The influence of wind farms on the wind speed above the wind farms

This paper was presented at The Science of making Torque 2012, 9-11 October 2012, Oldenburg, Germany

E.T.G. Bot
P.J. Eecen
A.J. Brand

October 2012
ECN-M--12-068



The influence of wind farms on the wind speed above the wind farms

Peter Eecen, Edwin Bot and Arno Brand

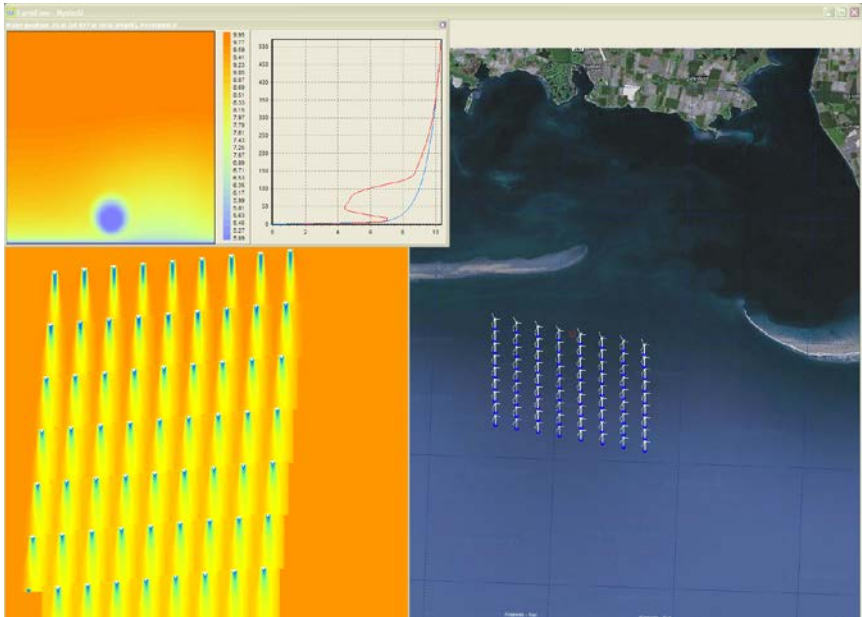
The Science of Making Torque from Wind 2012
11-10-2012, Oldenburg

EU project FP7-ENERGY-2011 283145 /
ClusterDesign

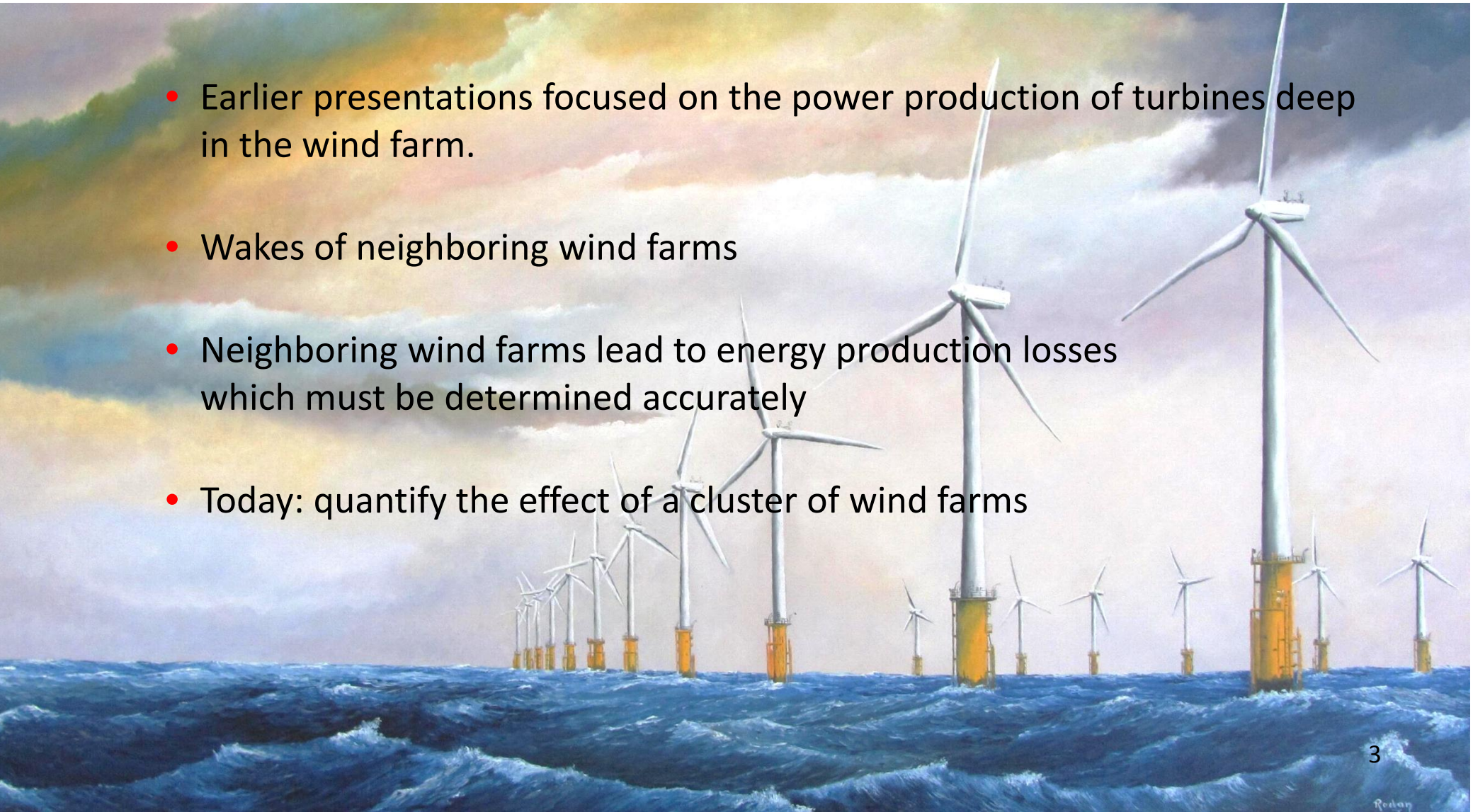


Outline

- Background and objective of a wind farm cluster study
- Approaches to such a study
- ECN approach: Wind farm design code FarmFlow
- Production of and wind speed in large offshore wind farms with emphasis on spacing between wind farms
- Summary and conclusion

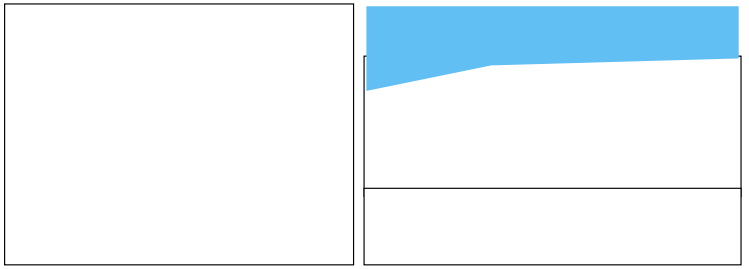


Background & Objective



- Earlier presentations focused on the power production of turbines deep in the wind farm.
- Wakes of neighboring wind farms
- Neighboring wind farms lead to energy production losses which must be determined accurately
- Today: quantify the effect of a cluster of wind farms

Past Approaches



- Over the last 30 years several approaches have been developed.

- Self-similar approaches (convective force and the span wise turbulent fluxes are assumed to dominate the flow)
  * Standard wake-like solutions

- Meso-scale approaches (the Coriolis force and the vertical turbulent flux gradients are assumed to dominate the flow)
  * extra surface drag, or
  * generic methods

- Both: Lack of realistic formulations for the turbulence and the turbines

Current Approaches

- Advanced approaches are now exploited in the EU project **ClusterDesign** along 2 different routes
  EU project FP7-ENERGY-2011 283145 / ClusterDesign
  see poster Rory Donelly

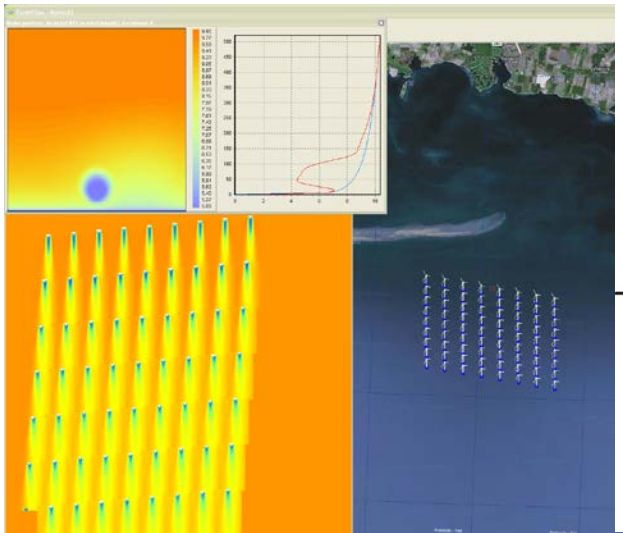
- Route 1: Employing the potential of the mesoscale models
  ForWind – WRF; contact Gerald Steinfeld

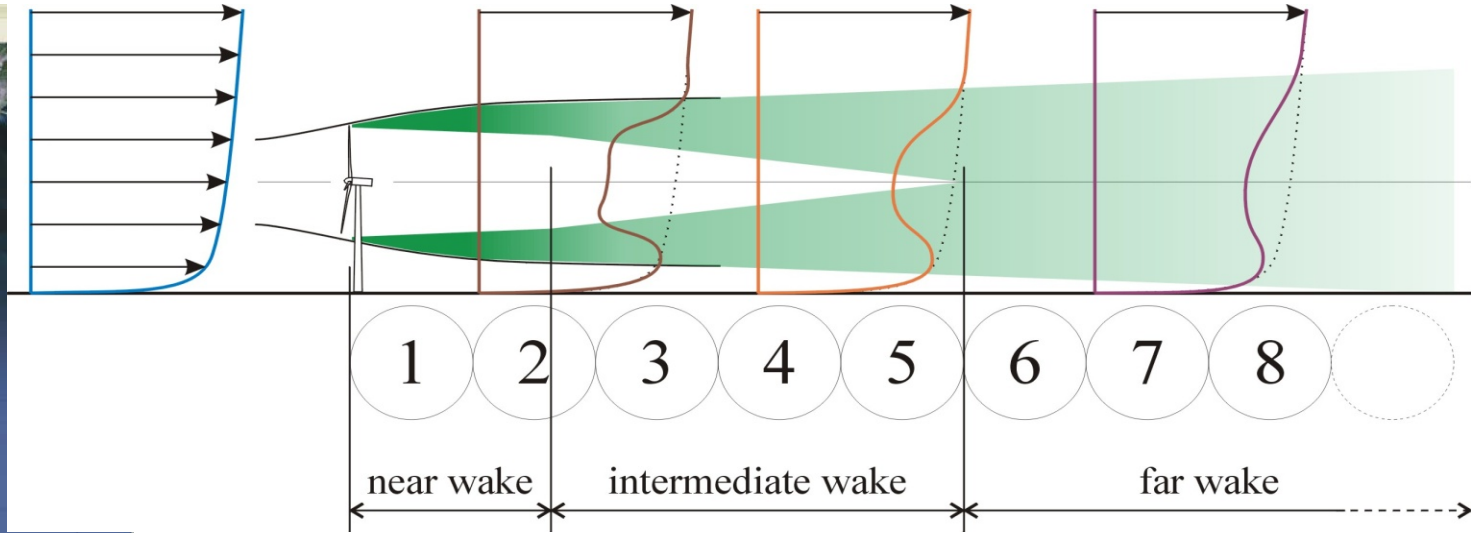
- Route 2: Expanding the scope of existing wind farm models
  ECN – FarmFlow; this presentation

Wind Farm Design Code FarmFlow

FarmFlow calculates wind speeds, turbulence and power in wind farms

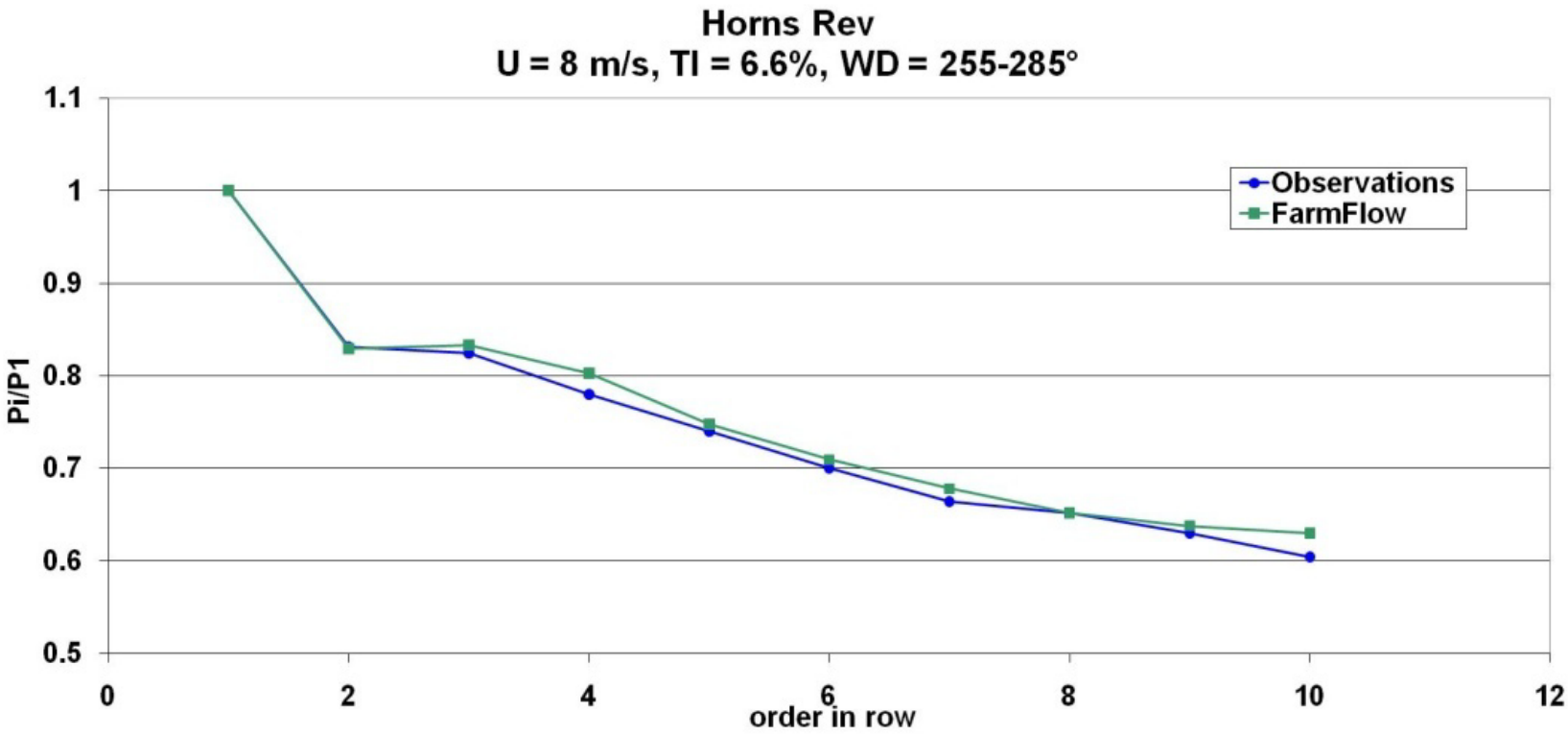
- Solves the Parabolized Navier-Stokes equation
- Permeable disc for the turbines
- k-e turbulence model
- Adjusted k-e turbulence model parameters in near wake





FarmFlow Validation

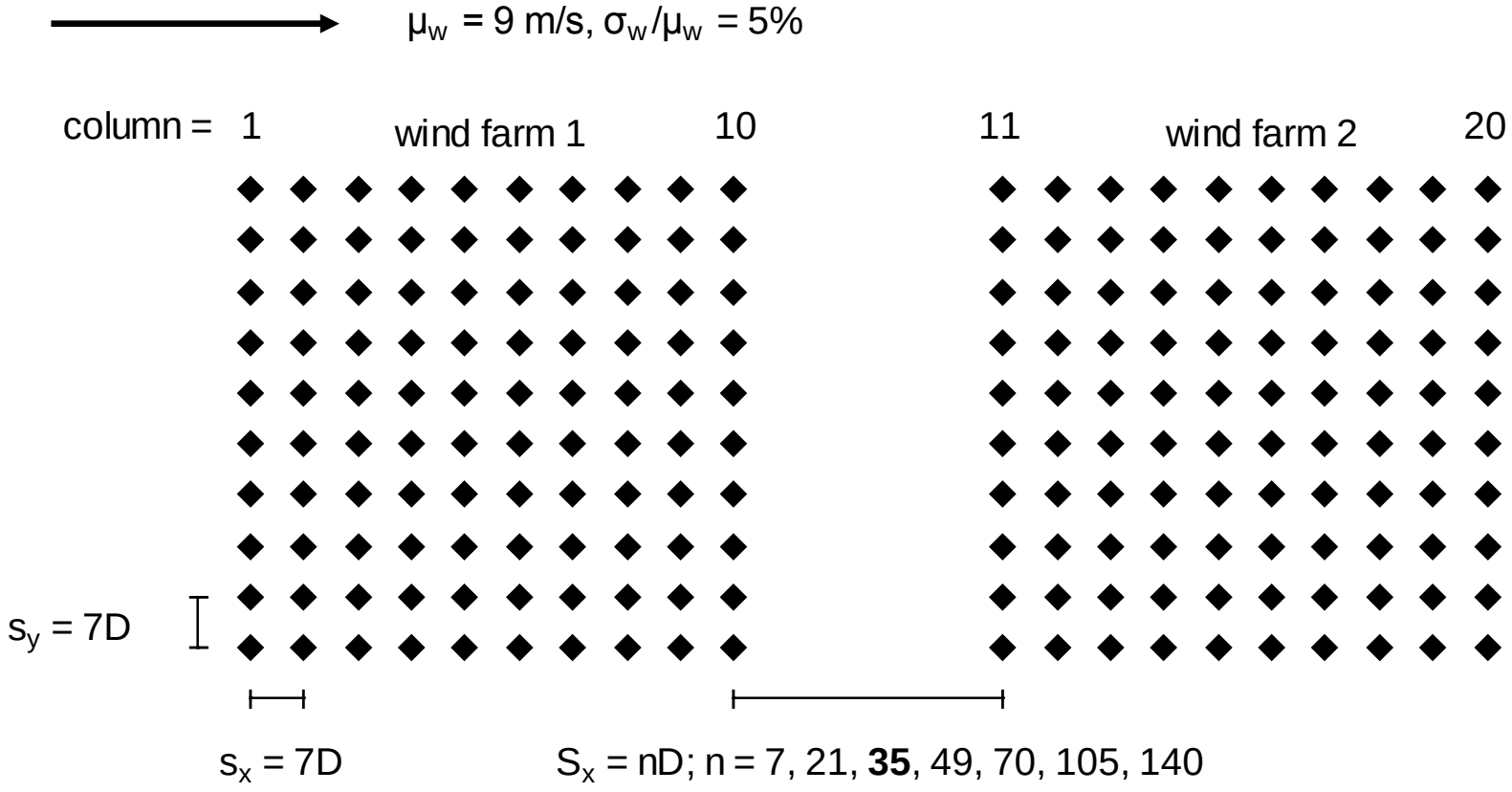
EWTW
Horns Rev
OWEZ
Nysted, etc.



- FarmFlow predicting the power production in the Horns Rev wind farm

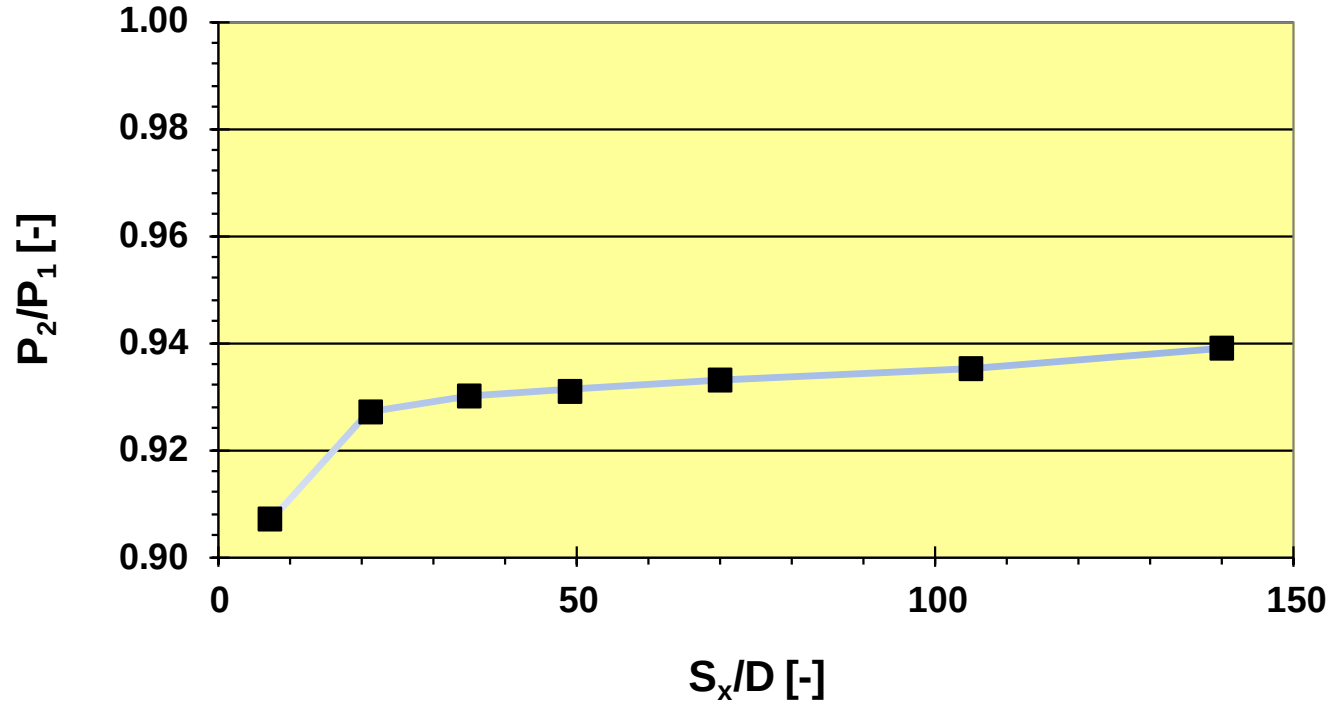
Two offshore wind farms

wind turbine: NREL 5 MW, H = 90 m, D = 126 m



Power of the downwind wind farm

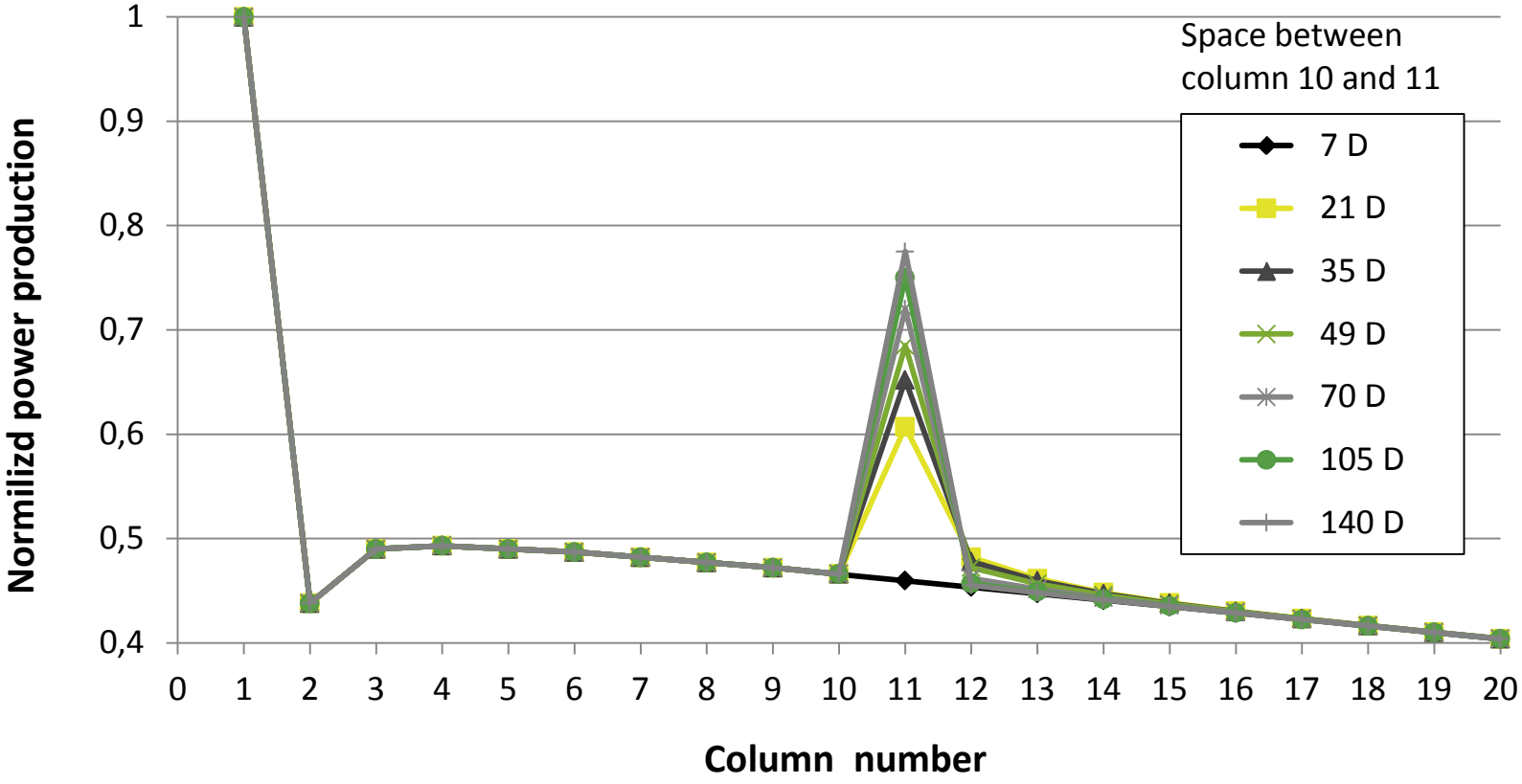
Versus the space between the wind farms



50D = 6.3km, 100D = 12.6km, 150D = 18.9km

Power along a row of turbines

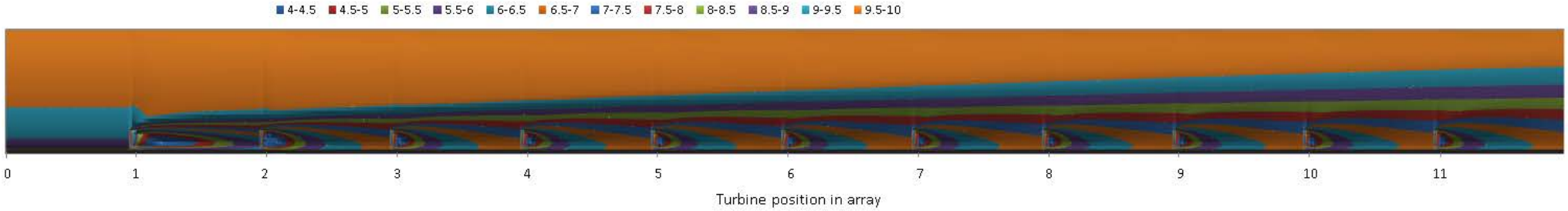
Versus the space between columns 10 and 11



increased mixing due to the added turbulence

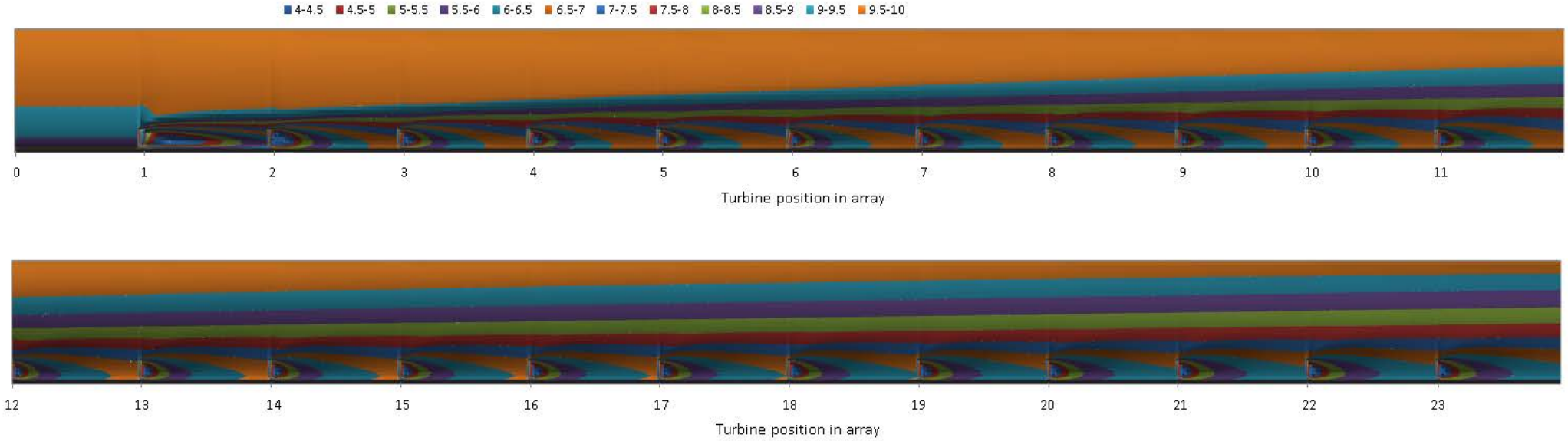
Row of 35 Wind Turbines

Turbines separated 7 rotor diameters



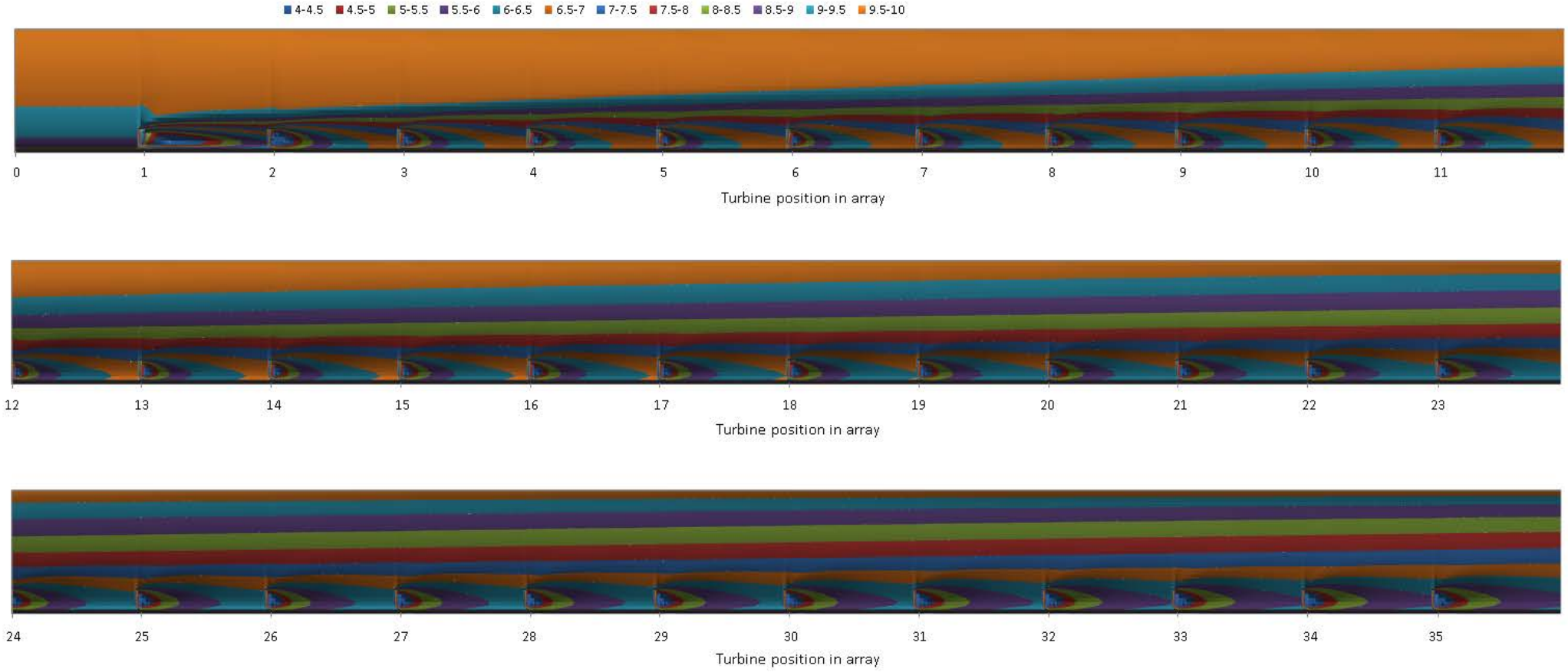
Row of 35 Wind Turbines

Turbines separated 7 rotor diameters

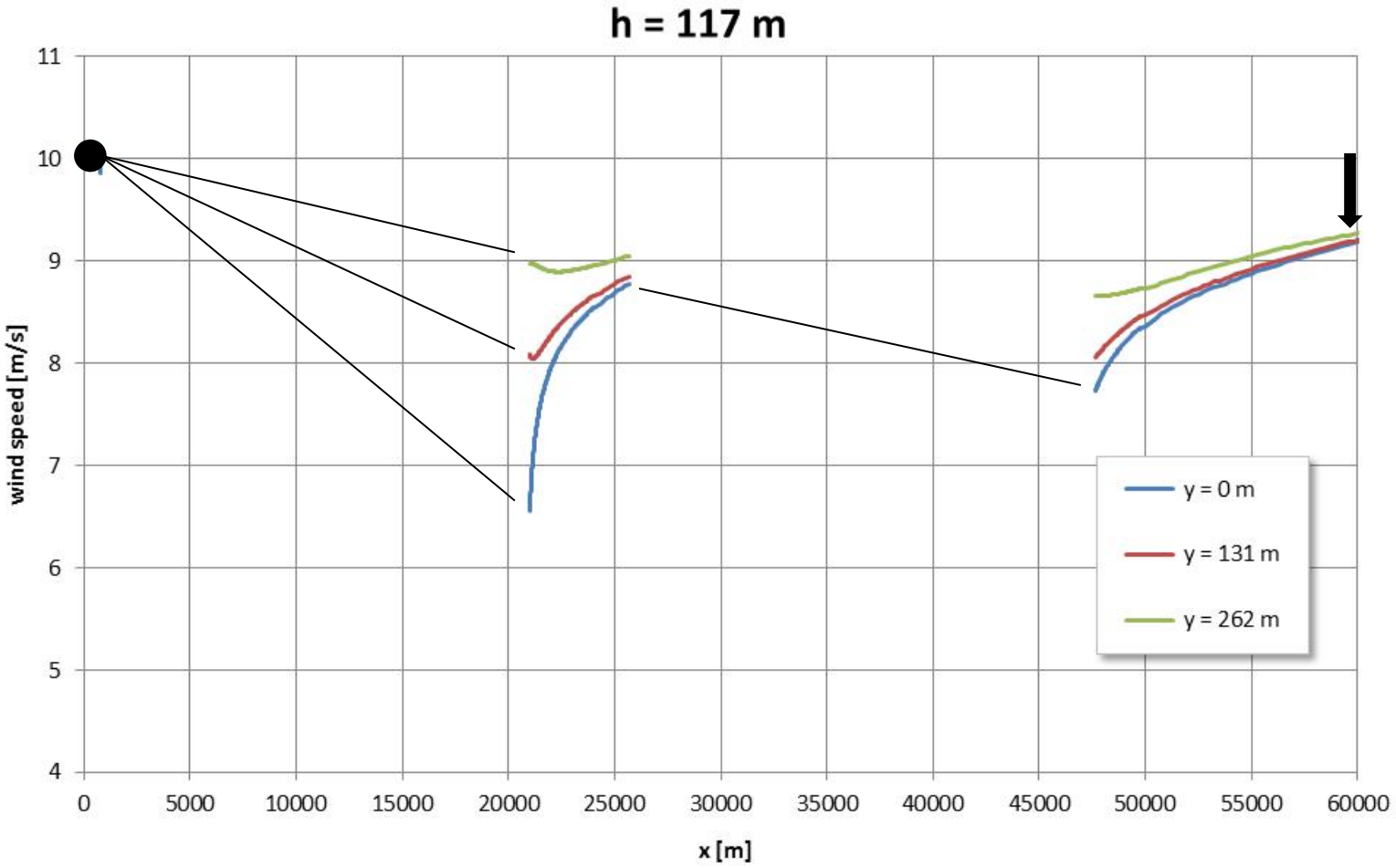


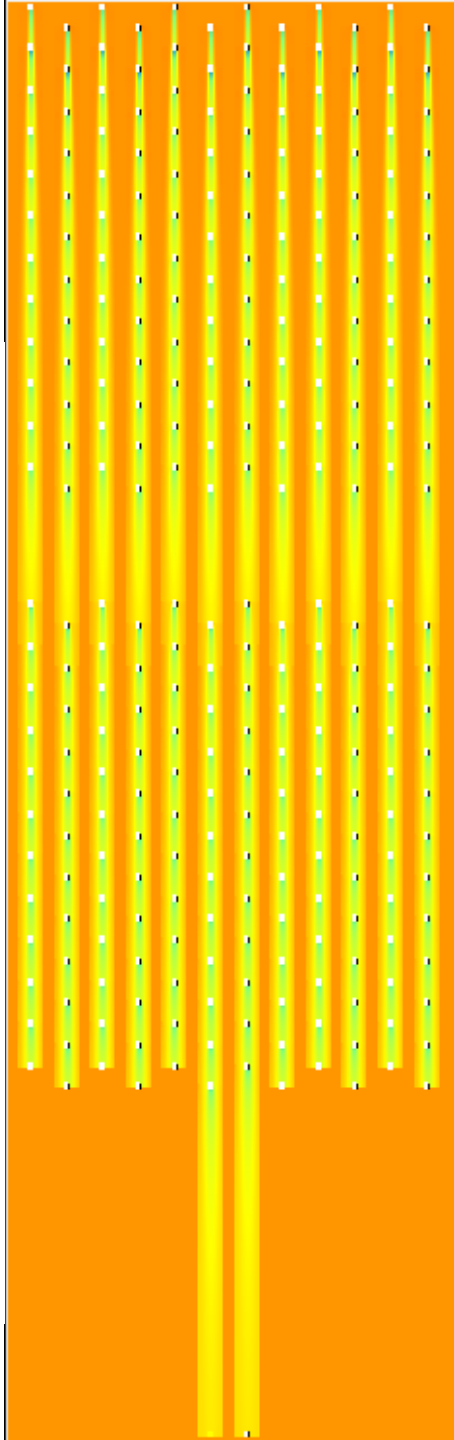
Row of 35 Wind Turbines

Turbines separated 7 rotor diameters



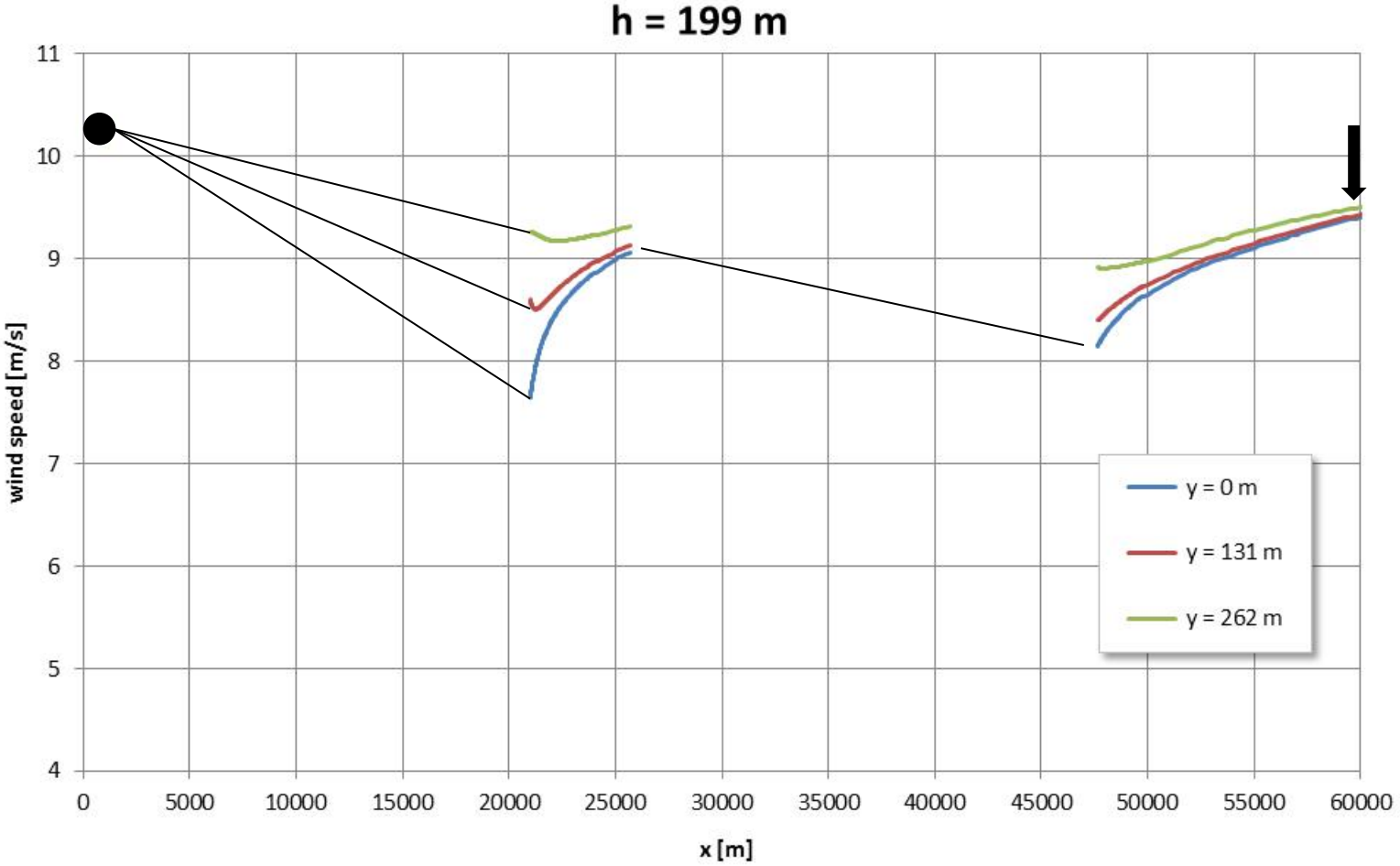
2 x 1GW wind farms
7MW turbines, D=164m, h=117m

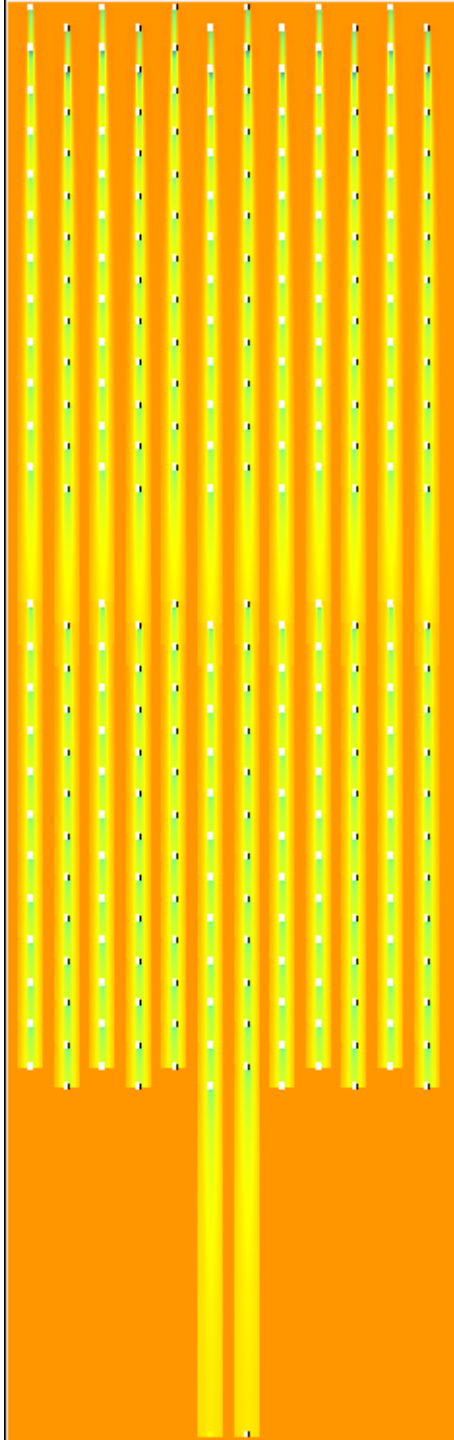




18-10-2012

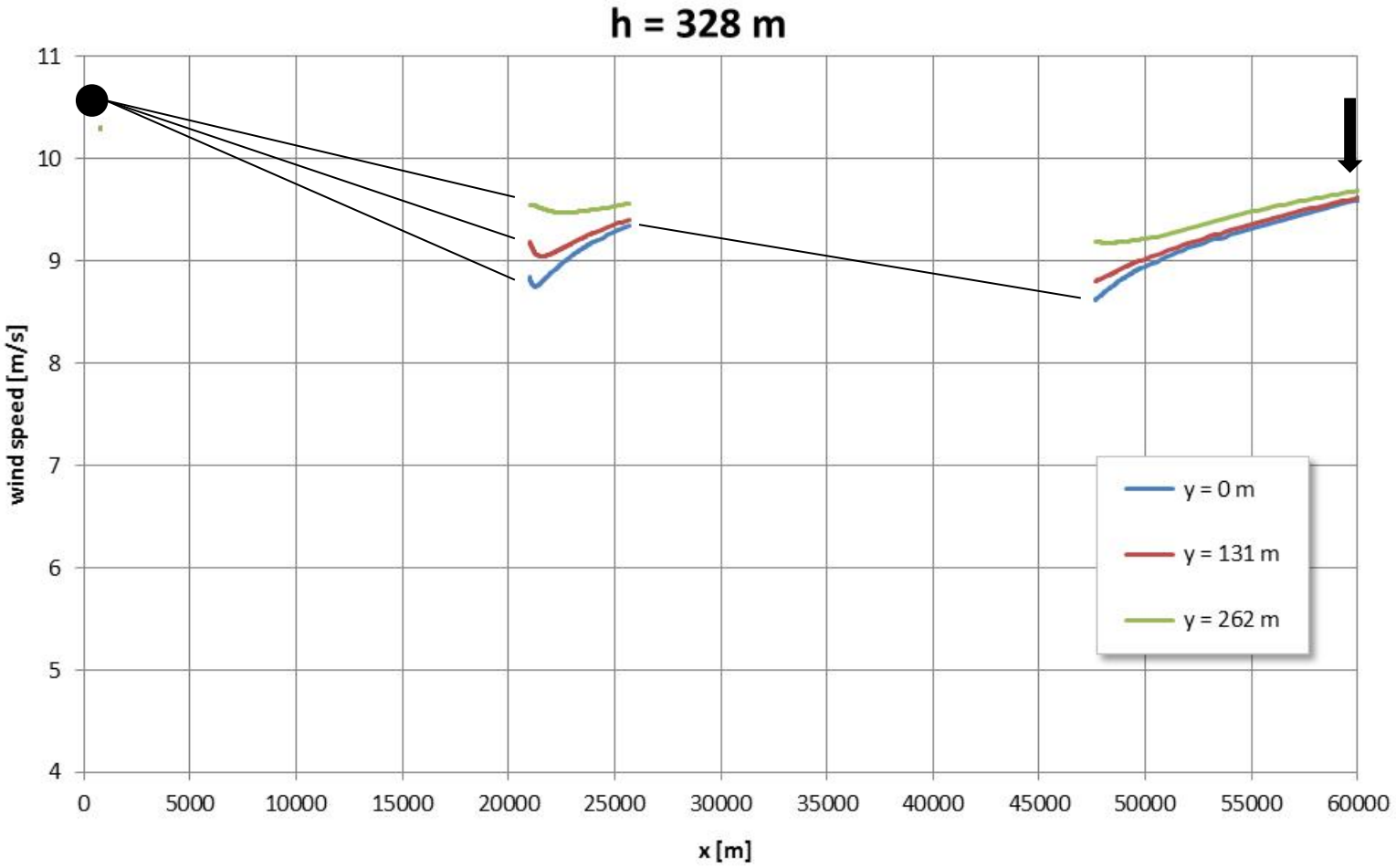
2 x 1GW wind farms
7MW turbines, D=164m, h=117m

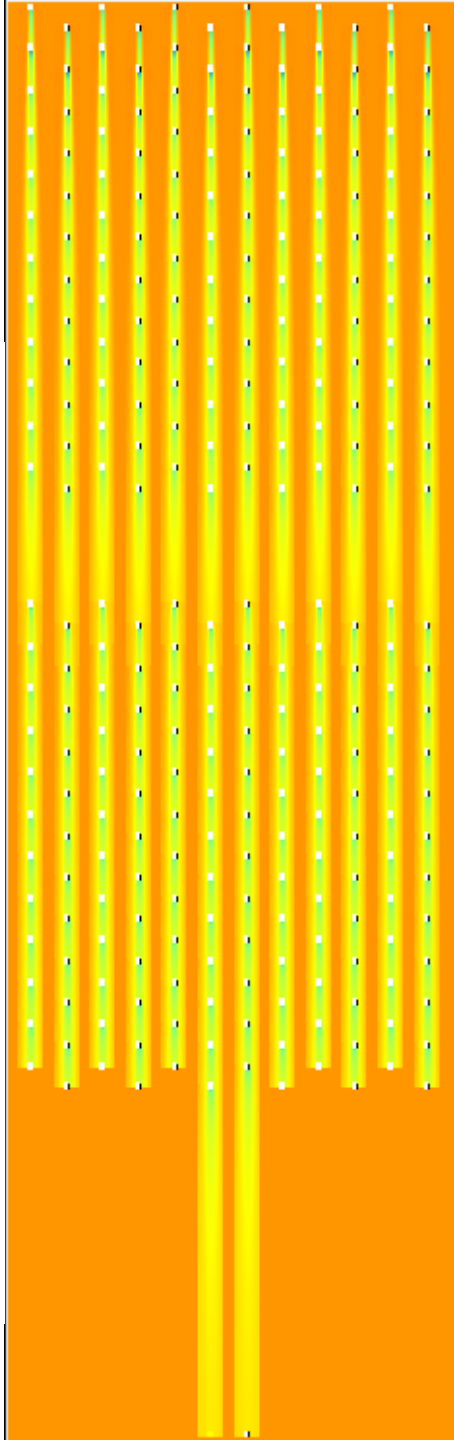




18-10-2012

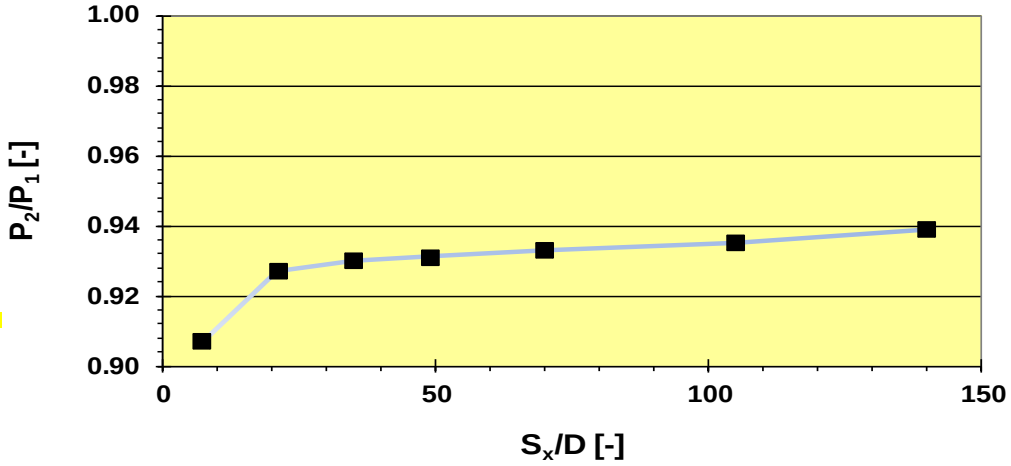
2 x 1GW wind farms
7MW turbines, D=164m, h=117m





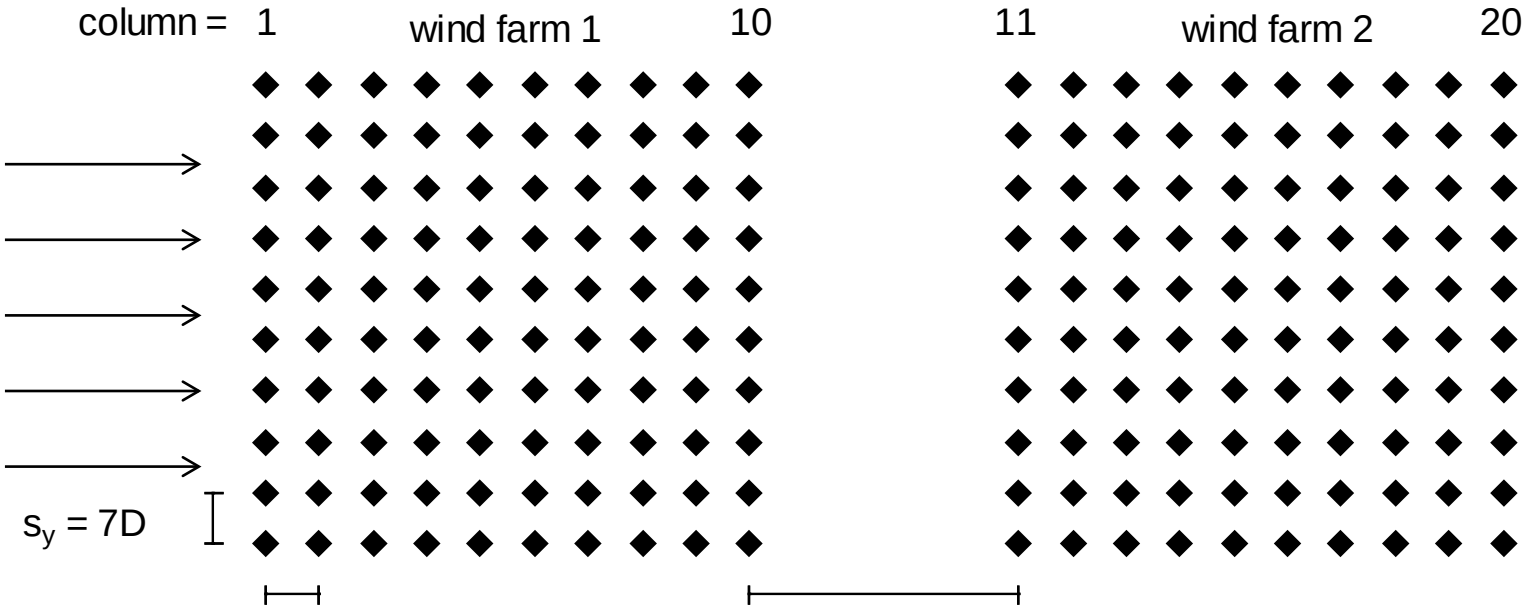
18-10-2012

summary



wind turbine: NREL 5 MW, H = 90 m, D = 126 m

μ_w = 9 m/s, σ_w/μ_w = 5%



Summary & Conclusion

- The effect of the streamwise space between two wind farms has been quantified
- Increasing the space between two wind farms does not benefit the production of the downwind wind farm considerably
  (in the case the wind farm is completely in the wake of the other)
- Apart from immediately downwind of the slot, the wake loss increases and the wind shear decreases with every next turbine
- An internal boundary layer prevents the feed-in of high-speed wind

Contact

- Technical information

  Edwin Bot

  Wind Energy Research Scientist

  E: bot@ecn.nl

  T: +31 88 515 4940

- ClusterDesign project information

  Arno Brand

  Wind Energy Research Scientist

  E: brand@ecn.nl

  T: +31 88 515 4775

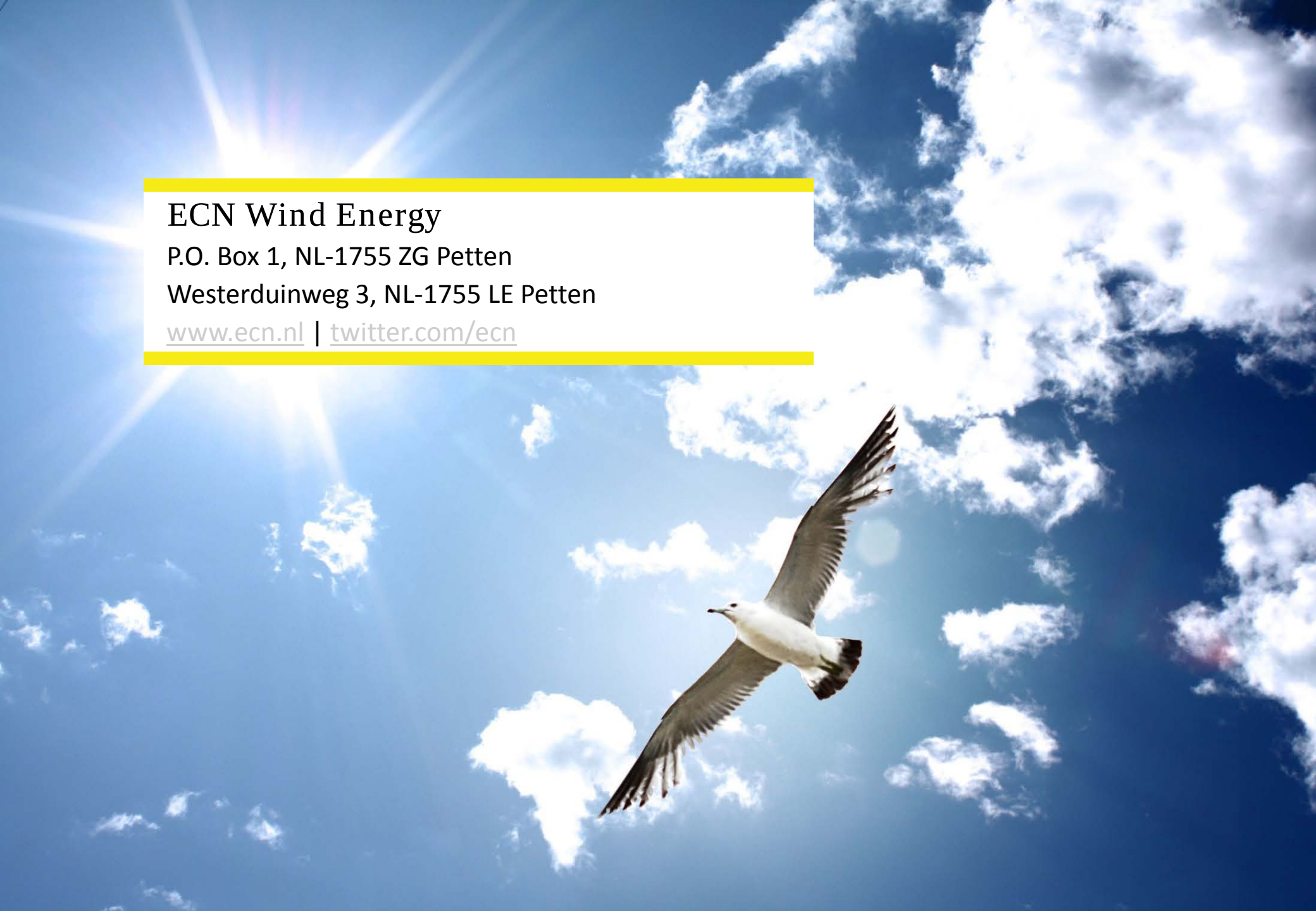
- ECN programme development

  Peter Eecen

  Programme Development Manager

  E: eecen@ecn.nl

  T: +31 88 515 8279



ECN Wind Energy

P.O. Box 1, NL-1755 ZG Petten

Westerduinweg 3, NL-1755 LE Petten

www.ecn.nl | twitter.com/ecn