, Jake Badger, and Kenneth Karlsson

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Background

Global wind potentials

- Based on coarse resolution wind speed data
- Less complex estimation techniques
- Disregard small scale variability of wind

Local wind potentials

- High resolution measured data
- More complex estimation techniques
- Estimates are not available for every country
- Not uniform assumptions across studies

Global Wind Atlas project is aiming at producing global microscale wind climate data from existing mesoscale datasets by means of statistical downscaling.

Note: mesoscale: 3-100 km, microscale: < 3 km
Aim

• Demonstrate a new methodology for estimating wind energy potential using GWA data

• Provide an indication of how high resolution wind data influences the estimated wind energy potential
Test Area

- Mostly located in Washington State
- Characterised by complex terrain
- Area size 310x300 km
Methodology – Input Data

Wind climate data (DTU Wind)
• Weibull parameter k by sector
• Weibull parameter A by sector
• Sector frequency
• Spatial resolution - 250 m
• Height - 100 m a. g. l.

Wind turbine data
• Vestas V90 3MW power curve

Area exclusion data
• Protected areas of Pacific States
Methodology – Gross Technical Potential

1) Weibull cumulative distribution function:
\[ F(u, s) = 1 - \text{Exp}(-(u/A(s))^{k(s)}) \]

2) Probability of a wind speed interval (i.e. 1 m/s interval)
\[ p([u_1, u_2], s) = F(u_2, s) - F(u_1, s) \]

3) Mean power generation by sector:
\[ \overline{TP(s)} = \sum p([u_1, u_2], s) \times TP((u_1 + u_2)/2) \]

4) Omnidirectional mean power generation:
\[ \overline{TP} = \sum f(s) \times \overline{TP(s)} \]

5) Annual energy production:
\[ AEP = \overline{TP} \times 8766 \]

\( u \) – wind speed, m/s
\( s \) – sector
\( f \) – frequency
\( p \) – probability
\( TP \) – turbine output, MW
Methodology – Area Exclusion

Some areas are not suitable for wind power development due to e.g., their physical characteristic or management practice.

We use GIS to exclude (based on IUCN classification):

• Strict nature reserves
• Wilderness areas
• National parks
• Natural monuments
• Habitat/species management areas
• Protected landscape/seascape areas
• Managed resource protected areas

Other areas are necessary to exclude to estimate an actual potential.
Methodology - Methods for estimating net wind power potential

Maximum approach
Maximum AEP in a 4x4 grid cell array

Average approach
Average AEP in a 4x4 grid cell array

Binary integer programming approach

\[
\sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \times AEP_{ij} \rightarrow \text{max}
\]

subject to:

\[
\begin{cases}
\sum_{i=1}^{I+G-1} \sum_{j=1}^{J+G-1} x_{ij} \leq 1 \quad \forall I \in \{1,2,3, \ldots , m - G + 1\}, \forall J \in \{1,2,3, \ldots , n - G + 1\} \\
x_{ij} \in \{0,1\} \quad \forall i \in \{1,2,3, \ldots , m\}, \forall j \in \{1,2,3, \ldots , n\}
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\]
Methodology – Other Aspects

**Economic potential**
Many factors influence costs of project development e.g., distance to grid, access to roads etc.

We exclude grid cells with CF<.35 to simplify the comparison

**Comparison with mesoscale data**
Mesoscale data for the same area was not available

Used simulated mesoscale data, produced by averaging microscale AEP values with grid cell spacing of 30 km
Results - AEP

- Microscale variation 0 to 14.9 GWh (left)
- Mesoscale variation 6.4 to 9.6 GWh (right)

- 20% mean AEP difference for the top 5% grid cells
- 14% mean AEP difference for the top 10% grid cells
Results – Net Wind Potential

Technical potential

Low variation in capacity factors from mesoscale data

Economic potential

Potential is at least twice as high with microscale data
Results – Economic Potential

Mesoscale potential is just enough to cover power demand of Washington State (i.e. roughly 100 TWh)

BIP approach results in 45-51 TWh lower potential than other microscale approaches

Capacity needs to produce target AEP are higher for the mesoscale data
Conclusions

- Overall potential is higher when using microscale data

- More than doubling of economic potential when going from mesoscale resolution to microscale

- Three approaches: BIP is conservative, maximum approach is optimistic and the average approach combines lower wake uncertainty and simplicity

- Implications for global energy system modelling:
  - More realistic potential
  - Higher competitiveness of wind power
  - Increased climate change mitigation potential
Way Forward

Methodology refinement

• Ability to use several power curves

• More sophisticated wind turbine spacing calculations

• Introducing cost intervals
Plans (Wishes) for Global Wind Atlas

- Use Global Wind Atlas to update wind energy potential in ETSAP-TIAM (global energy system model, 15 regions)

- Data for different heights => to use with different turbines

- Temporal variability data => to produce aggregated profiles
Thank you for attention!