Ökad kunskap och förbättrade modeller genom en kombination av observationer och modellering

Produktionsförluster pga nedisning och blockerings effekter

Stefan Söderberg

Använd det bästa från två världar!

Genom att kombinera modellering med observationer kan vi bättre förstå komplexa processer och utveckla modeller för att beskriva dessa vilket inte annars vore möjligt.

Produktionsförluster på grund av nedisning

DNV GL joins forces with Swedish cold climate experts WeatherTech

The combined expertise of DNV GL and WeatherTech will enable the development of an innovative new icing model, which can be applied globally to better predict the performance of wind turbines in cold climates

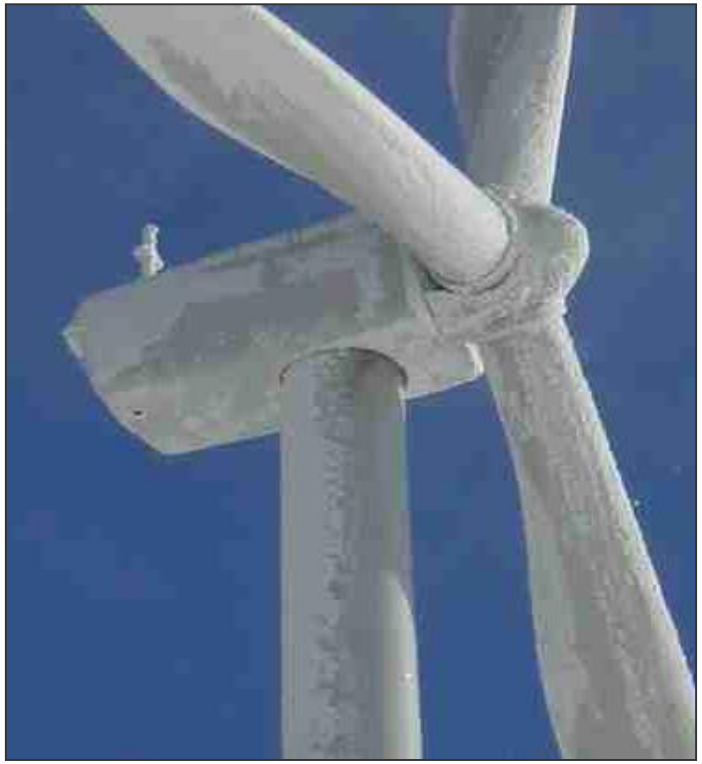
Published: 13 September 2018 **Author:** Mona Ghobadi **Keywords:** Wind energy, Energy

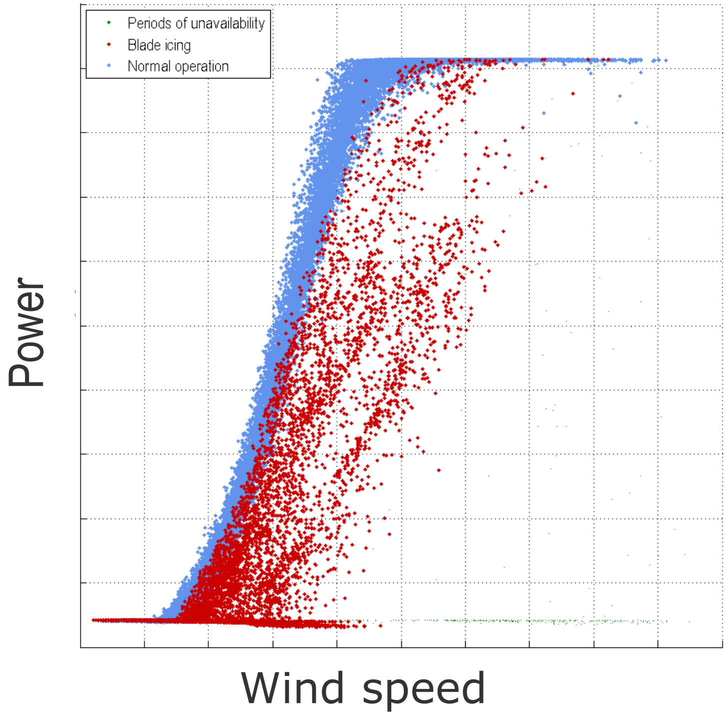
Contact: Prajeev Rasiah Regional Manager, Energy-North West Europe, Middle East & Africa

STOCKHOLM, Sweden - 13 September 2018 – DNV GL, the world's largest resource of independent energy experts and certification body, today announced that it has joined forces with Swedish atmospheric science experts, WeatherTech. The combined expertise of both companies will enable the development of the most advanced icing model for wind turbines available on the market, allowing customers to better predict the performance of turbines in cold climates.

https://www.dnvgl.com/news/dnv-gl-joins-forces-with-swedish-cold-climate-experts-weathertech-129038

Produktionsförluster på grund av nedisning

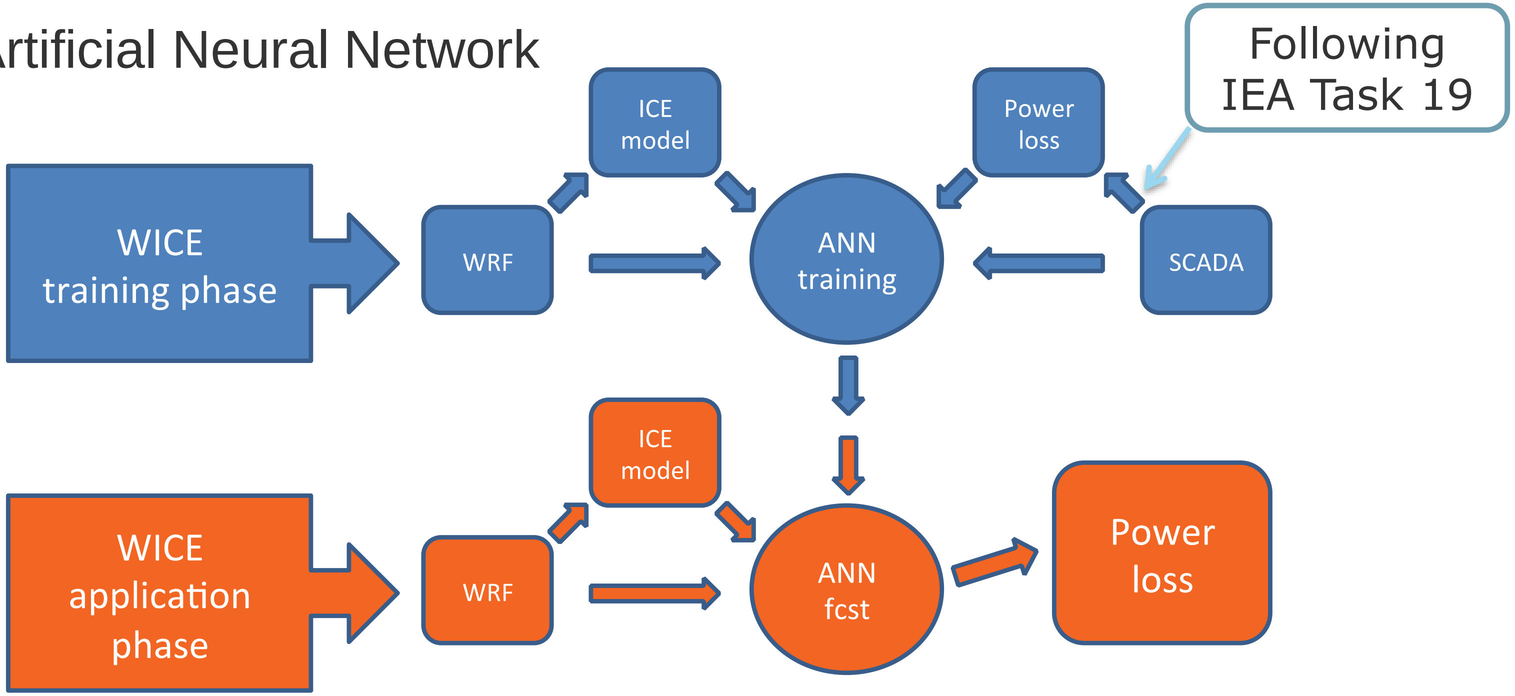




Produktionsförlustmodell - WICE

A combination of physical and statistical modelling

ANN – Artificial Neural Network



WICE modellkedja

NWP

- WRF model
- High resolution
- Microphysics

2013
2016

Ice model

- Makkonen
- Turbine blade
- IPS

2013
2014
2018

Production loss

- WICE
- SCADA

EWEA 2013 VIENNA
EUROPE'S PREMIER WIND ENERGY EVENT
4 - 7 FEBRUARY

2013

Long term

- 30yrs
- Condensates

2012
2015
2017

WICE validering och vidareutveckling

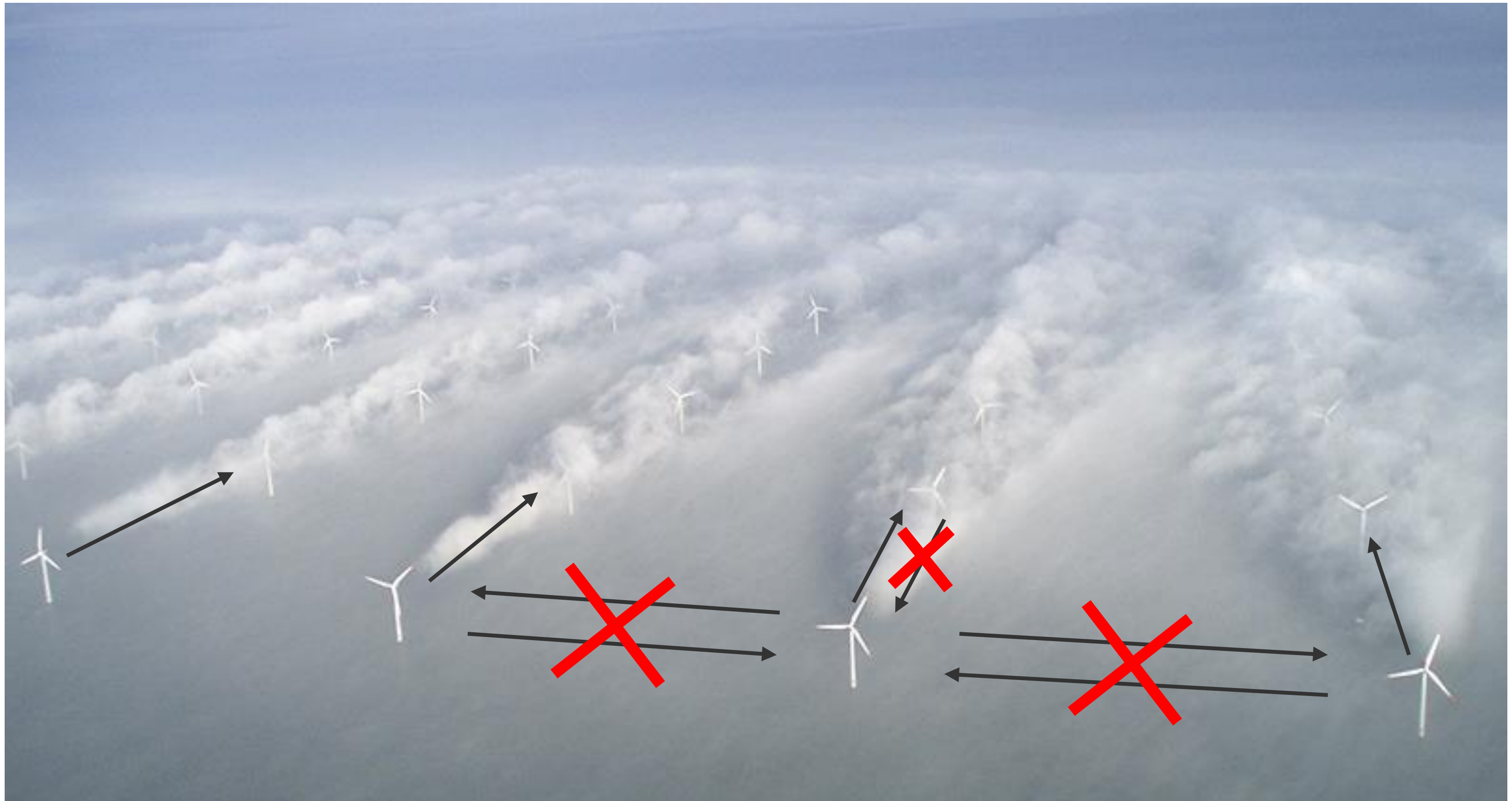
- Pågående valideringsstudie;
- Inkludera ett större dataset i träningen;
- Lägga till effekten av underkylt regn;

Blockage effect

James Bleeg, Mark Purcell, Renzo Ruisi, Elizabeth Traiger, Carl Ostridge, Christiane Montavon

DNV·GL

Traditional approach in wind industry: wakes-only turbine interaction



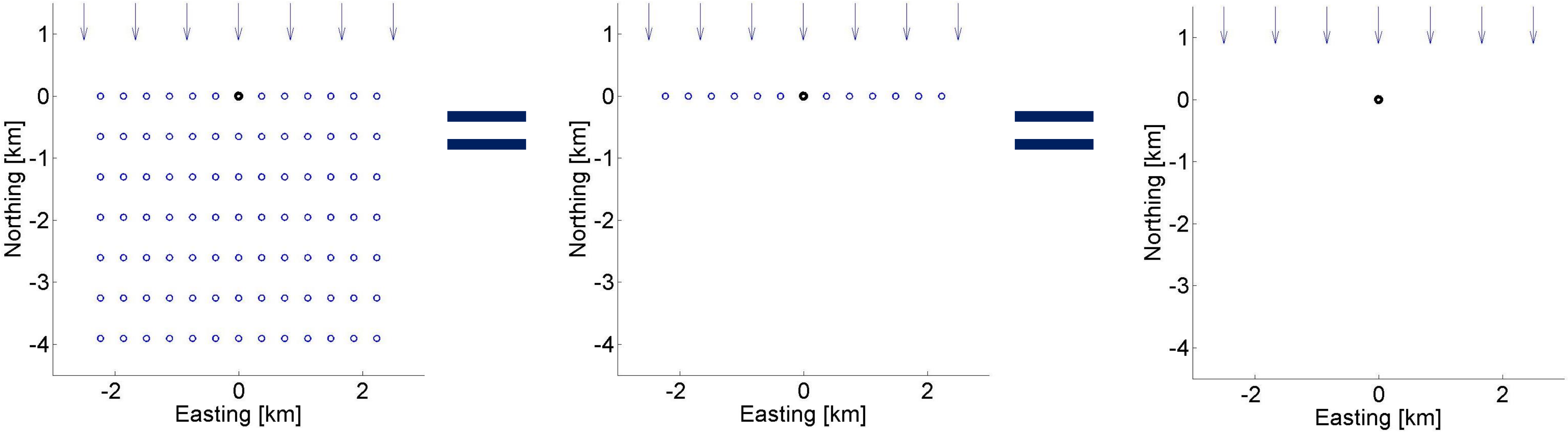
Courtesy: Vattenfall. Photographer is Christian Steiness

EPAs almost always assumes that turbine interactions are limited to wake effects and their impact on turbines downstream—any influence of a turbine on turbines upstream or laterally is ignored.

EPA : Energy Production Assessment

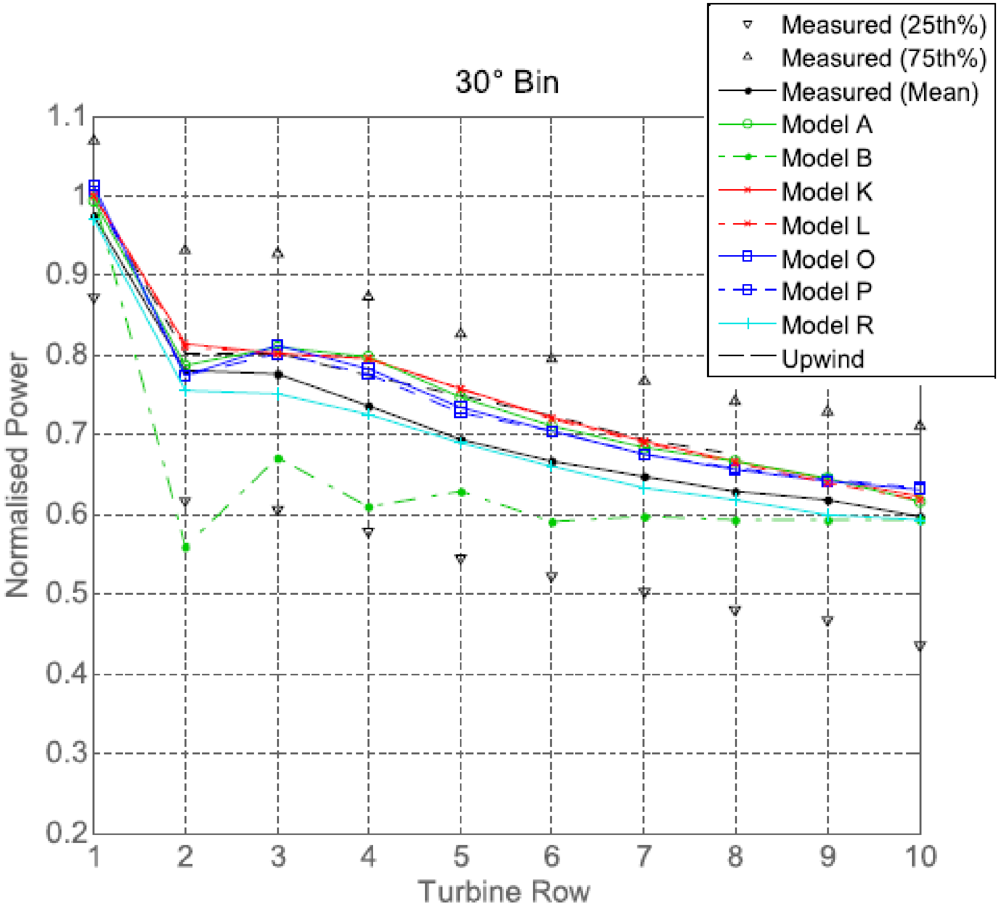
The wakes-only turbine interaction (continued)

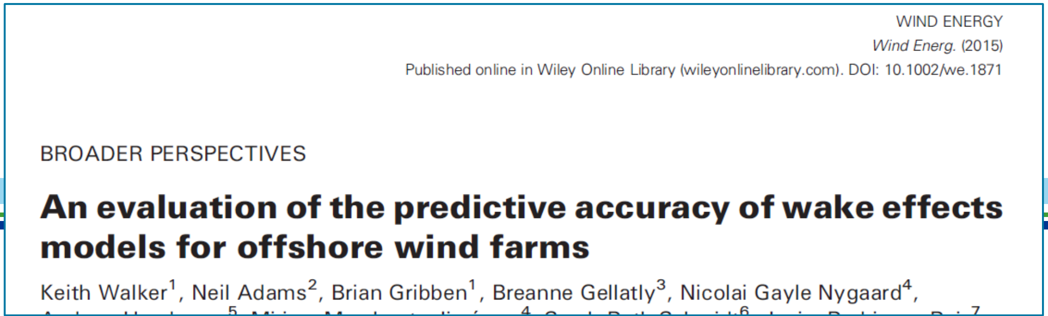
The wakes-only approach assume that the highlighted turbine produces the same amount of energy in each of the three situations below.



We are not aware of any direct evidence substantiating this assumption.

Turbine interactions in EPAs





WIND ENERGY
Wind Energ. (2015)
Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/we.1871

BROADER PERSPECTIVES

An evaluation of the predictive accuracy of wake effects models for offshore wind farms

Keith Walker[1], Neil Adams[2], Brian Gribben[1], Breanne Gellatly[3], Nicolai Gayle Nygaard[4],

Current practice in the wind industry:

$$E_{Potential} = \eta_{wake} E_{Gross}$$

- η_{wake} from wind farm flow models
- E_{Gross} yield if all turbines operating in isolation
- ‘Wakes-only’ models are validated (tuned) to predict the row-by-row *variation* of $P_i/P_{upstream}$ seen in SCADA data

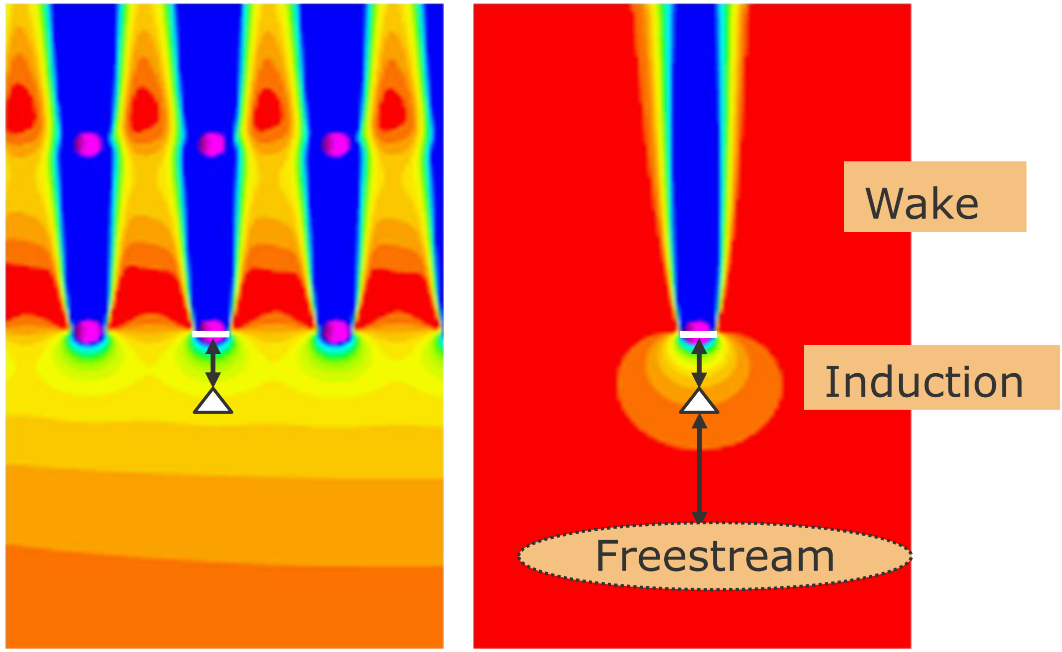
*If an upstream row underproduces isolated operation by 2%, then the wakes-only approach will on average overpredict energy production for the **entire wind farm** by the same 2%.*

Additional loss - ‘wind-farm-scale blockage’

Wind-farm-scale blockage – what is it?

- Single turbines modify the flow around them:
  - Wake
  - Induction zone upstream
- Array of turbines → turbine interactions:
  - Downstream interactions (traditional wake model)
  - Lateral and upstream interactions too

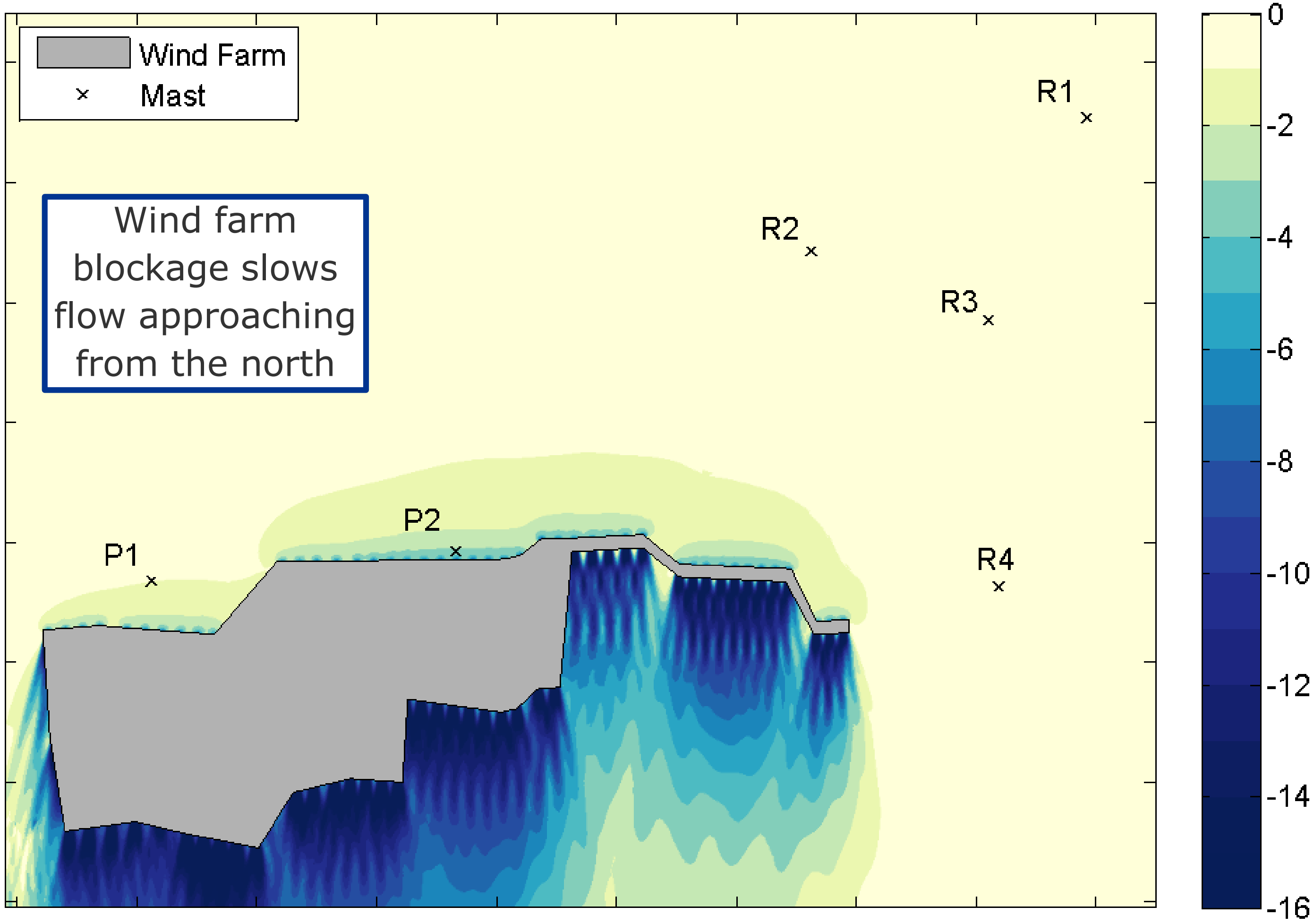
  → flow modification upstream of the array



- Turbines at the upstream edge of the wind farm see, on average, a reduced wind speed compared to when they operate in isolation.
- **Neglected loss by 'wakes-only' models** = difference in power between isolated and array operation for the turbines at the upstream edge of the wind farm
- Shorthand*: **Wind-farm-scale blockage loss**

*: wakes and blockage are tightly coupled and can not be precisely separated

Onshore Wind Farm A – Results



Colors = % change in hub-height wind speed relative to freestream

More than a year of data at each mast before *and* after COD

Quantifying the wind-farm-scale blockage using CFD

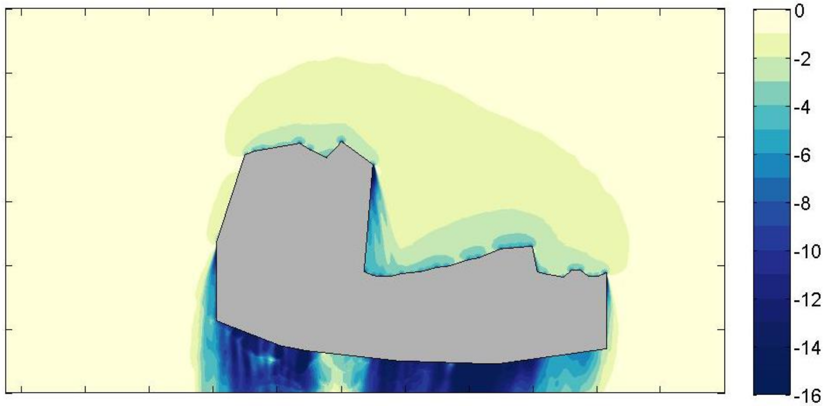
Methodology to evaluate blockage loss factor

- Aim: $E_{Potential} = \eta_{bl}\, \eta_{wake-only}\, E_{Gross}$
  - Loss factor as a correction to wakes-only models

- CFD simulations of elliptic RANS can account for feedback from wind farm onto background flow.
- Two sets of back-to-back CFD simulations:
  - Freestream
  - Wind farm with all turbines in operation (turbines modelled with actuator disk model)

  → total turbine interaction loss factor calculated as

  → blockage loss L_{bl} and loss factor η_{bl} calculated as



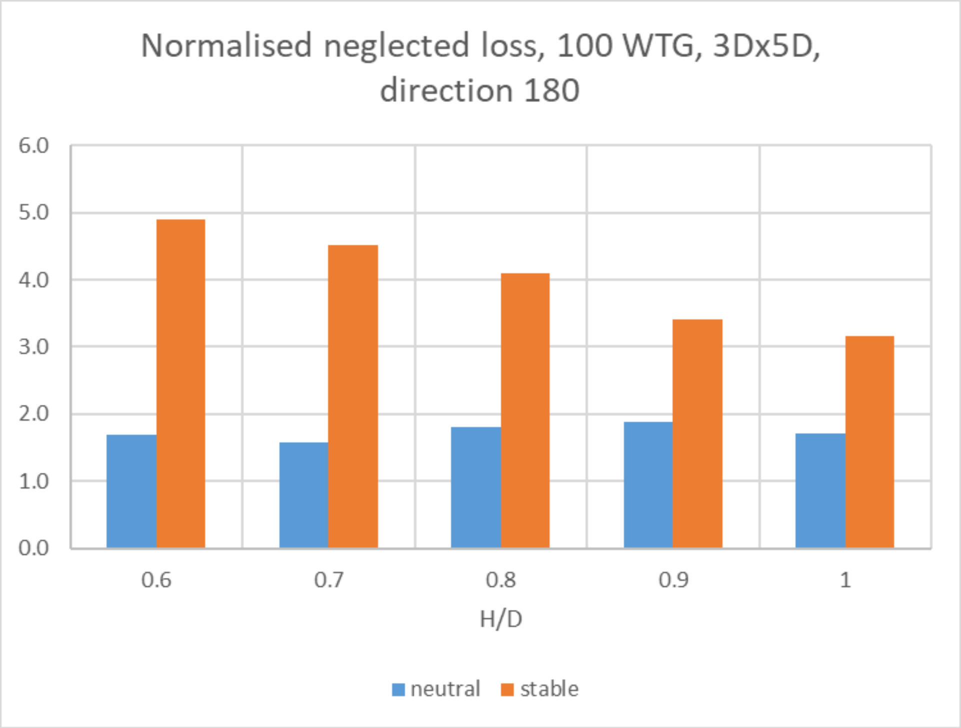
$P_{i,wf}$: power from turbine *i* when whole wind farm is operational

$P_{i,wf}$: power from turbine *i* operating in isolation

$$\eta_{total\_turb\_interaction} = \frac{\sum_{All} P_{i,wf}}{\sum_{All} P_{i,I}}$$

$$\eta_{bl} \cong \frac{\sum_{unwaked} P_{wf}}{\sum_{unwaked} P_{I}} \qquad L_{bl} = 1 - \eta_{bl}$$

Blockage loss sensitivity to stability and hub-height-to-diameter ratio HH/D

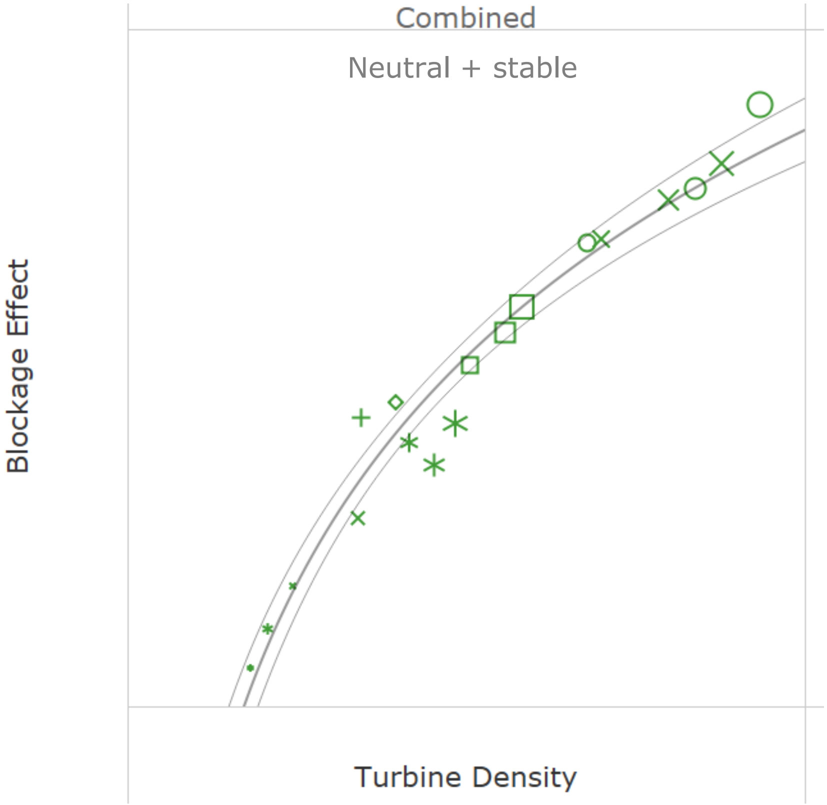


Blockage loss in terms of power, normalised with that of a 5D x 10D layout

- Sensitivity tested for densely packed layout (3D x 5D spacing), HH/D = 0.9
- Blockage stronger in stable than in neutral conditions
- In stable conditions, blockage loss increases as HH/D decreases. In neutral conditions, not a strong sensitivity to HH/D.

DNV·GL

Blockage loss (wind speed): sensitivity to turbine density



Conditions: mixed stable and neutral surface stability, upstream wind speed of 7 m/s, HH/D = 0.9

- Wind farm layout distilled to a single parameter: average turbine density
- For each layout, a range of wind directions were simulated, and the corresponding blockage loss averaged.
  - One symbol = one type of spacing
  - Size of the symbol scales with the number of turbines

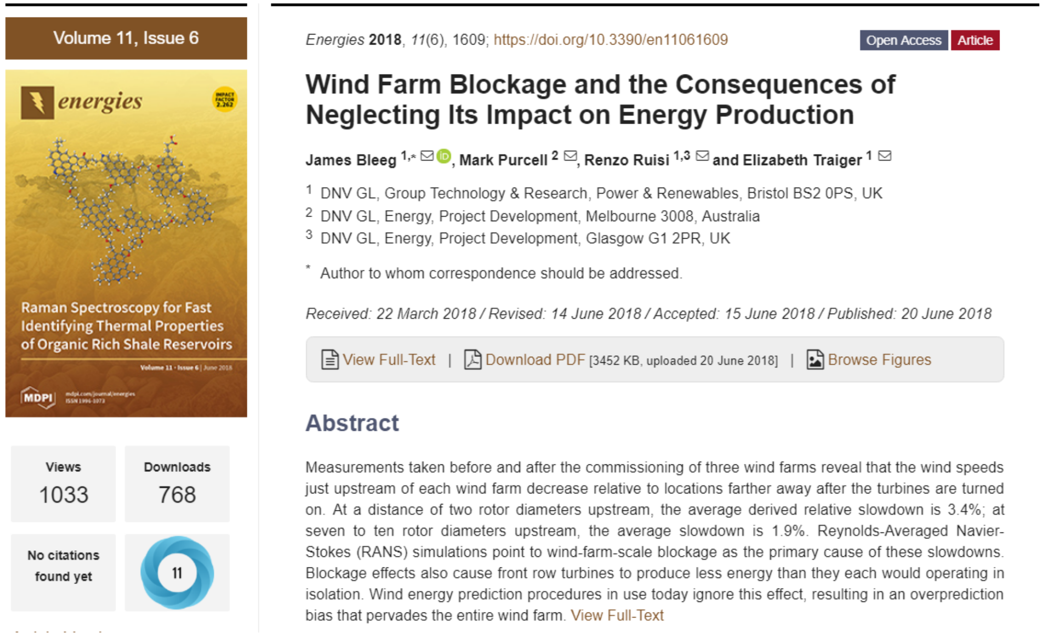
→ Turbine density, despite being a crude representation of the layout, appears to be a reasonable predictor of the blockage loss.

Validation

- Wake model validation:
  - Comparison with wind tunnel data
  - Comparison with power data from SCADA (Horns Rev, Whitelee)
  - Pattern of production for un-waked turbines

- Blockage effect at masts upstream of wind farms:
  - Onshore wind farms, with mast pairs measuring before and after 'commercial operation date' (COD). Comparing change in relative wind speed between perimeter and reference mast from CFD and wind data

More details and evidence for blockage can be found here: http://www.mdpi.com/1996-1073/11/6/1609



Energies **2018**, *11*(6), 1609; https://doi.org/10.3390/en11061609 Open Access Article

Wind Farm Blockage and the Consequences of Neglecting Its Impact on Energy Production

James Bleeg [1,*], Mark Purcell [2], Renzo Ruisi [1,3] and Elizabeth Traiger [1]

[1] DNV GL, Group Technology & Research, Power & Renewables, Bristol BS2 0PS, UK
[2] DNV GL, Energy, Project Development, Melbourne 3008, Australia
[3] DNV GL, Energy, Project Development, Glasgow G1 2PR, UK

[*] Author to whom correspondence should be addressed.

Received: 22 March 2018 / Revised: 14 June 2018 / Accepted: 15 June 2018 / Published: 20 June 2018

View Full-Text | Download PDF [3452 KB, uploaded 20 June 2018] | Browse Figures

Abstract

Measurements taken before and after the commissioning of three wind farms reveal that the wind speeds just upstream of each wind farm decrease relative to locations farther away after the turbines are turned on. At a distance of two rotor diameters upstream, the average derived relative slowdown is 3.4%; at seven to ten rotor diameters upstream, the average slowdown is 1.9%. Reynolds-Averaged Navier-Stokes (RANS) simulations point to wind-farm-scale blockage as the primary cause of these slowdowns. Blockage effects also cause front row turbines to produce less energy than they each would operating in isolation. Wind energy prediction procedures in use today ignore this effect, resulting in an overprediction bias that pervades the entire wind farm. View Full-Text

Stefan Söderberg
stefan.soderberg@dnvgl.com
+46 (0)703074278

www.dnvgl.com

SAFER, SMARTER, GREENER