ProdBase

Theoretical power production in the time domain using Wind Farm Simulator

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and Erik Berge (Civitas)

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Outline

- What is ProdBase?
- What is Wind Farm Simulator (WFS)?
- Examples/results
- Possibilities

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KVT ProdBase

- **ProdBase** is an interactive web interface
- Presentation of up-to-date wind farm conditions
  - Actual production
  - Estimated / potential / theoretical production
  - Wind speed/direction
- Monitor wind farm health, statistics, *uncover problems early*
- Presented visually (graphs) + data (time series) for download
- *In operational use for 11 wind farms, including offshore*

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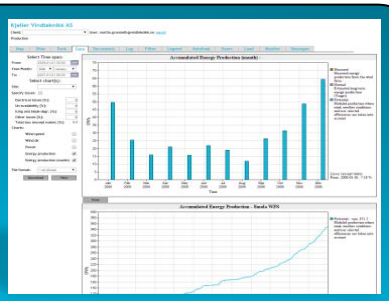
ProdBase
Web interface/frontend



Wind Farm Simulator (WFS)
Backend engine
Estimated production

Meteorological data

SCADA,etc

Real production

Model data
KVTMeso

Measurements
metmast/other

Wind Farm data (from client)

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Wind Farm Simulator (WFS)

- Developed by Statkraft, UiO and Kjeller Vindteknikk
- Simulates meteorological conditions at individual turbines
- Driven by measured data or model data (KVT Meso) (or both)
- Estimate production each time step

- Modules for
  - Wake effects (N. O. Jensen (NOJ), Dynamic Wake Meandering (DWM))
  - Fine scale transfer coefficients between reference point, turbine positions
  - Air density correction
  - High wind hysteresis
  - Rotor equivalent wind speed, REWS (Gryning wind profile)
  - IceLoss (icing conditions, optionally for individual turbines)
  - SCADA data interpreter
  - Downrating/curtailment of individual turbines
  - WFS v1.0 released 2014.

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Statkraft

Forskningsrådet

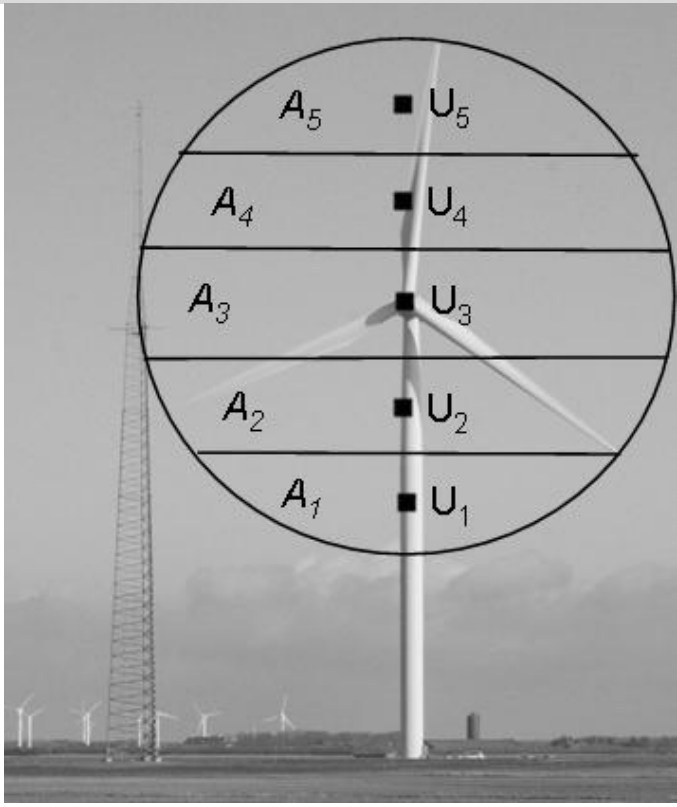
REWS: Rotor Equivalent Wind Speed

- Take into account
  wind shear / wind profile when
  calculating power output of turbine

- REWS to be included in IEC 61400-12-1.
  Definition, Wagner et al. (2014)

$$U_{eq} = \left(\sum_{i=1}^{N_h} U^3{}_i \frac{A_i}{A} \right)^{1/3}$$

- In **Wind Farm Simulator** (**WFS**):
  - Gryning profile (Gryning et al. (2007))
  - For each individual turbine, each time step:
    - Estimate profile
    - Compute REWS
  - Use calculated REWS in wake and power calculations



From Ioannis et al. 2013.

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Theoretical production: Wind Farm Simulator

- Model data as input
  - Wind speed, wind direction, Turbulence Intensity (TI), +++
- Density correction (each timestep), correct use of power curve
- Scaling free wind at each turbine (WAsP; 12 or 36 sectors)
- REWS (Rotor Equivalent Wind Speed), account for wind shear.
- Wake model, loop all turbines downwind, each time step
- Time dependent IceLoss, scaled to match target percentage
- Production at individual turbines *(only the grand total is presented currently)*
- *Scale model wind speed so*

  target AEP (Annual Energy Production) is reached,

  iteration for reference period (14 years).

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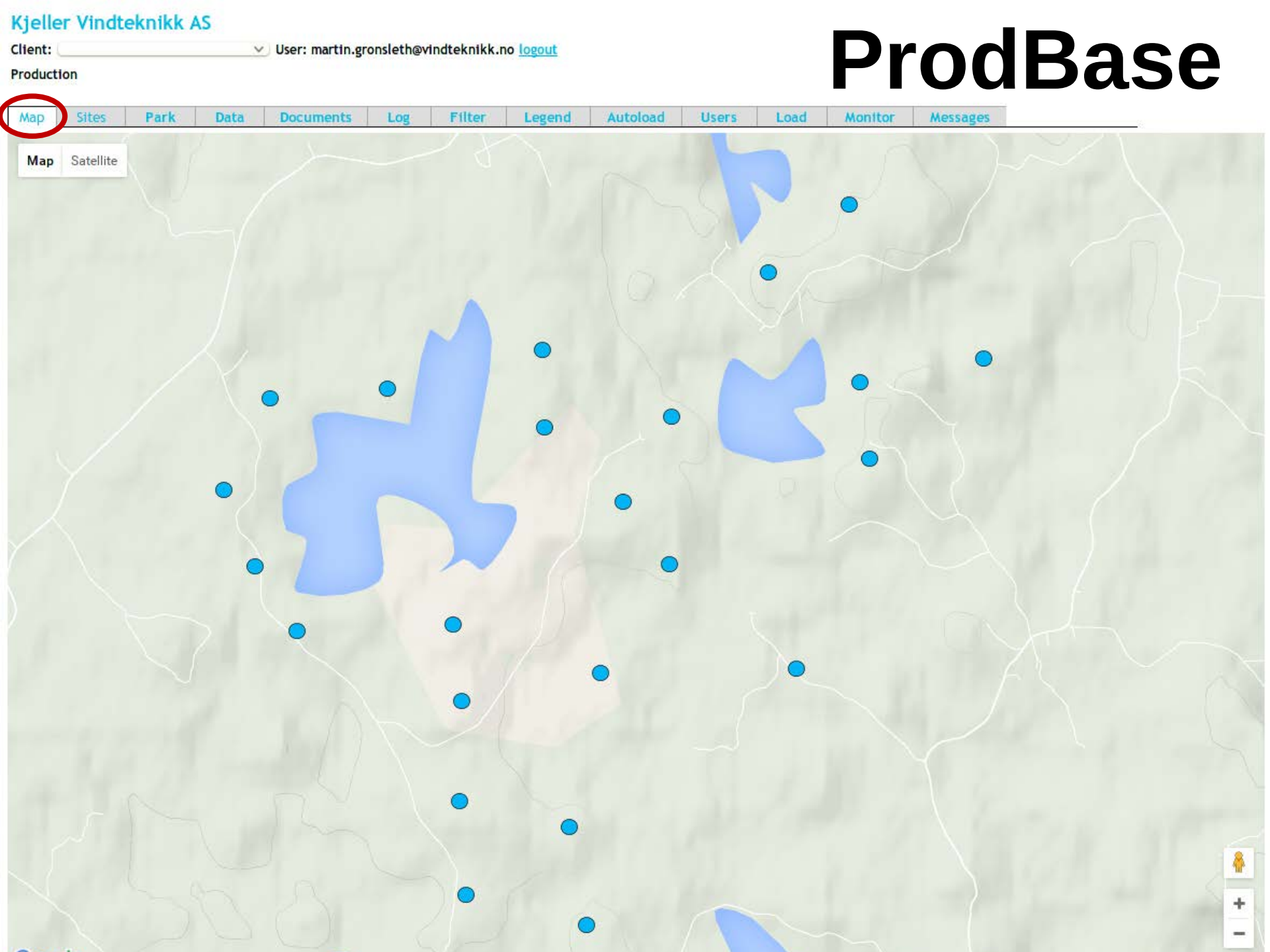
KVT ProdBase
Examples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Client:
User: martin.gronsleth@vindteknikk.no logout
Production
ProdBase
Map
Sites
Park
Data
Documents
Log
Filter
Legend
Autoload
Users
Load
Monitor
Messages
Map
Satellite

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Production

Map | Sites | Park | Data | Documents | Log | Filter | Legend | Autoload | Users

Site:

Park settings:

2000-01-01

Gross annual production (wake losses included):	[redacted]	GWh
Gross annual production (wake and ice losses included):		GWh
of which ice losses constitutes:		%
Electrical losses		%
Un-availability		%
Blade degradation		%
Other losses		%
Total loss (except wake and ice):		%
Net annual production:		GWh

Loss parameteres valid from: 2000-01-01

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Production

Map | Sites | Park | Data | Documents | Log | Filter | Legend | Autoload | Users | Load | Monitor

Select Time span:

From: 2016-01-01 00:(

Year/Month: 2016 January

To: 2016-01-14 12::

Select chart(s):

Site:

Specify losses:

Electrical losses [%]:

Un-availability [%]:

Blade degradation [%]:

Other losses [%]:

Total loss (except wake and ice):

Charts:

Wind speed

Wind dir

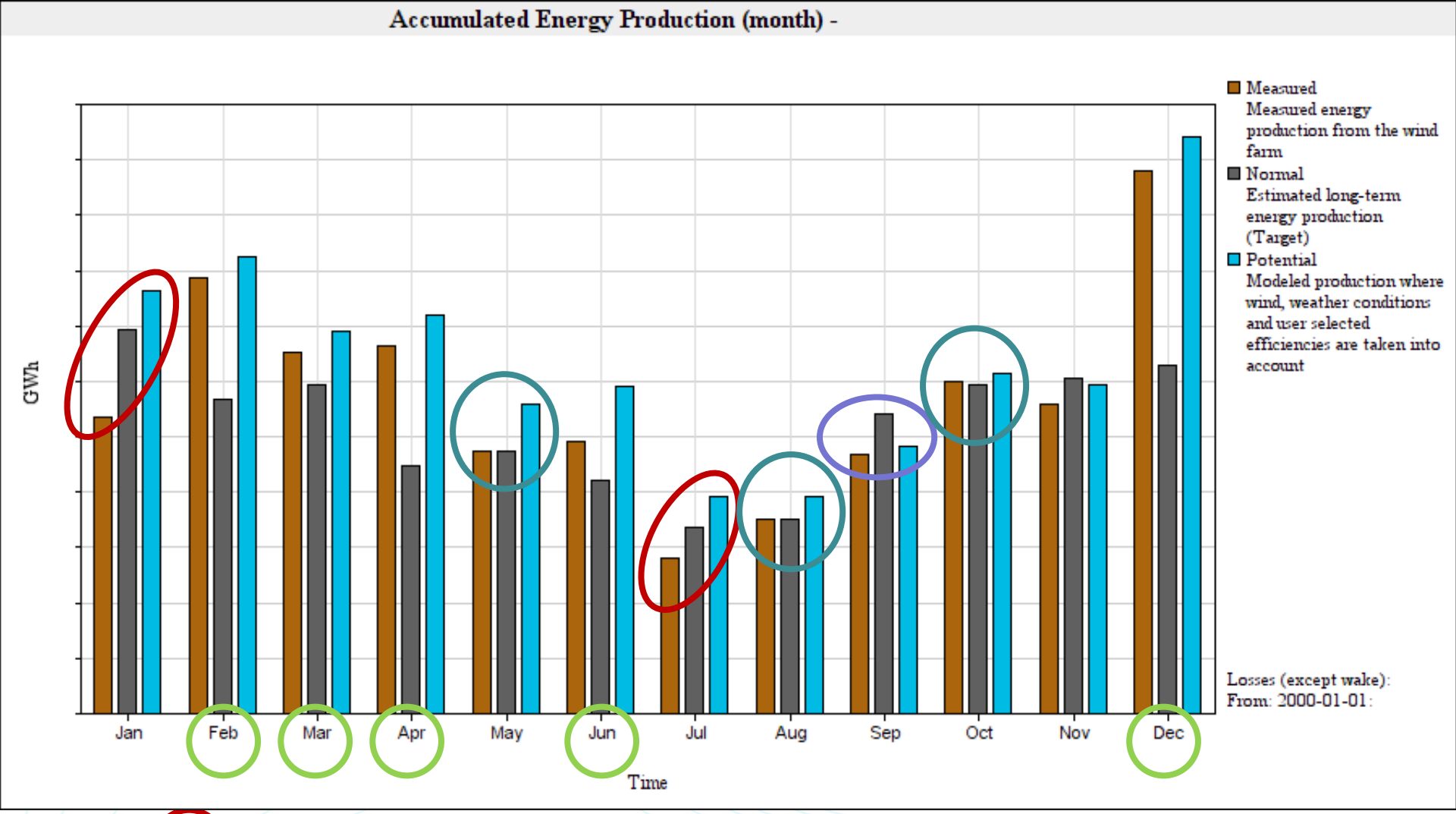
Power

Energy production

Energy production (month)

File format: *.xls (Excel)

Download View



1. Underperformance (icing/maintenance/other?)
2. Performance as normal year, OK?
3. Overperformance? No
4. Problems? No!

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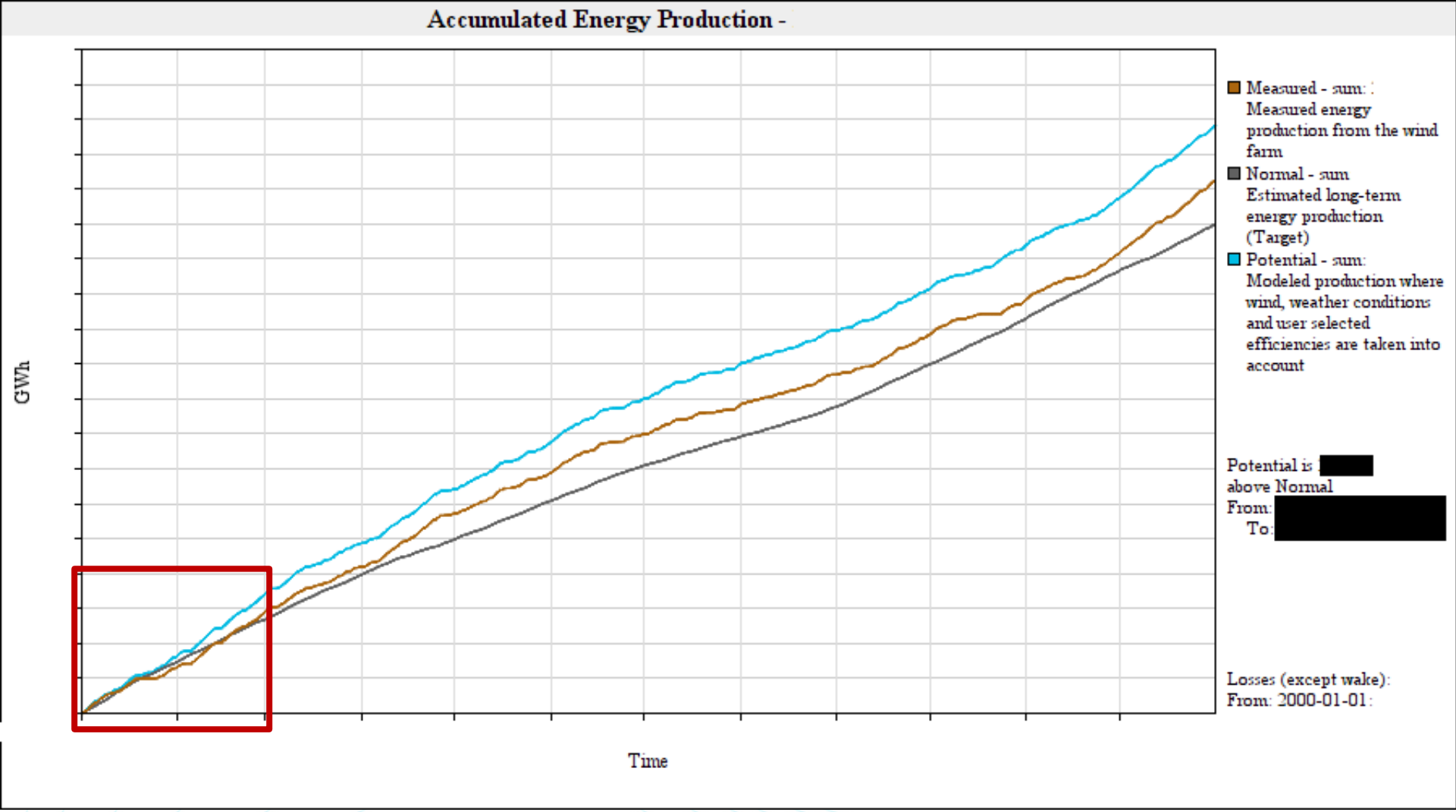

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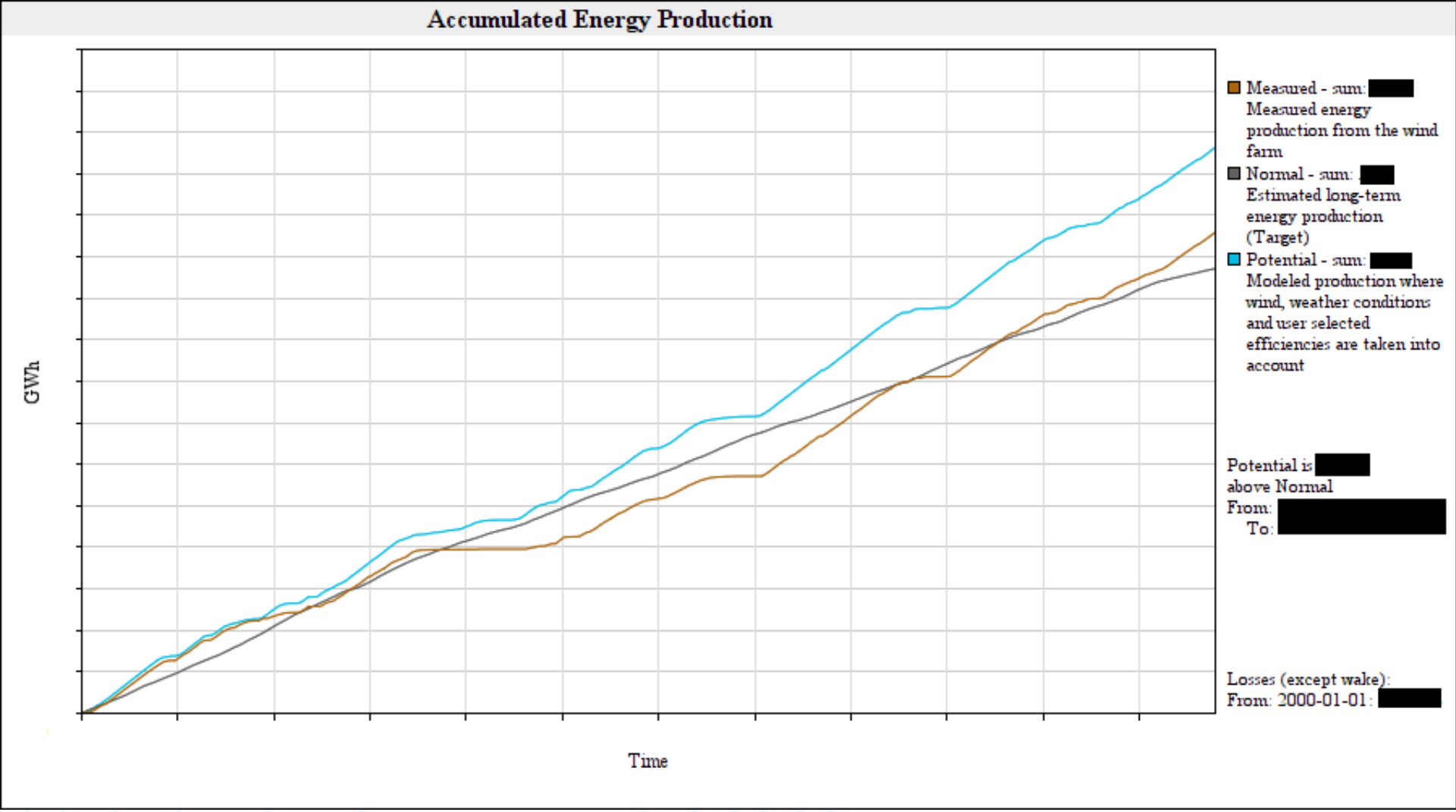
Accumulated Energy Production



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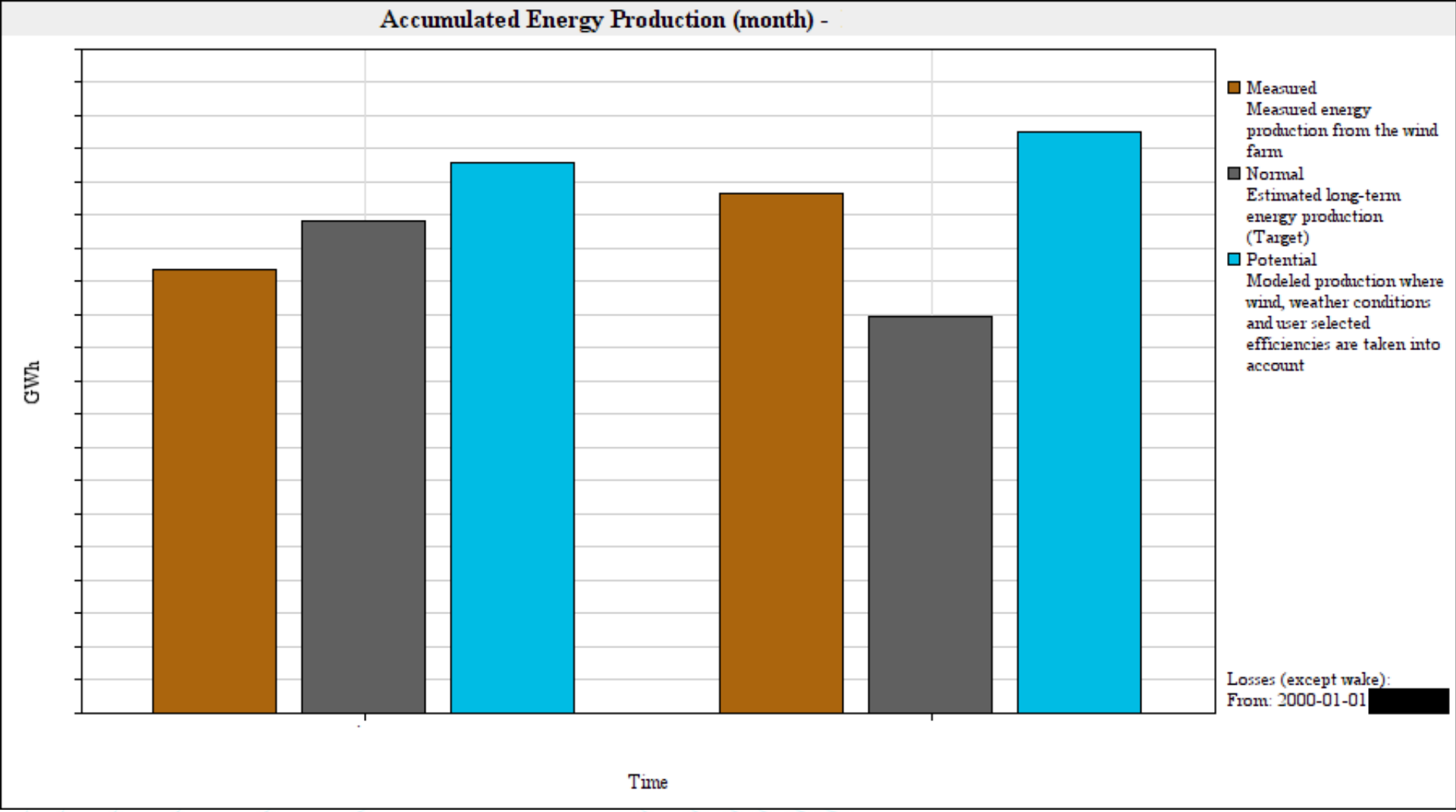

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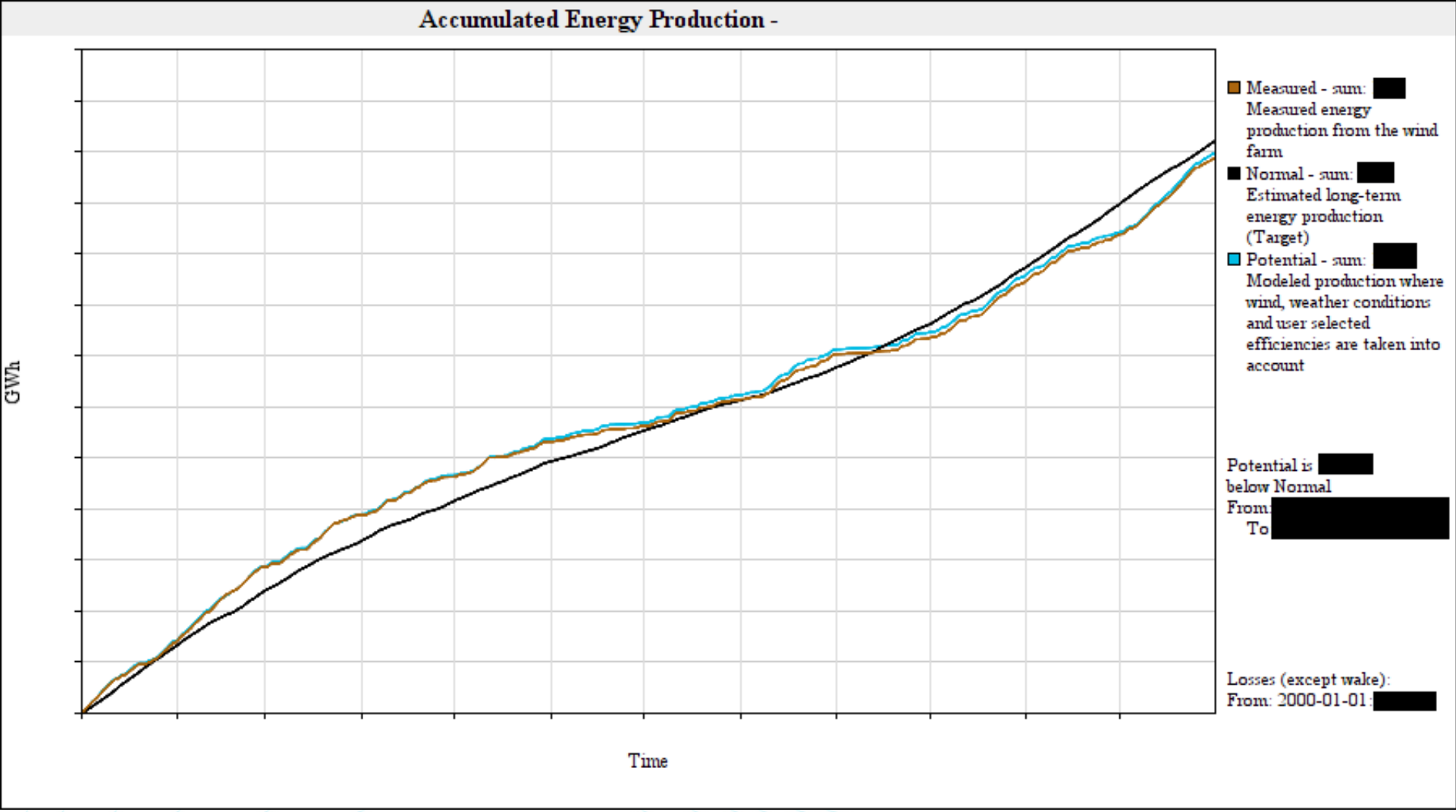
Offshore



- Offshore farm, Year A
- Real production <1 % under potential / theoretical production

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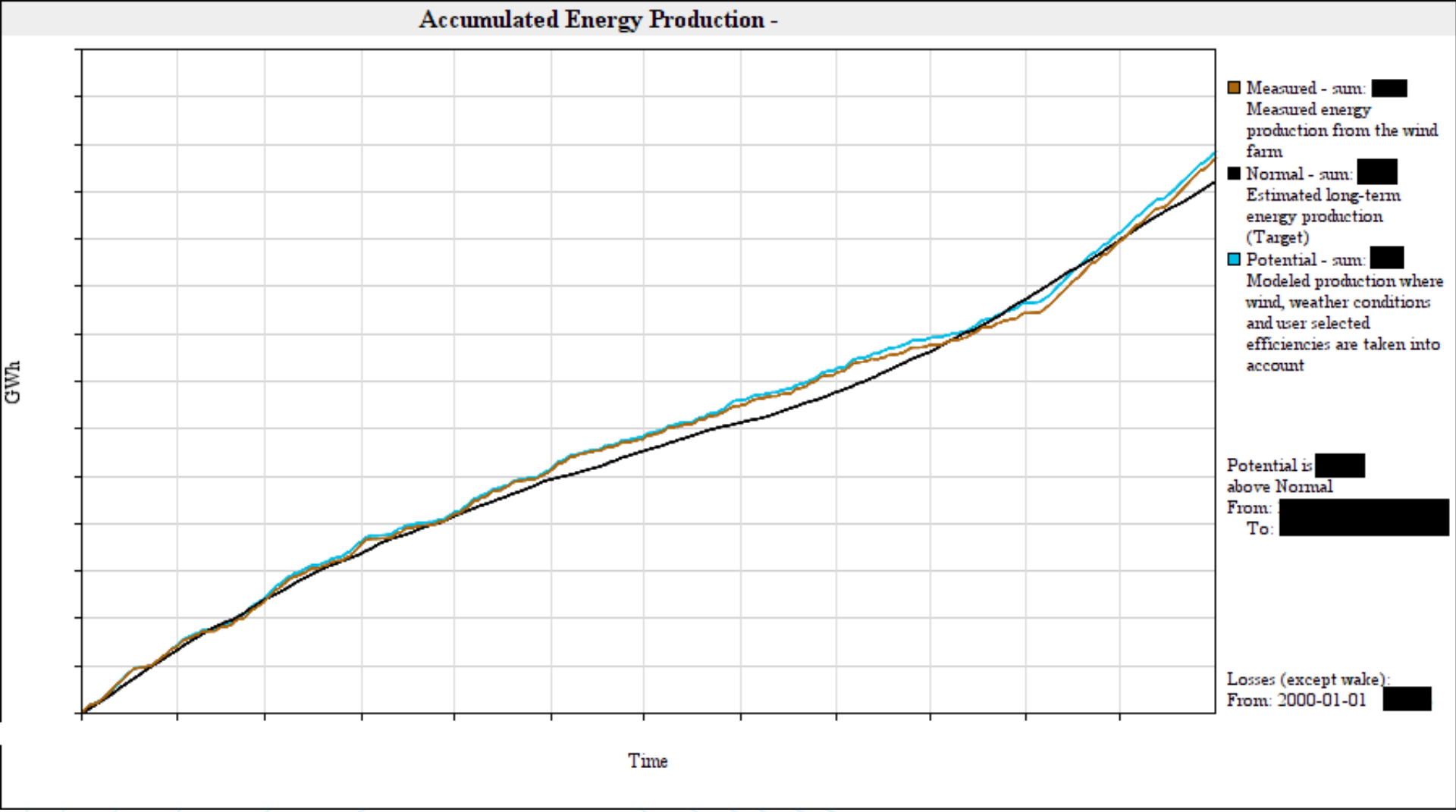

- Offshore farm, Year B
- Real production ~1% under potential / theoretical production

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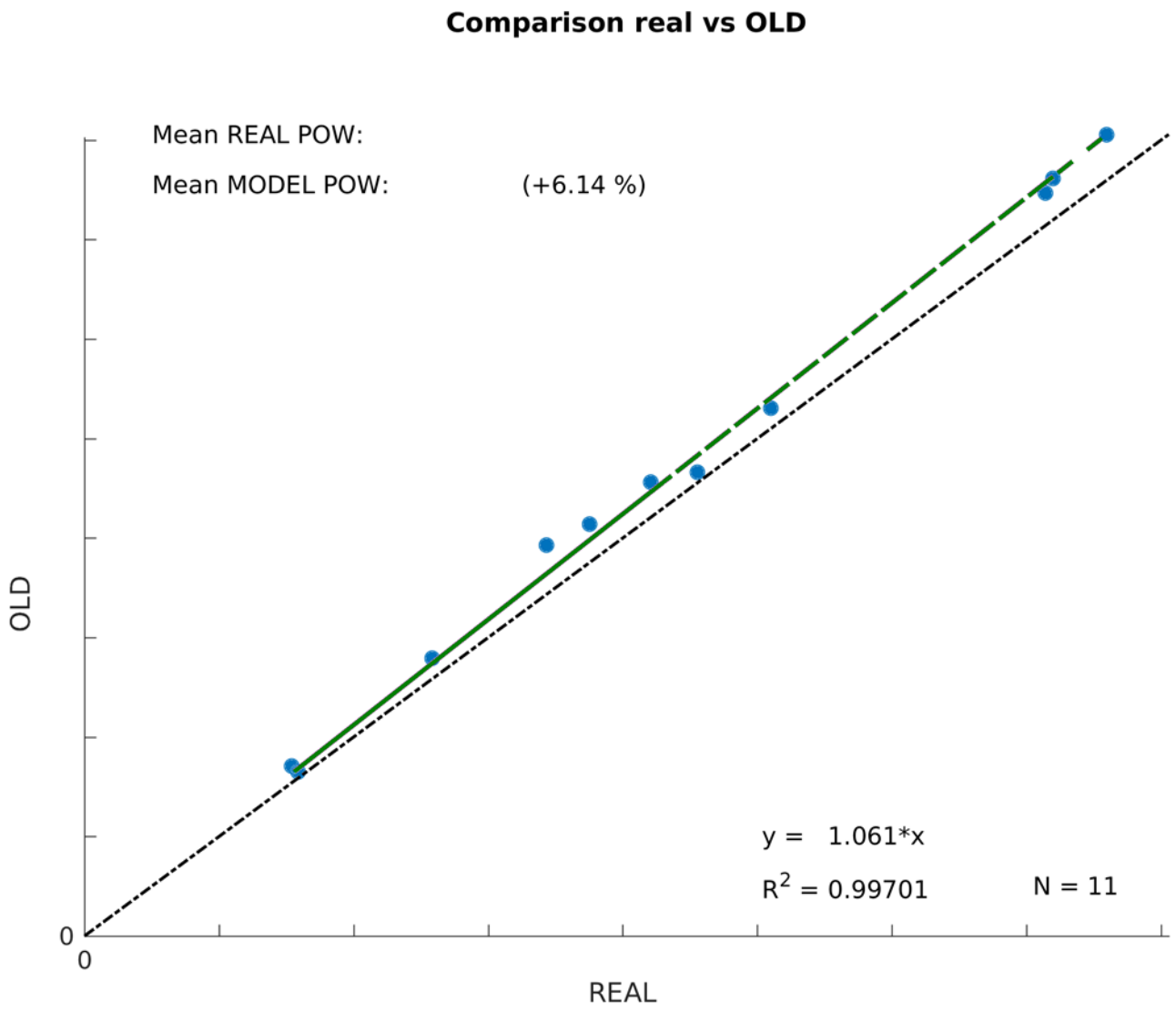
OLD Method (park power curve)



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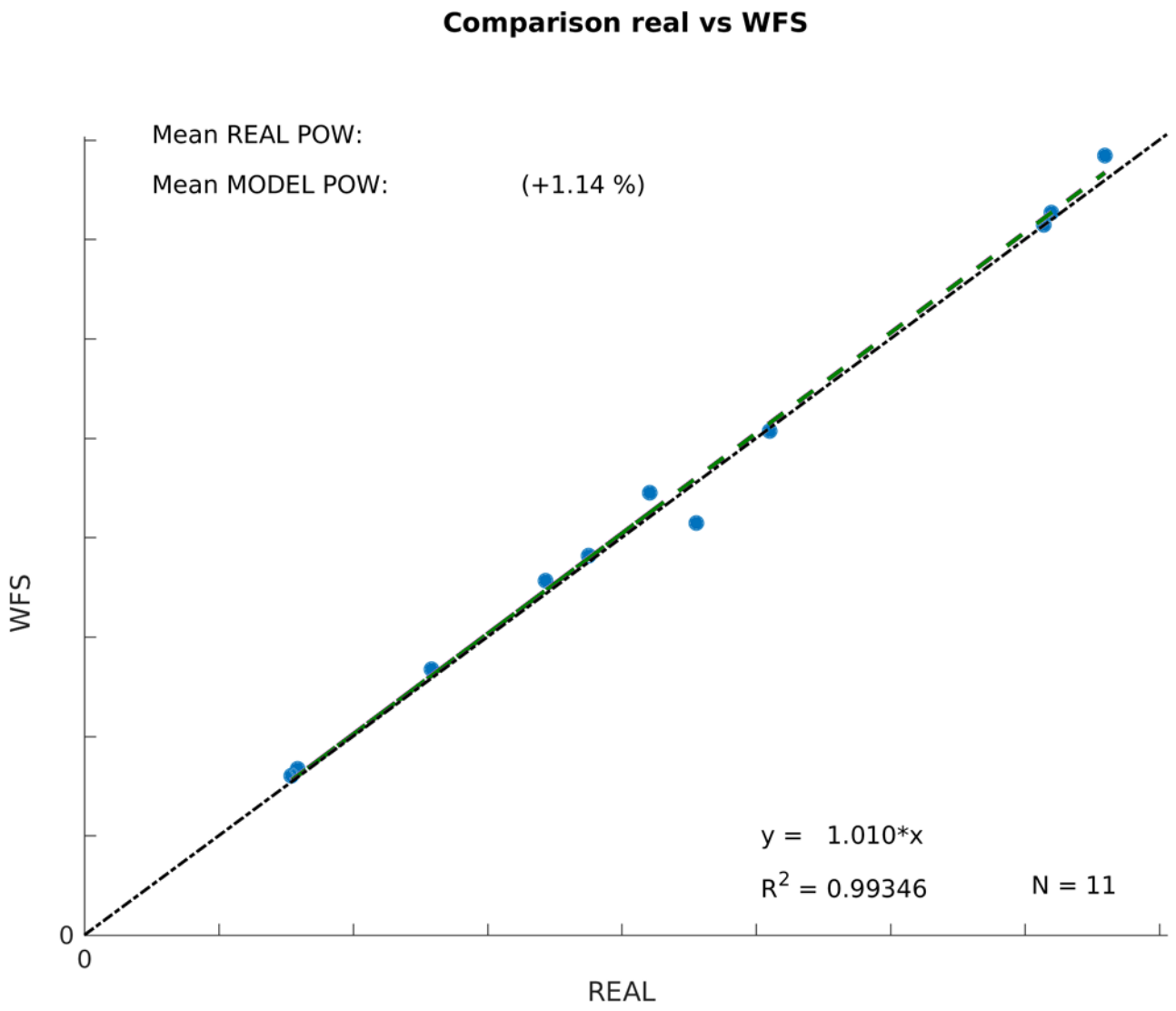
WFS without Rotor Equiv. Wind Speed (REWS)



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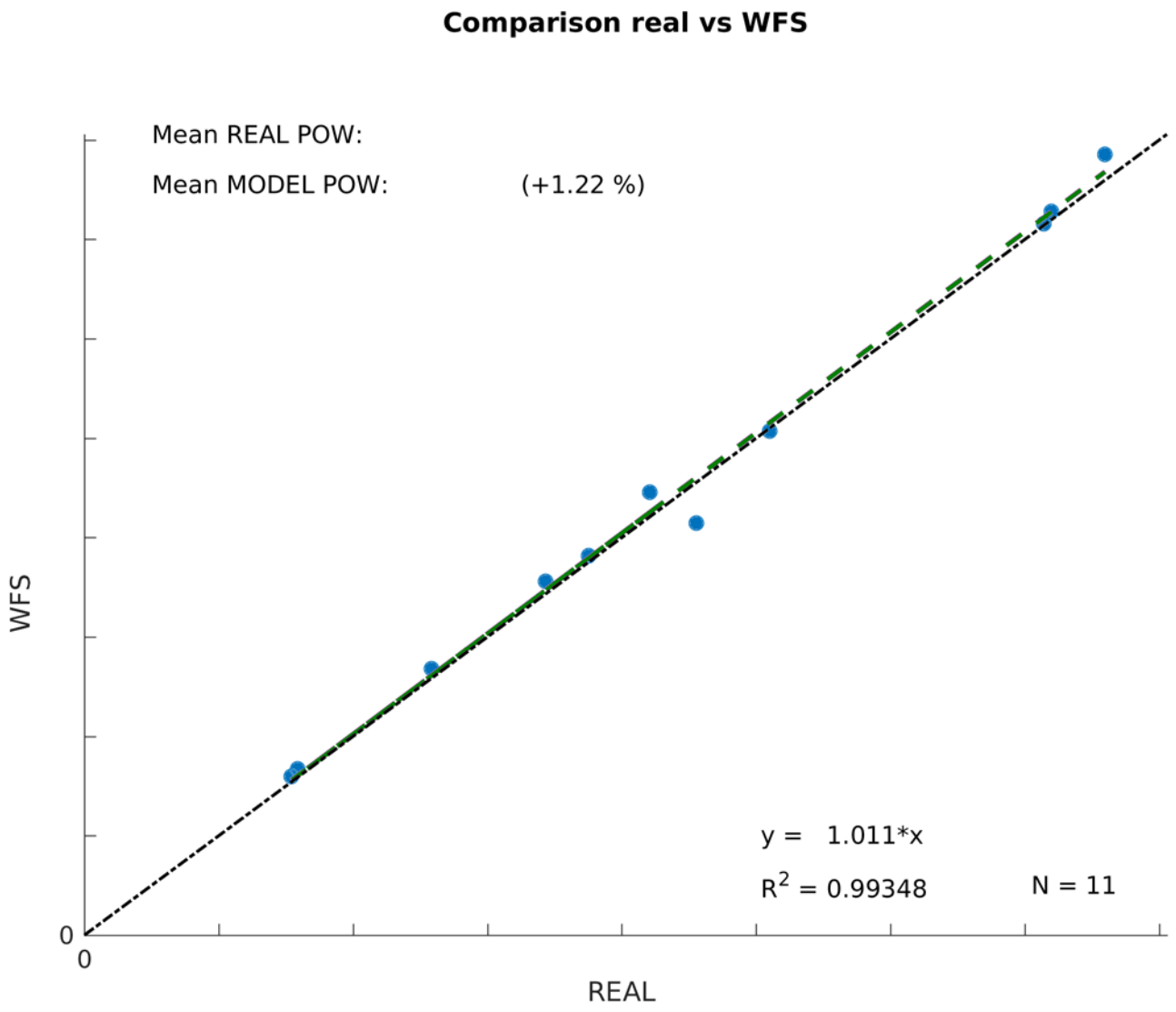
WFS with Rotor Equiv. Wind Speed (REWS)



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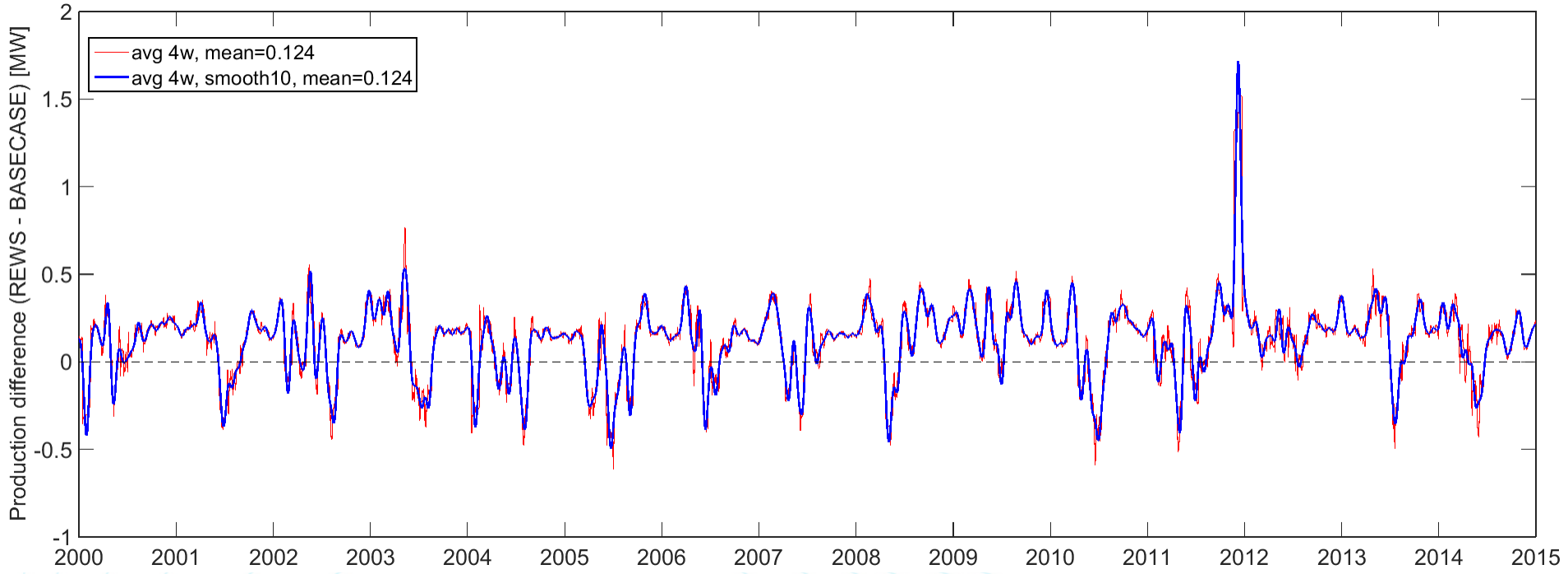
Effect of Rotor Equiv. Wind Speed (REWS) on potential production Offshore



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Possibilities with WFS and ProdBase

- Currently only historical, total production presented in ProdBase

Future:

- Present data from individual turbines
- Forecast of power production
  - Next hour(s)
  - Next day(s)
- Optimize operation <- simulate scenarios
- Maintenance planning. Minimize loss during downtime.
- Include observations within wind farm as input to WFS
- Take operational status into account (*SCADA*)
- Use individual power curves, conditional curtailment
- Extend ProdBase to other platforms, mobile, app.
- More…

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Thank you!

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Example on results from Gryning et al. (2007):

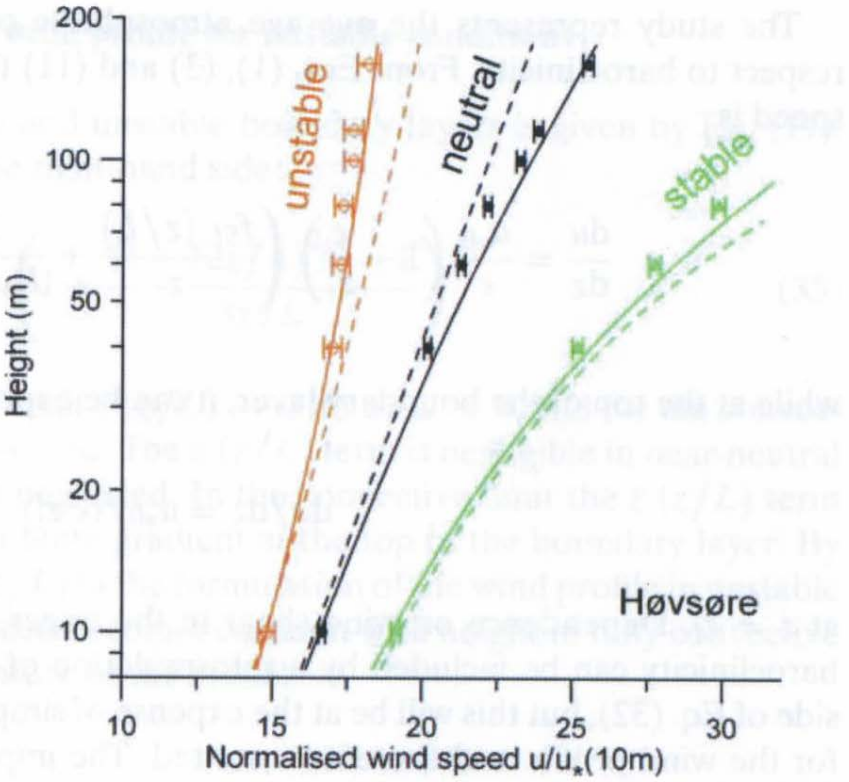

Fig. 7 Comparison between surface layer theory with Monin-Obukhov scaling for the stability according to Dyer (1974) (dashed lines) and the wind profile expressions suggested here (full lines). The stability ranges of L are: unstable (−50 to −100 m), neutral (−500 to 500 m) and stable (50 to 200 m). Measurements from Høvsøre site are shown by symbols and bars indicate the standard deviation of the mean wind speed. The values of L and z_0 that are used in the wind profile calculations are given in Table 3, and those of z_i in Table 2