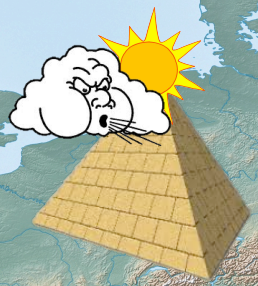
REatlas – a global wind and solar atlas for energy system modeling

Gorm B. Andresen

@ 2nd Open Energy Modeling Workshop

Berlin, April 2015



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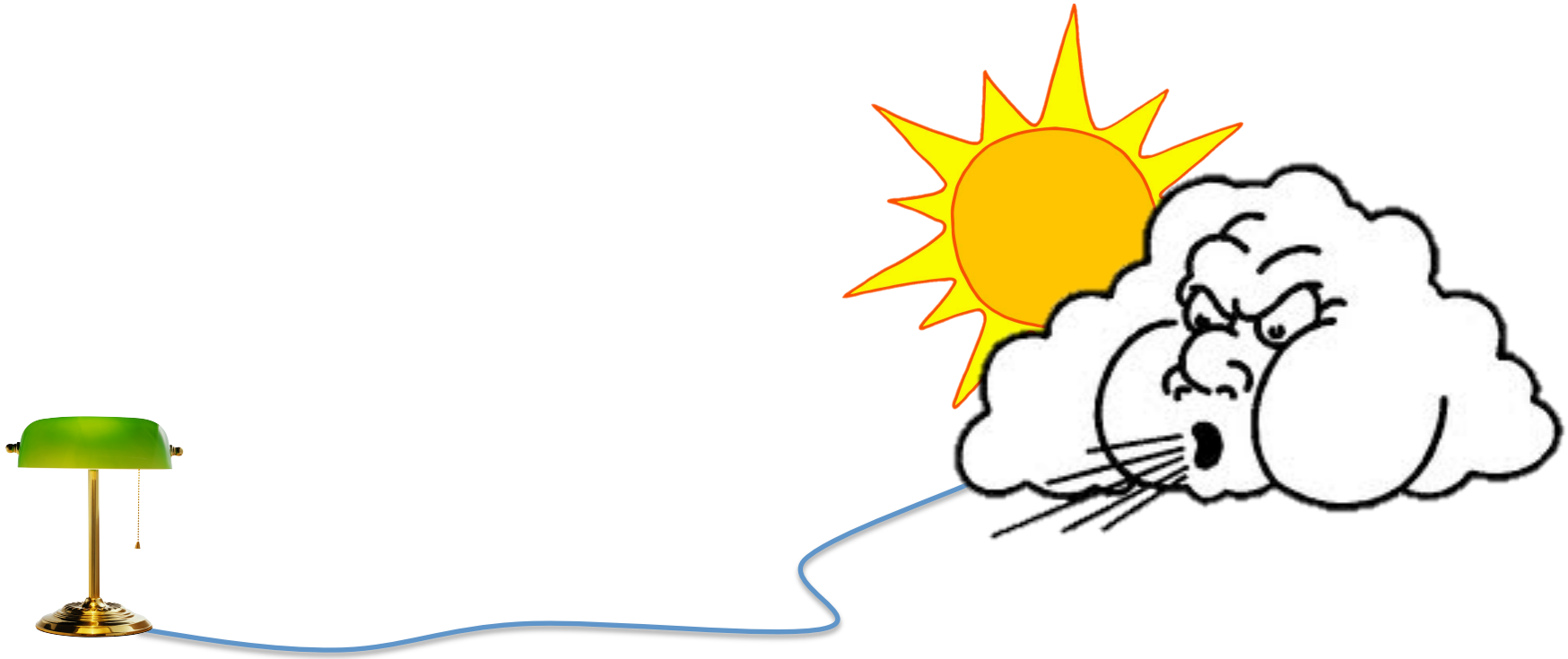
Outline

- Weather-driven modeling.
- Global Renewable Energy Atlas.
- Wind power data – pay attention to the details.
- Summary.

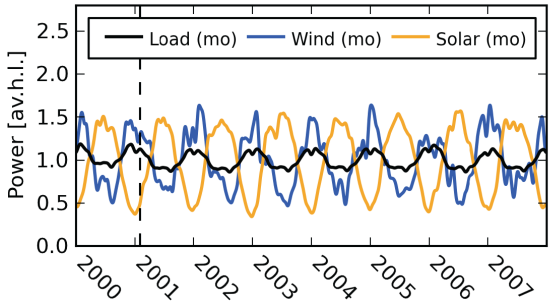


We cannot control when the wind blows or the sun shines

WEATHER-DRIVEN MODELING

Previous research

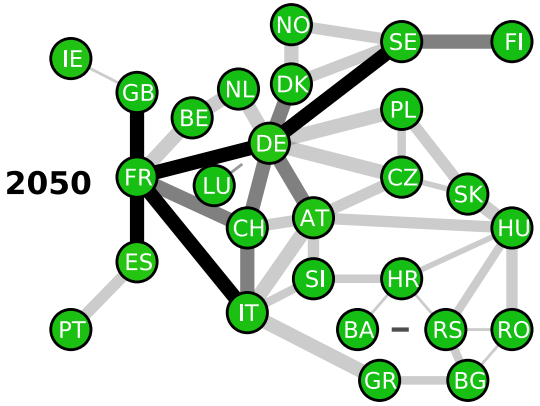
Combining resources to match demand



Wind and solar power can be combined to match, e.g. seasonal variations in the electricity demand and reduce the need for new transmission lines, storage systems and other supporting infrastructure.

D. Heide *et al*, *Renewable Energy*, **35** (2010), D. Heide *et al*, *Renewable Energy*, **36** (2011).

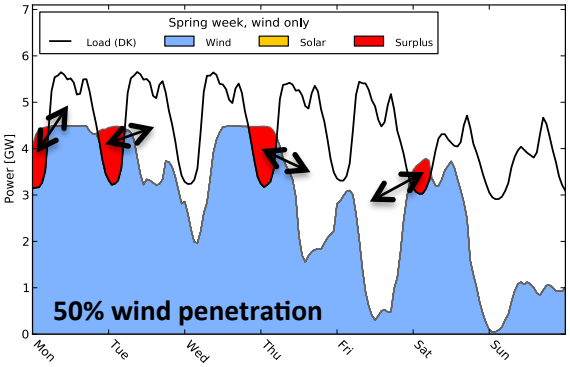
Interconnecting countries to smooth variations



Based on long time series of potential wind and solar power generation, the benefit and optimal layout of a strong international transmission grid can be evaluated.

R.A. Rodriguez *et al*, *Renewable Energy*, **63** (2014), S. Becker *et al*, *Energy*, **64** (2014).

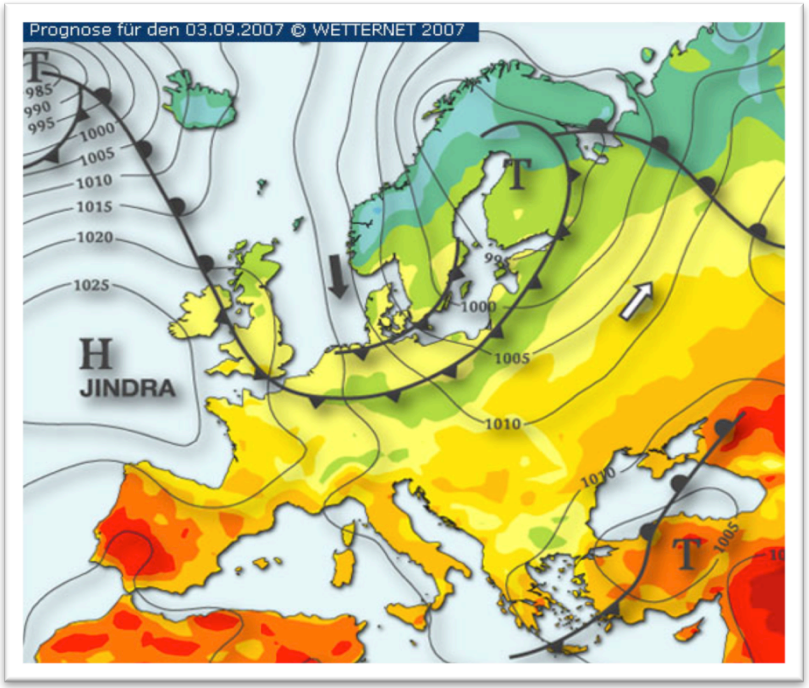
Estimating surplus and the need for storage



Wind and solar power generation may exceed the hourly demand for electricity. For large penetrations of renewables, this can't be avoided, and storage may be a viable solution.

M.G. Rasmussen *et al*, *Energy Policy*, **51** (2012), G.B. Andresen *et al*, *Energy*, **76** (2014).

“Let the weather decide!”

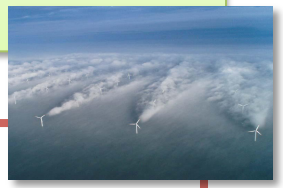


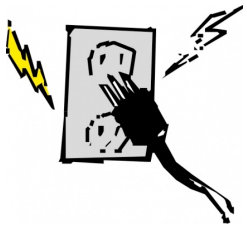
OLD

High-resolution weather data (70,128 h):
50 x 50 km^2, 1 hour weather data covering the 8-year period 2000-2007 for 27 European countries on and offshore.

ISET

High-resolution wind and solar PV power generation.

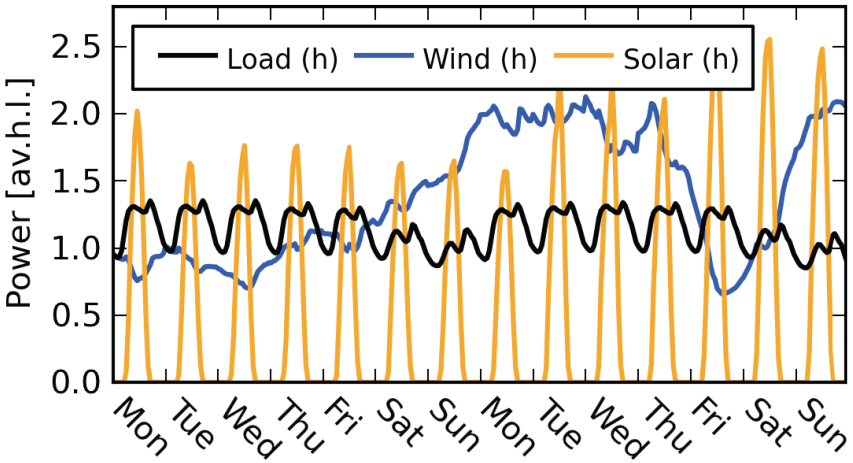




Regional electricity demand:
Hourly electricity demand for 50 individual regions.

Weather based power generation

To design a well functioning power system based on weather-driven sources we need high-quality weather data for large areas.



Our future energy supply may be based on wind and solar power generation.

To exploit the very different temporal and geographical characteristics that are important for the underlying power system and energy markets, we believe that analysis of high-quality weather data represents the most promising route.

High-temporal resolution:
- System stability (<15 min).
- Best match between production and demand (about 1 h).
- Market dynamics and design.

High spatial resolution:
- Local resource variations.

Large geographical regions:
- Spatial smoothing and transmission grid investments (continent/countries).
- Long-term planning for developing countries.

Many years of data (10+ years):
- Resource quality and potential.
- Annual variations and investment risk.

Ensemble data:
- System stability and reserve requirements.
- Market dynamics and design.

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Weather data for the win!

REatlas: NEW WIND AND SOLAR POWER TIME SERIES

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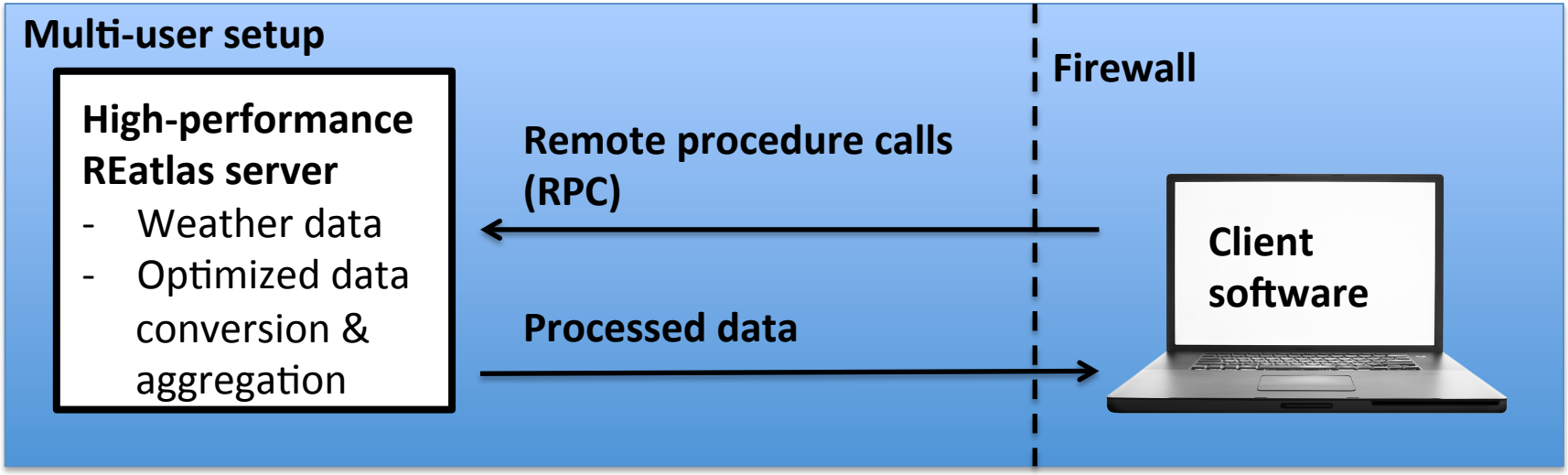
Main design goals

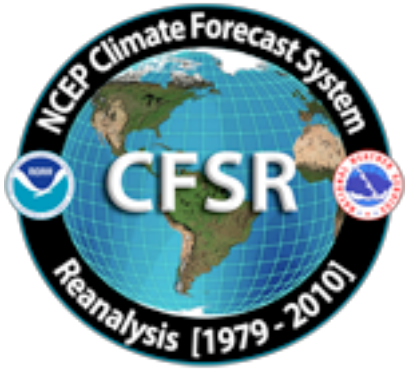
GLOBAL RENEWABLE ENERGY ATLAS

- Flexible and fast (repeated) conversions of different technologies.
- Including cross-correlations between wind and solar.



What does it do?

GLOBAL RENEWABLE ENERGY ATLAS



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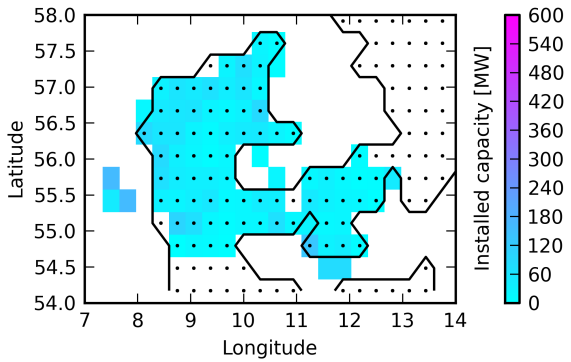
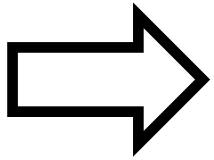
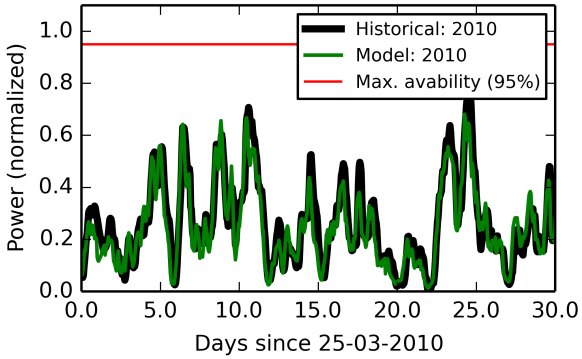


Global state-of-the-art climate data

All Danish wind turbines





The REatlas is a software tool to convert reanalysis data to **time series** of **wind** and **solar** power.

- Global weather data
- Regional data set
- Single time series for a specific technology

See also:

- G. B. Andresen *et al*: "Validation of Danish wind time series from a new global renewable energy atlas for energy system analysis", http://arxiv.org/abs/1409.3353
- S. Becker *et al*: "Features of a fully renewable US electricity system: Optimized mixes of wind and solar PV and transmission grid extensions", Energy **72** (2014).

Some (ongoing) applications

GLOBAL RENEWABLE ENERGY ATLAS

Global renewable power grid

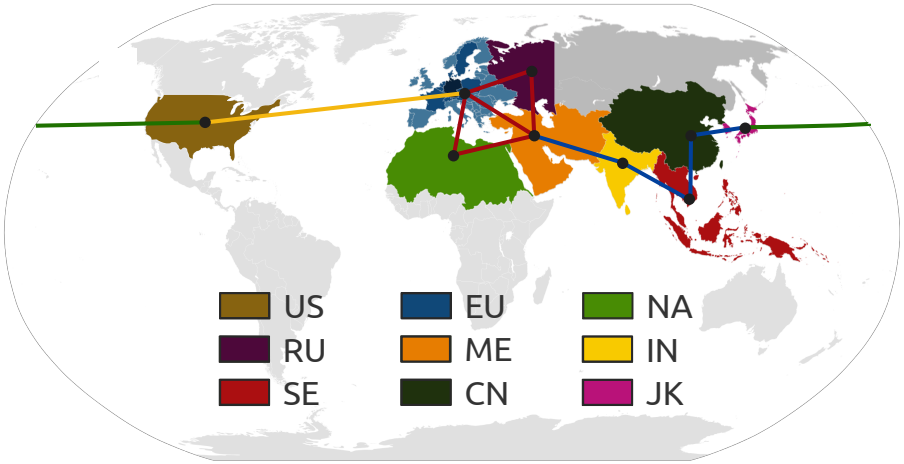
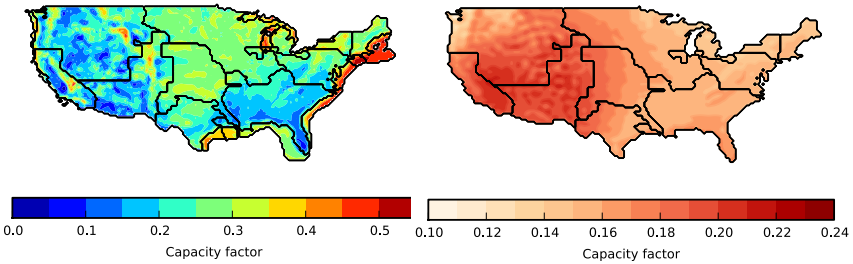
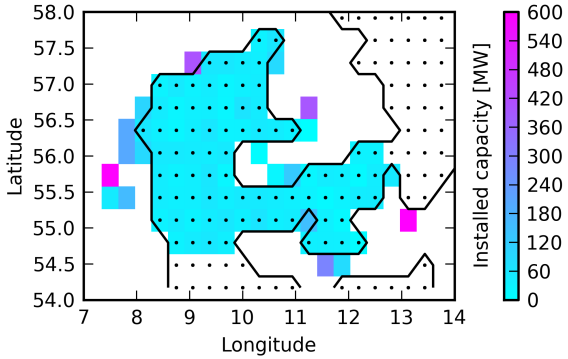


Figure 1: The division of the Northern Hemisphere of the globe into 9 super regions. Load and RES generation time series are aggregated across these super regions.

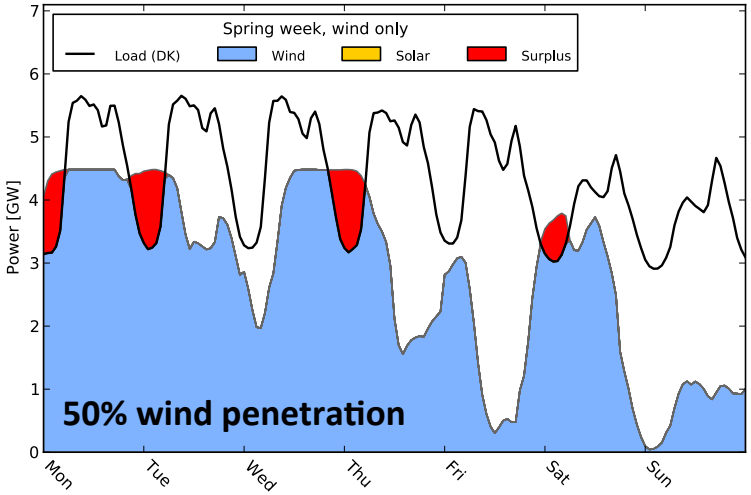
Wind and solar power in the US

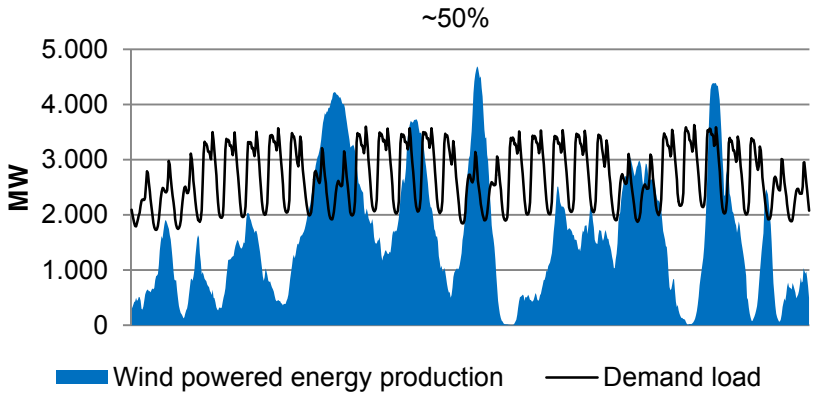


Wind power in Denmark: 2000 - 2035



Germany,
Europe,
Australia …





Stolen from: Klaus B. Hilger, DONG Energy.

Prediction is very hard – especially about the future

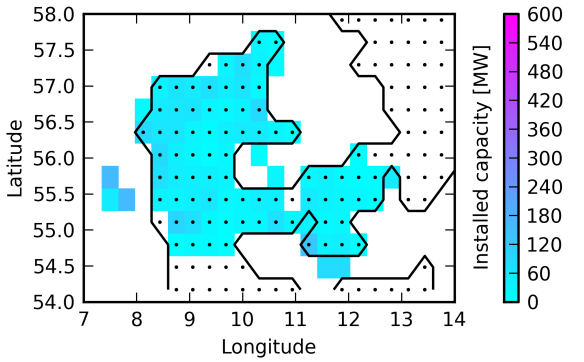
WIND POWER DATA

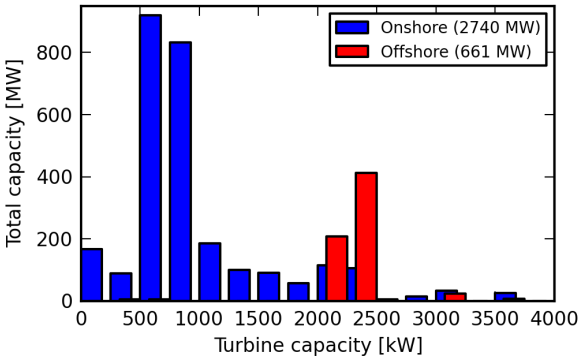
New Danish wind time series

GLOBAL RENEWABLE ENERGY ATLAS

State-of-the-art climate model

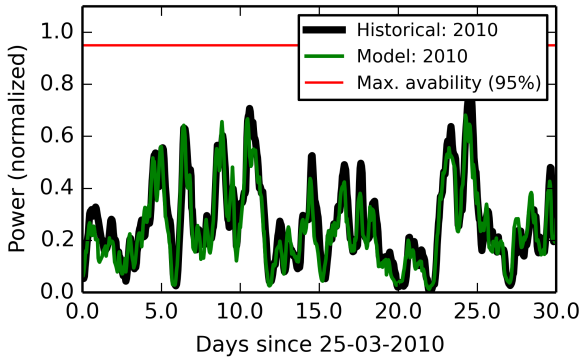
- 30+ years
- 300,000 hours

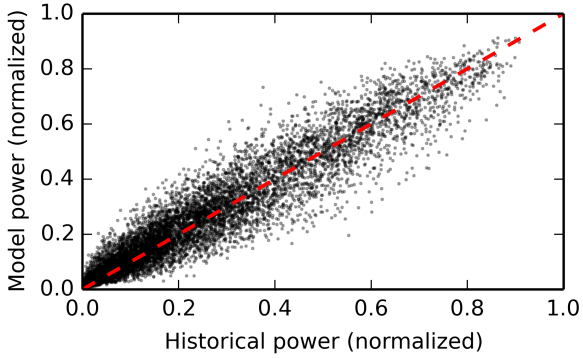




Jan. 1st 2010:

- All Danish turbines





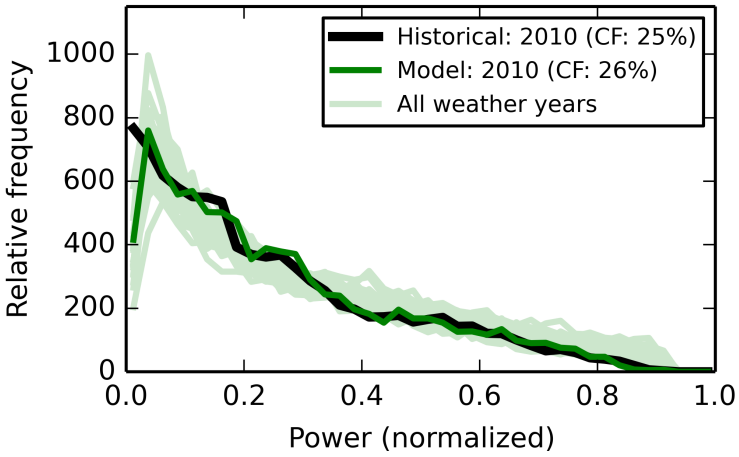
Calibration & validation

- Model vs. historical data.

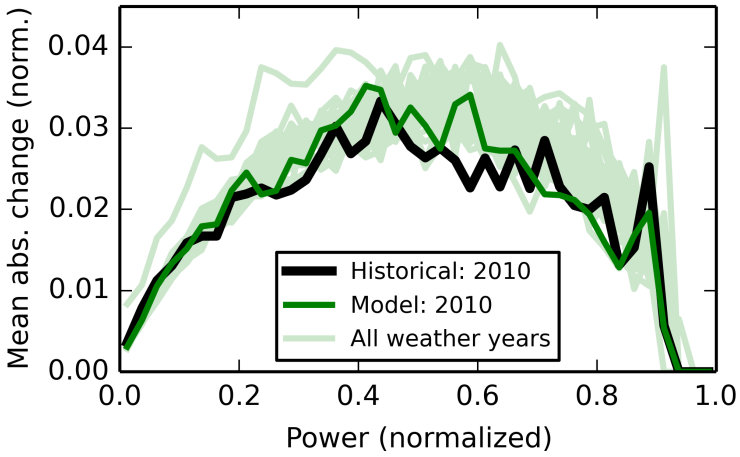
Source: G. B. Andresen *et al.*: "Validation of Danish wind time series from a new global renewable energy atlas for energy system analysis", http://arxiv.org/abs/1409.3353

Other measures for comparison (2010)

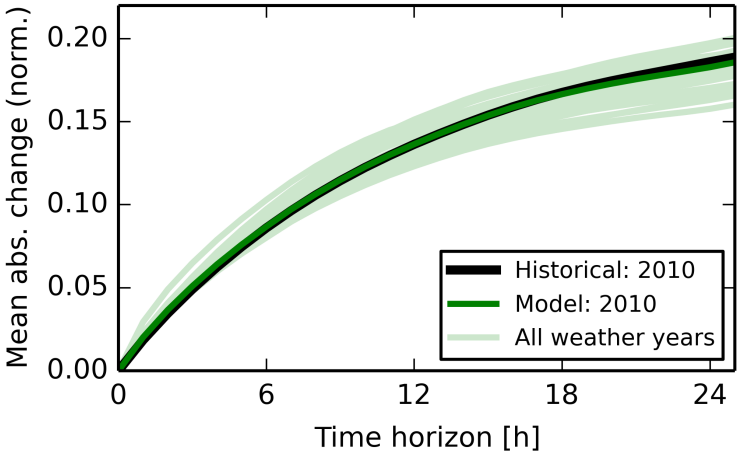
Distribution of power generation:



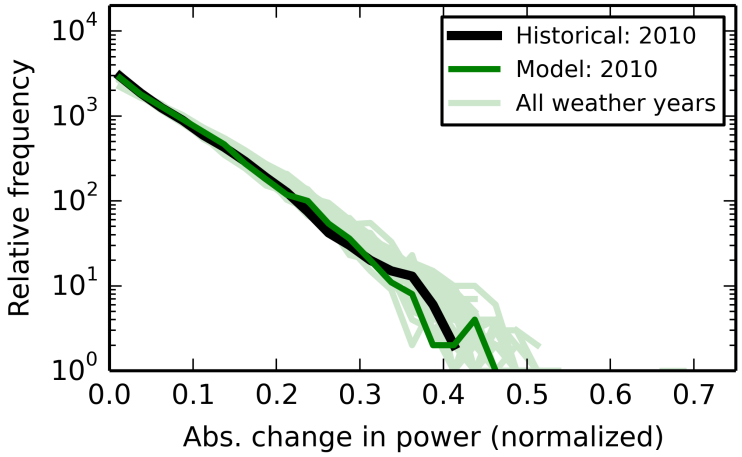
Mean abs. change vs. power generation



Mean abs. change vs time horizon



Distribution of mean abs. change



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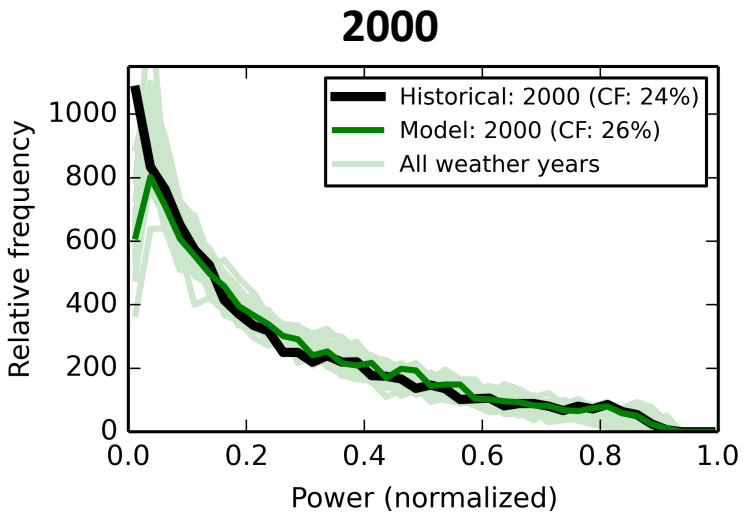
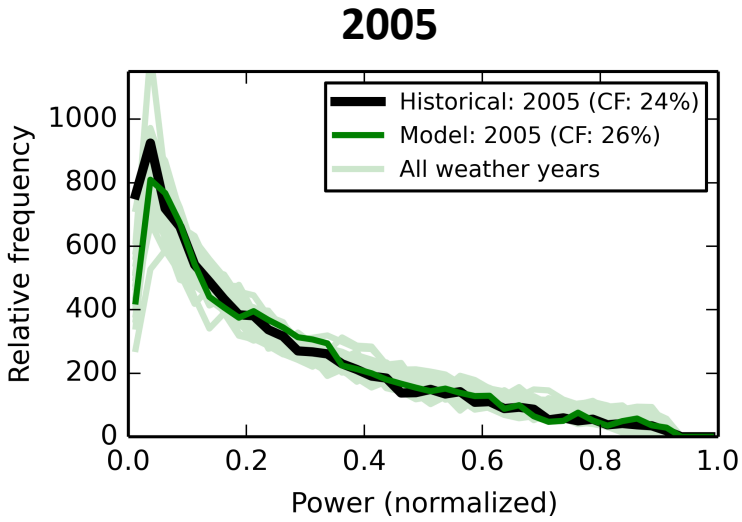
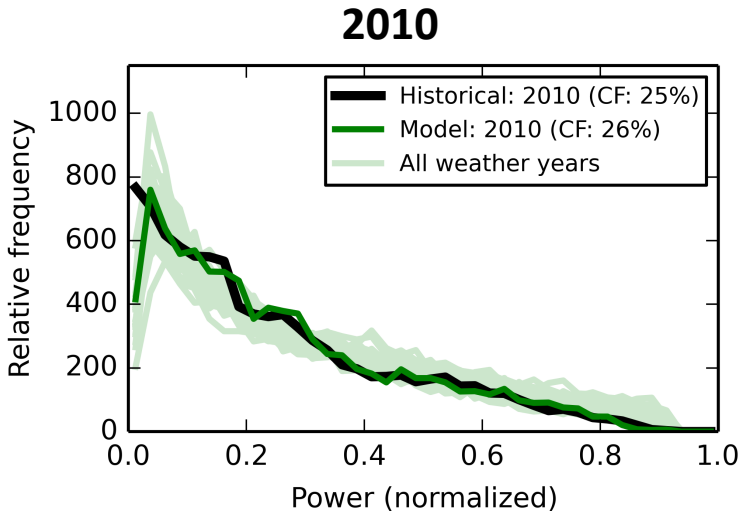
Validation for other historical years







The calibration was done for the year 2010 alone. But it results in good matches for other historical years too.

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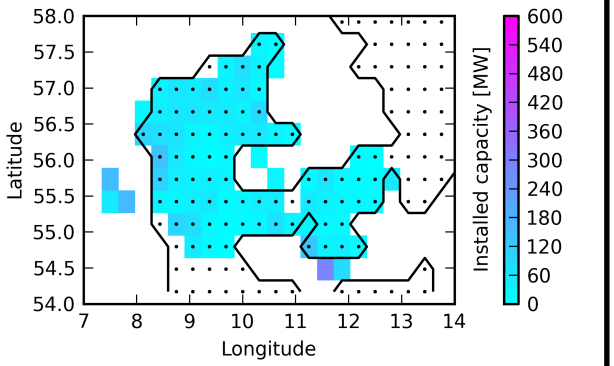
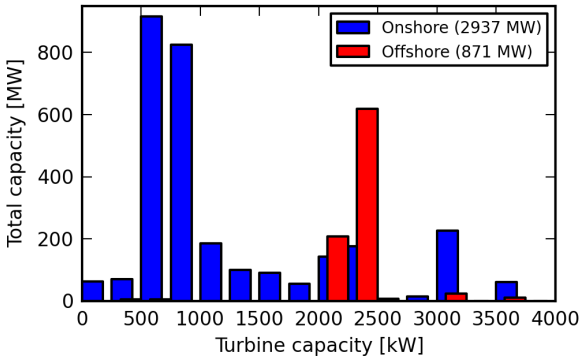
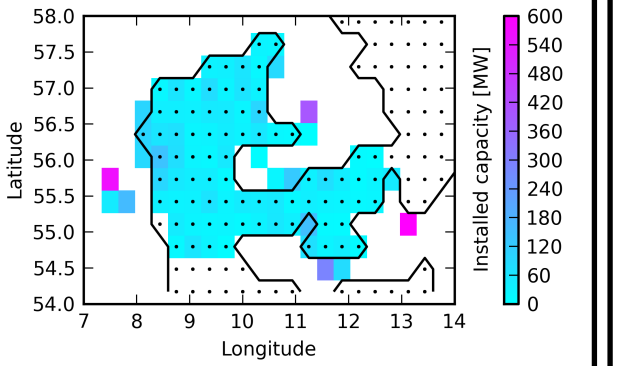
Predicting the future

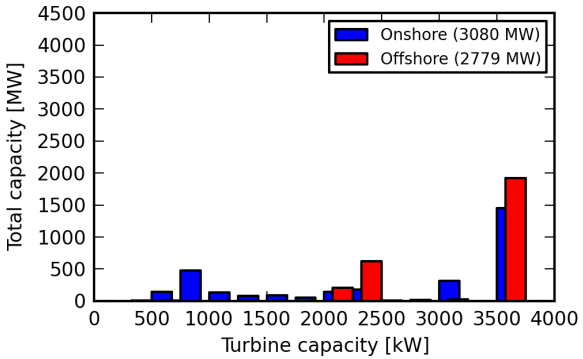




2012

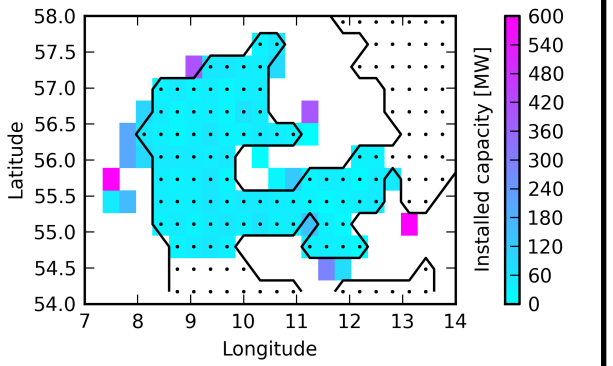
- Many old onshore turbines.
- Some modern offshore parks

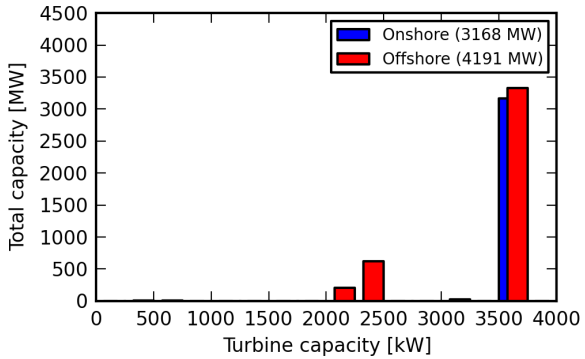




2020

- Partial replacement of old onshore turbines with modern ones.
- Many modern offshore parks.



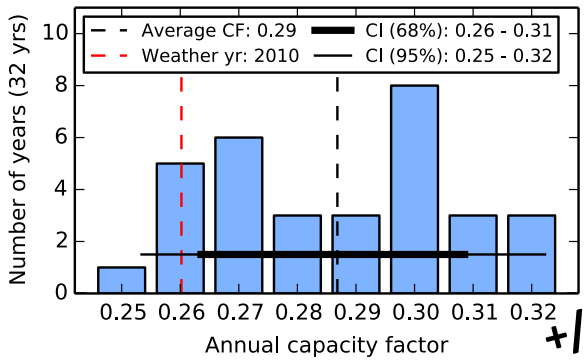


2035

- Full replacement of old onshore turbines with modern ones.
- Many modern offshore parks.

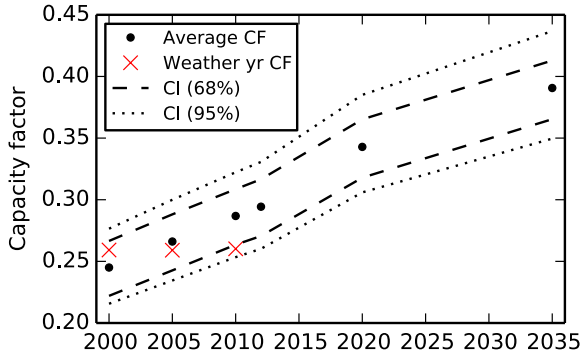
Variations between individual years

Capacity factor (2010)

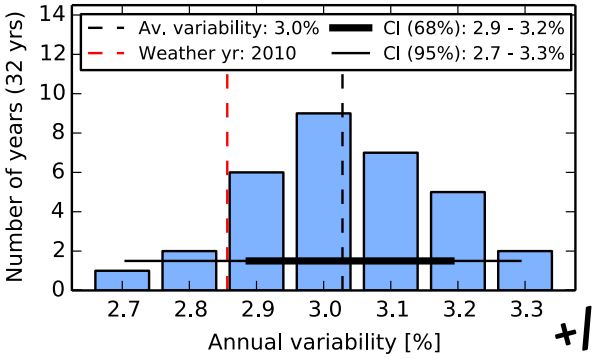


+/- 10%

Projected change: 2000 - 2035

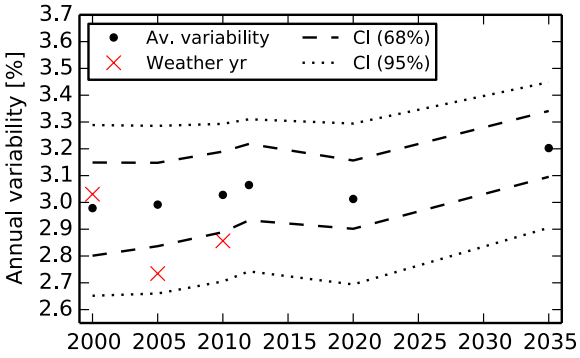


Variability (2010)



+/- 10%

Projected change: 2000 - 2035



Comparison of wind time series

Annual energy production → Capacity Factor

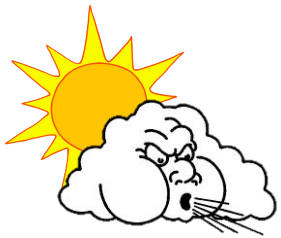
Reserve requirement → Variability

	Capacity Factor	Variability
REatlas 2020	34.3% (30.6;38.5)	3.0% (2.7;3.3)
REatlas 2035	39.1% (35.0;43.7)	3.2% (2.9;3.4)
ISET	40.9% (36.5;44.8)	3.6% (3.3;3.9)
EnergyPLAN	35.5%	3.7%
RAMSES 6.12	36.1%	3.5%
DE	37.9%	2.5%

Most favorable for wind.

- **10 to 15% lower installed capacity** for the the high CF data sets if the annual energy generation is kept constant.
- **40% more reserve capacity** is required if the low variability data is exchanged with the high variability data.

Source: G. B. Andresen *et al.*: "Validation of Danish wind time series from a new global renewable energy atlas for energy system analysis", http://arxiv.org/abs/1409.3353



Summary

- **Good** energy system modeling requires **good** wind and solar power time series.
- A **fast and flexible** Global Renewable Energy Atlas for wind and solar power has been developed.
- For Denmark the REatlas has been validated and applied to predict future wind power.
- Comparison between different *future* model wind power time series show important differences.

PS. Thank you for listening!

Special thanks to:
Anders A. Søndergaard (AU)
Sarah Becker (FIAS)

Funding:
DONG energy
Højteknologifonden
danskenergi

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