Austrian Wind Potential Analysis - AuWiPot

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The project AuWiPot

- Funded by Austrian Promotion Agency (FFG)
- Run time 3 years (March 2009 to April 2011)
- Team:

  Energiewerkstatt°, Austria
  Project lead, technical/economical criteria, observation data

  Wegener Center, University of Graz, Austria
  Wind field modelling, observational data

  Meteotest, Switzerland
  Wind field modelling, observational data

  iSpace, Austria
  web-GIS modelling, data analysis
1. Introduction and Motivation
2. Methodology
3. Results
4. Conclusion
Potential estimations so far

(from Hantsch and Moidl, 2007)

- Broad spectrum of estimations ranging between 3TWh/a and 20TWh/a, depending on the methods applied and underlying assumptions
- e.g. Pokorny (1981): 6.6 TWh/a – 10 TWh/a based on 150’000 50 kW turbines
• Current status lies far behind any estimated potential
• Economical constraints have changed (e.g. feed-in tariff)
• New technological possibilities are available (e.g. turbine sizes have increased)
• Limiting factors can be considered much more in detail (wind, land use, feed-in tariff, …)
Aims:

• Calculation of a detailed (100 m × 100 m grid spacing) wind map for the Austrian territory with known uncertainty

• Comprehensive modelling of the theoretically achievable wind potential under changing economic/technologic conditions

• Provision of a flexible potential estimation tool to the general public via a web-based GIS application capable of fast “on-the-fly” calculations
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Problem of scales

- **>1000 km**
  - Global circulation, ocean/atmosphere oscillations (e.g., Monsoon, ENSO)
- **100 km to 1000 km**
  - Rossby Waves, high/low pressure systems, Hurricanes
- **10 km to 100 km**
  - Frontal systems, thunderstorms, cumulus nimbus, Föhn, Bora
- **10 m to 10 km**
  - Cumulus, slope flows, local circulations, turbulence, Tornadoes

*(Barry and Carleton, 2001)*
Methodology

Dynamical model

- Regional climate model (RCM): **MM5**
- Driving data: **ERA-40** (~100 km)
- Three nesting steps: 30 km (A1) → 10 km (A2) (reclip:more) → 2 km (A2) 
  
  (Loibl et al., 2007)
- Periods: 1981 to 1990 (from reclip:more)
- Evaluation: observation data from 65 ZAMG stations
- Output: mean annual wind speeds and frequency distributions

Geo-statistical model (Kunz et al., 2004)

- Observational data from MetServices (ZAMG, DWD, MeteoSwiss), local governments, University of Innsbruck, research projects (MAP, Alpine Windharvest), private observations from wind projects
  + data from 254 surface stations
  + results from dynamical model (A2)
- Simple bias correction included
- Output: highly resolved (100 m) wind maps (mean annual wind speeds, Weibull parameters) in several heights a.g.l.
Potential estimations and GIS application

First step (technical criteria)

- Surface altitude
- Terrain slope
- Land use
- Protection areas (national parks and other nature protection areas)
- Distances to settlements, buildings, streets and rail roads
- (access roads and socio-political limitations excluded)

Second step (economical criteria – derived from expert consultations via workshops)

- Calculate **site-specific production costs** (per grid cell) from
  
  → **mean annual energy yield**
  (wind conditions, specific power curves, distances between turbines, technical and wake losses)

  → **costs** (Installation costs, costs of operation, capital costs, machine life, …)

  → **site-specific production costs** / feed-in tariff

→ web-based GIS application
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Evaluation of the dynamic modelling step (1981 to 1990)

- Station averaged (65 ZAMG stations)
- Deviations from observations are reduced
  mean absolute error:
  - ERA-40: 2.6 m/s
  - 10 km: 2.2 m/s
  - 2 km: 1.7 m/s
- frequency distributions are improved
- → overestimation of wind speeds
- → added value due to the increasing resolution of the dynamic model
- → Output from dynamic models need to be “post-processed” (bias correction, MOS, etc.)
Wind map and its uncertainty

mean annual wind speed (100 m a.g.l.)

Available at [http://www.windatlas.at](http://www.windatlas.at)

- Cross-validation (leave one out) over more than 200 stations
- Spatially distributed standard deviations of biases (~0.8 m/s on average)
- Roughly correlates with the density of the stations
- Uncertainty in energy yield < ±15% (for stddev 0.4 m/s) at single sites
web GIS application

Available at http://www.windatlas.at
Theoretically achievable wind potential (on a district level)
Results

Realistically achievable wind potential

- Socio-political constraints have not been considered in AuWiPot (acceptance by the population, conflicting interests, praxis in awaiting approvals, ...) → difficult to implement

- First attempt (conducted by Energiewerkstatt° as an add-on): expert consultations within the Austrian wind energy community 
winds farms installed in 2011 
estimation of planned wind farms under realistic conditions

- Comparison

<table>
<thead>
<tr>
<th>Current status (observed)</th>
<th>theoretical potential (objective)</th>
<th>expert consultations (subjective)</th>
</tr>
</thead>
<tbody>
<tr>
<td>~1 GW</td>
<td>12.8 GW</td>
<td>2.8 GW</td>
</tr>
<tr>
<td>~4%</td>
<td>~50%</td>
<td>~11%</td>
</tr>
</tbody>
</table>
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Wind field modelling

- Highly resolved wind maps have been generated and published via www.windatlas.at
- Added value due to increasing resolution of dynamic model
- Output from dynamic model needs to be post-processed
- An overall uncertainty of ~0.8 m/s is reached

Potential modelling

- Austria’s wind potential estimated with respect to technical/economical constraints reflecting current state
- Flexible web-based GIS application with fast on-the-fly calculations implemented taking care of the complexity of wind potential estimations
- Wind potential analysis gives an upper limit per construction (access roads not considered; socio-political influences excluded)
- Realistically achievable potential is multiple times larger than currently installed wind energy turbines
- The modelling approach is ready to use for climate impact studies
Danke für Ihre Aufmerksamkeit!
→ Combined dynamical/geo-statistical modelling approach

Dynamical models (as used in NWP and climate research)
- Simulation of the temporal evolution of atmospheric processes
- Land/atmosphere interaction, planetary boundary layer processes, …
- + independent from observational data
- + generation of time series
- – limited spatial resolution (~km); small scales are unresolved
- – time consuming calculations (~months) → high performance computing systems

(Geo)-statistical models
- Interpolation of observational data based on empirical background information
- Small scale features are considered (land use, orography, …)
- + very high resolutions are achievable
- + short run times (desktop PCs are sufficient)
- – density and quality of observational data are crucial
- – generation of mean values; no sophisticated frequency distributions
Evaluation of the dynamic modelling step (1981 to 1990)

- Single stations show high variability

- Output from dynamic models need to be “post-processed” (bias correction, MOS, etc.)
Results

Statistical modelling step

• Application of a spatially distributed scaling factor
Results

65 ZAMG TAWES

ZAMG Klima
1971-80 Mittel: 3,9 m/s
1981-90 Mittel: 3,9 m/s
1991-00 Mittel: 3,9 m/s

14 Modelle (18 km Auflösung) aus dem ENSEMBELS Projekt