



USER MEETING 2011

COMPARISON OF RESOURCE AND ENERGY YIELD ASSESSMENT PROCEDURES

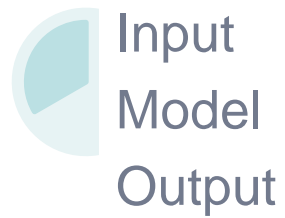
PRESENTED BY: Andrea Vignaroli and Li Di

windsim

Outline



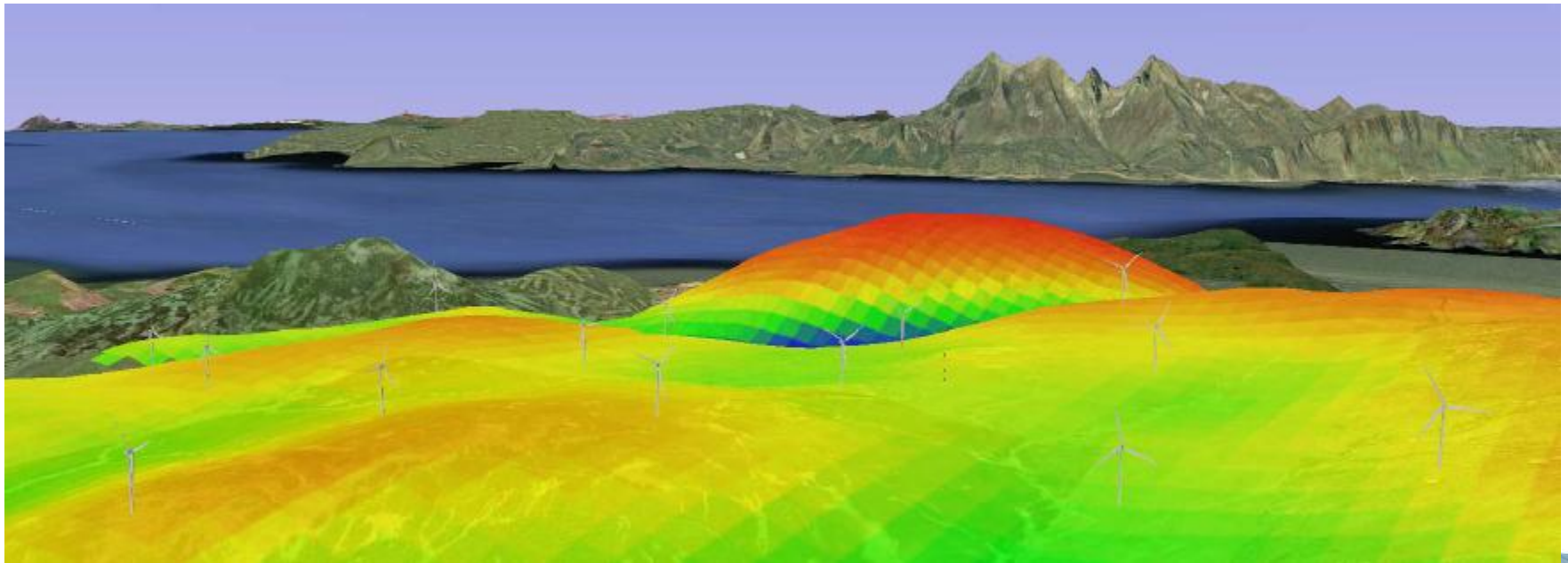
Background



Input
Model
Output



Results



windsim

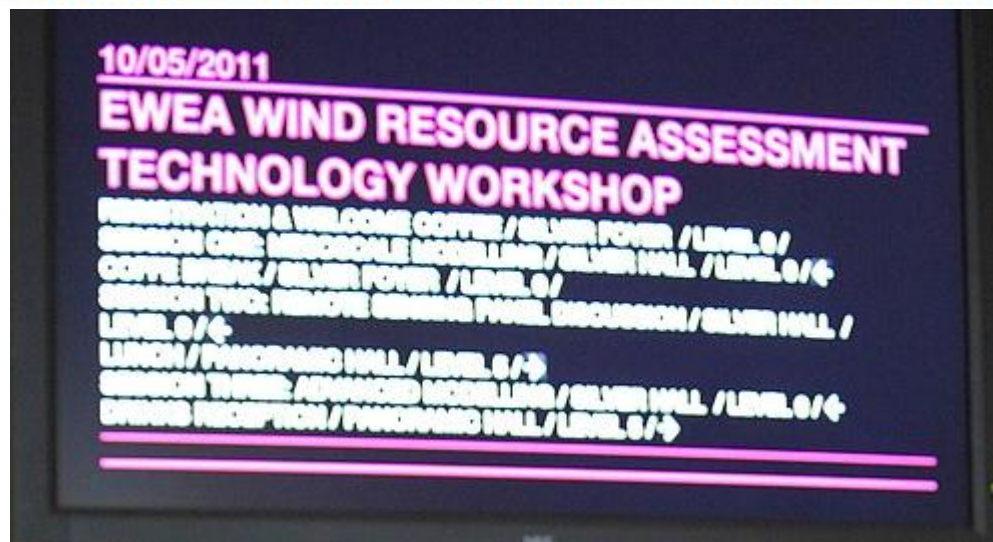
EWEA Wind Resource Assessment Technology Workshop

Brussels, 10 & 11 May 2011

Over 180 participants

Topics:

- Mesoscale Modelling
- Remote Sensing
- Advanced Modelling
- Wakes
- Concluding Session: Comparison of Resource and Energy Yield Assessment Procedures



Event available at <http://www.ewea.org/index.php?id=2024>

windsim

Participants

37 organizations from 16 countries submitted results

- consultancy (18), developer (7), wind turbine manufacturer (5), electricity generator/utility (3), R&D/university (2), component manufacturer (1), service provider (1)

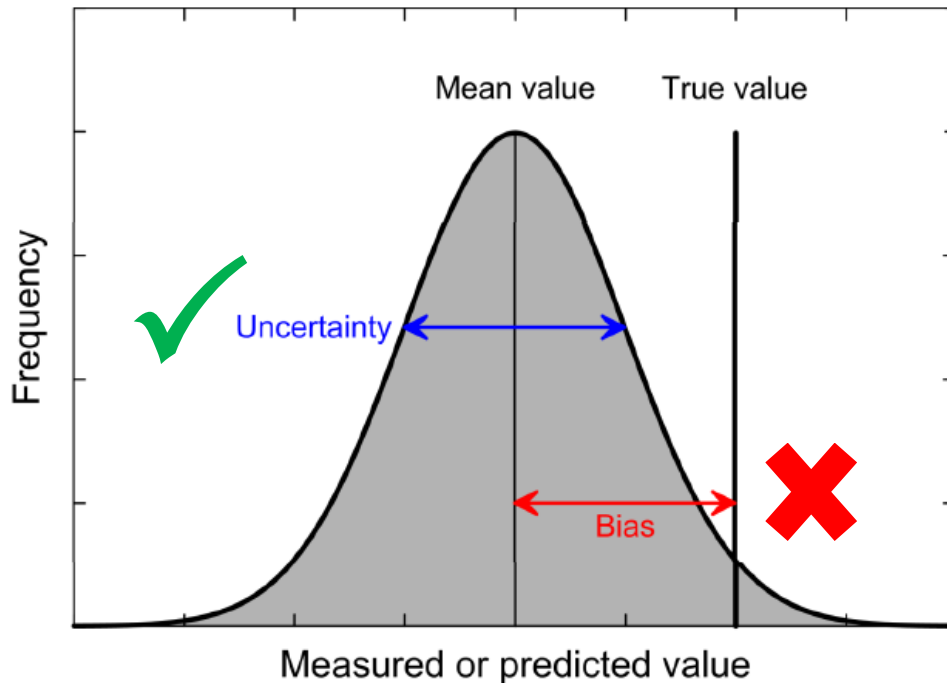
Names of organisations

- 2EN, 3E, CENER, Center for Renewable Energy Sources (CRES), Det Norske Veritas (DNV), DONG Energy A/S, Dulas, Ecofys, EMD International, Eolfi - Veolia, ESB International, GAMESA Innovation & Technology, GL Garrad Hassan, ITOCHU Techno-Solutions Corporation, Kjeller Vindteknikk AS, METEODYN, Mott MacDonald, MS-Techno Co. Ltd., Natural Power, Nordex, ORTECH Power, Prevailing Ltd., Repower Systems AG, RES – Renewable Energy Systems Ltd, RES Americas Inc., RWE Innogy, Samsung Heavy Industries, SgurrEnergy, Suzlon Wind Energy A/S, The Wind Consultancy Service, Tractebel Engineering, Vestas, WIND-consult GmbH, WindGuard, **WindSim AS**, Windtest Grevenbroich GmbH.

Input and Output

Case study wind farm

- Wind farm and turbine data
- Wind-climatological inputs
- Topographical inputs



Comparison of results and models

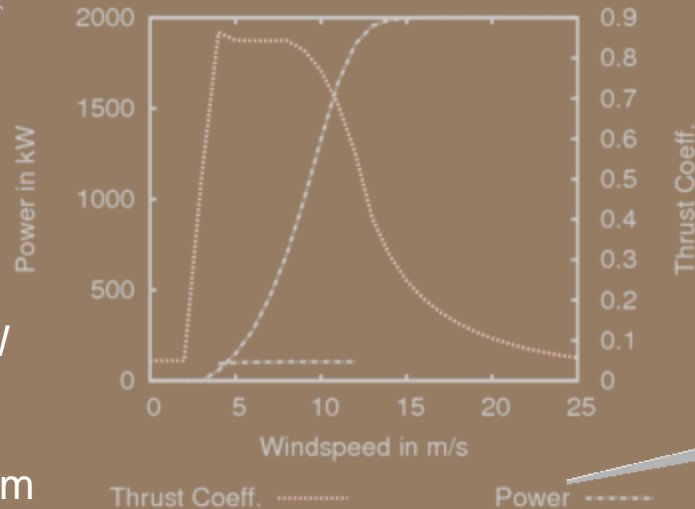
- Long-term wind @ 50 m
- Long-term wind @ 60 m
- Reference energy yield
- Gross energy yield
- Potential energy yield
- Net energy yield P_{50}
- Net energy yield P_{90}

Input - wind farm and turbine data

28-MW wind farm

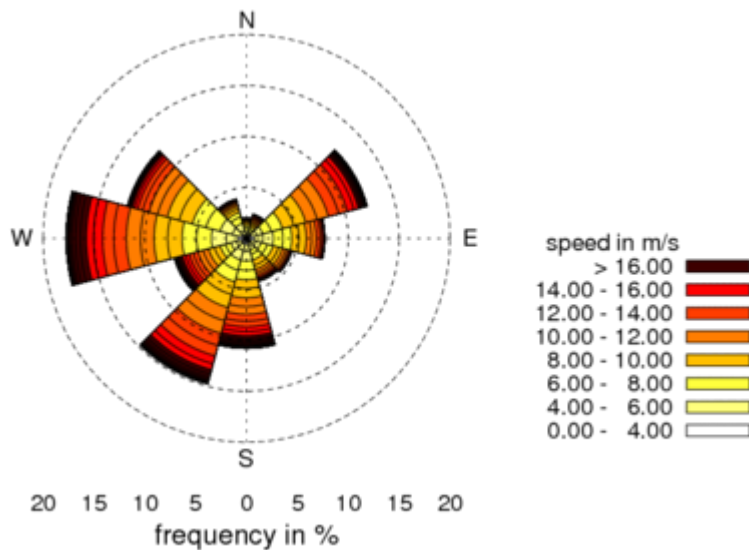
- 14 wind turbines
- Rated power: 2 MW
- Hub height: 60 m
- Rotor diameter: 80 m
- Air density: 1.225 kg m^{-3}
- Spacing: irregular, $3.7D - 4.8D$ to nearest neighbouring turbine

Step : 1

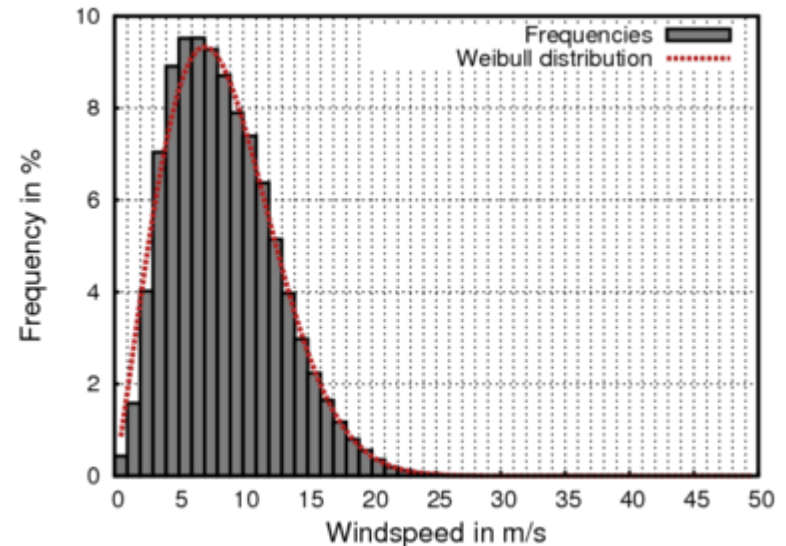


Input - wind-climatological inputs

- Site meteorological mast
 - Wind speed @ 49.6 and 35 m
 - Std. deviation @ 49.6 and 35 m
 - Wind direction @ 33.6 m
 - 4 year, Sep. 2002 – Oct. 2006
 - recovery 92%
- Reference station
 - Monthly U , 1993-2006 (14y)
 - Hourly U and D , Sep. 2002 – Jan. 2007 (5y)
 - Observed Wind Climate, 1993-2001 (9y)

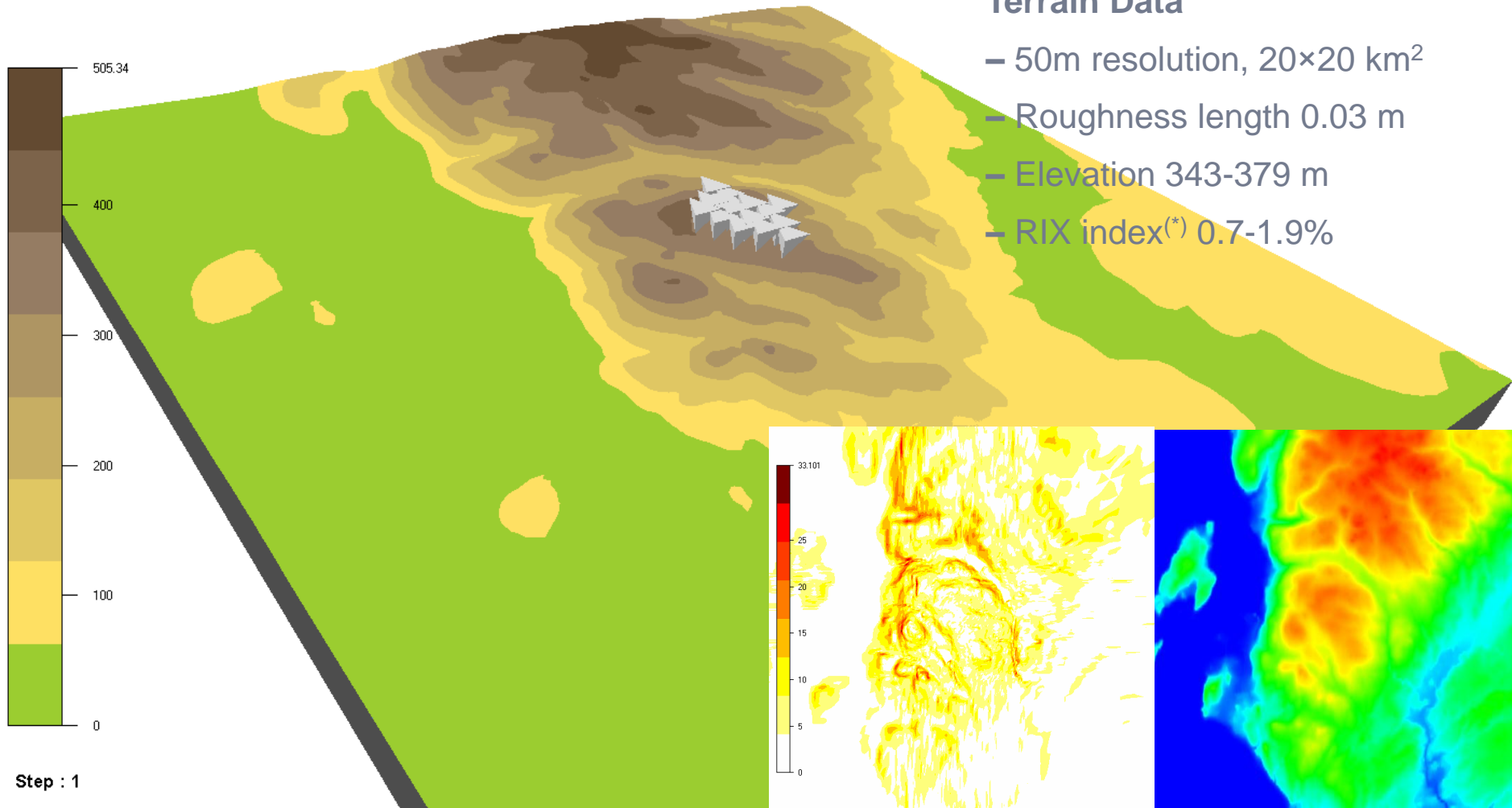


Site mast wind rose



Site mast speed distribution @ 49.6m

Input - topographical inputs



Terrain Data

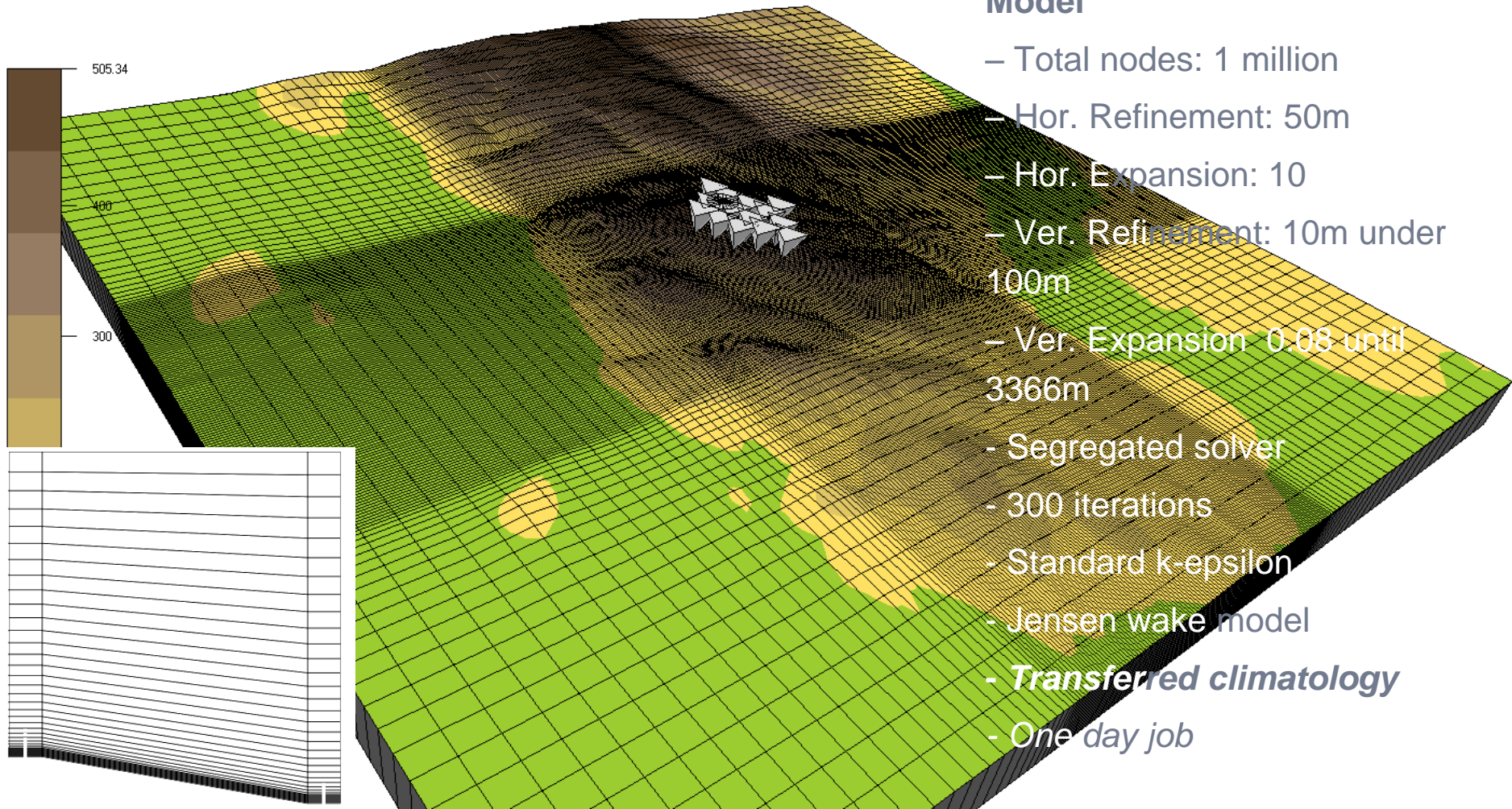
- 50m resolution, 20×20 km²
- Roughness length 0.03 m
- Elevation 343-379 m
- RIX index^(*) 0.7-1.9%

* RIX index: percentage fraction of the terrain within a certain distance from a specific site which is steeper than some critical slope, say 0.3 (17°).
<http://www.wasp.dk/support/FAQ/WebHelp/RuggednessOfTerrain.htm>

Inclination angle and elevation map

windsim

Model



Model

- Total nodes: 1 million
- Hor. Refinement: 50m
- Hor. Expansion: 10
- Ver. Refinement: 10m under 100m
- Ver. Expansion: 0.08 until 3366m
- Segregated solver
- 300 iterations
- Standard k-epsilon
- Jensen wake model
- **Transferred climatology**
- *One day job*

Grid distribution horizontally and vertically

Output

Results

1. LT wind @ 50 m = Measured wind \pm [long-term correlation effects]
– comparison of long-term correlation methods
2. LT wind @ 60 m = LT wind @ 50 m + [wind profile effects]
– comparison of vertical extrapolation methods
3. Gross AEP = Reference AEP \pm [terrain effects] \pm [MCP correction]
– comparison of flow models
4. Potential AEP = Gross AEP – [wake losses]
– comparison of wake models
5. Net AEP (*P*50) = Potential AEP – [technical losses]
– comparison of technical losses estimates
6. Net AEP (*P*90) = Net AEP (*P*50) – 1.282 \times [uncertainty estimate]
– comparison of uncertainty estimates

Tools

Data analysis – long-term correlation

- MCP (matrix method, hourly values, **monthly means**) (31), correlation with NWP or reanalysis data (2), NOAA-GSOD index (1), none (3)

Vertical extrapolation

- Observed power law/log law profile (19), WAsP (10), **WindSim (2)**, unspecified CFD (2), NWP (1)

Horizontal extrapolation – flow models

- WAsP (23), MS3DJH (2), **WindSim (2)**, unspecified CFD (2), NWP (1), MS-Micro/3 (1), other (1)

Wake models

- **WAsP PARK (17)**, WindPRO PARK (8), WindFarmer Eddy Viscosity (5), Ainslie Eddy Viscosity (3), EWTS II (2), CFD Actuator (1), Confidential (1)

MCP method used - 1

Wind index MCP

Principle:

Makes the production calculation with the local data, then corrects the result with a modification factor based on the local period energy index to be applied to the AEP

Advantages:

- Preserves local data and dynamics
- Allows for poor directional correlation
- Very stable
- Quick to implement

Disadvantages:

- Needs a relatively long measurement period
- Long-term and overlapping short-term reference data must have a good directional correlation
- Does not correct direction
- A bit crude
- Does not result in a site specific tws/wws

Results - long-term correlation effects (on wind speed)

Long-term correlation effects

Data points used = 36 (of 37)

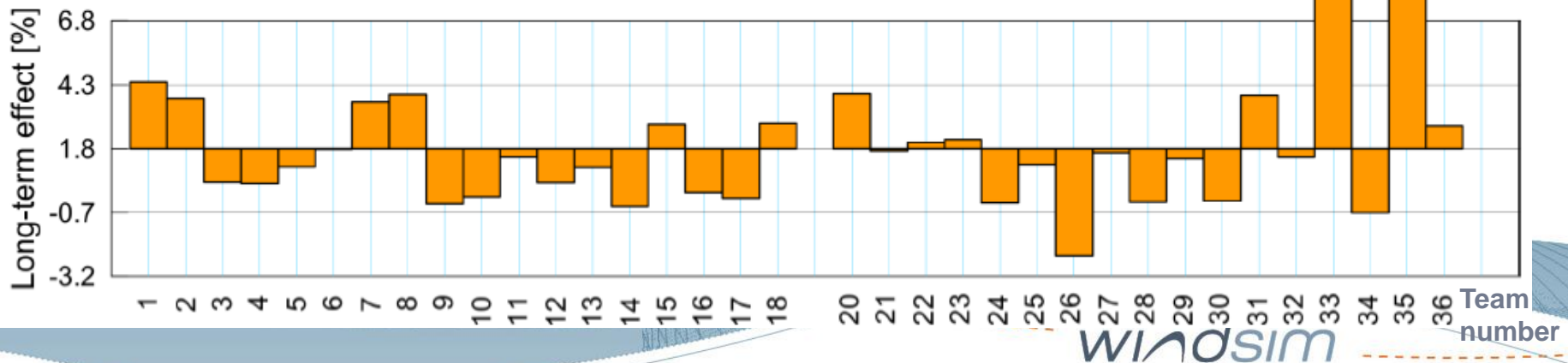
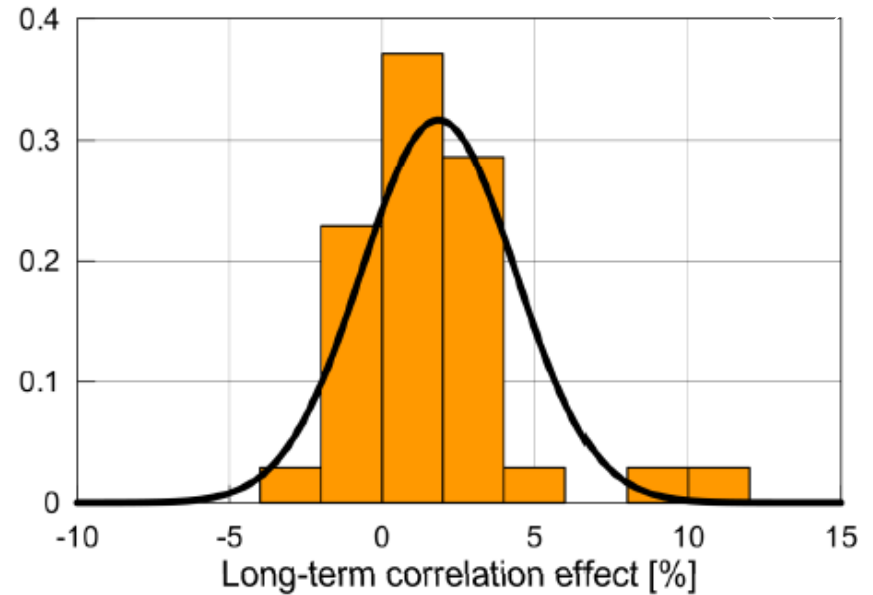
Team 19 result disregarded

Mean long-term effect = **1.8%**

Std. deviation = **2.5%** (139%)

Range = -2.4 to 10.6% (713%)

(measured U_{50} of 8.5 ms^{-1} assumed)



Results - long-term wind speed @ 50m

LT mean wind speed @ 49.6 m

Data points used = 37 (of 37)

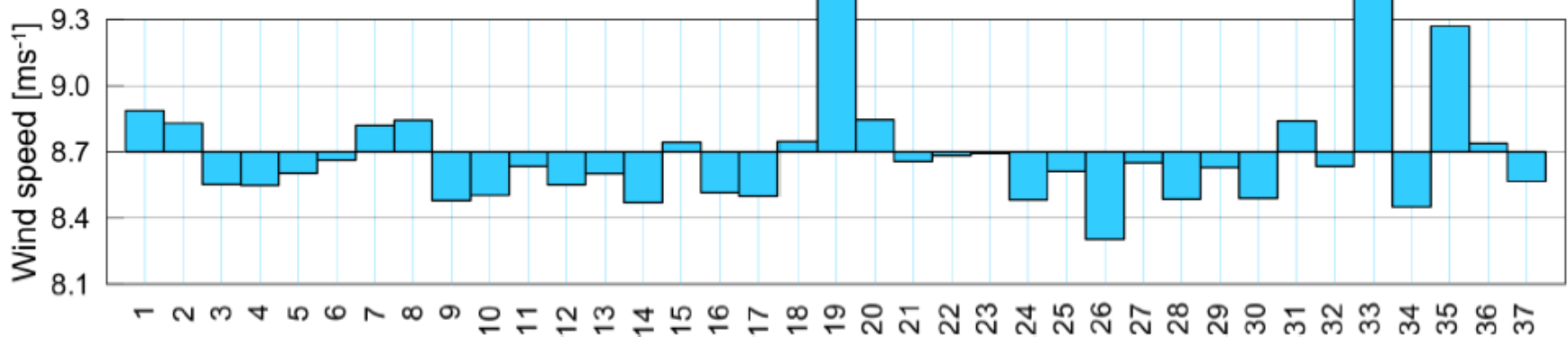
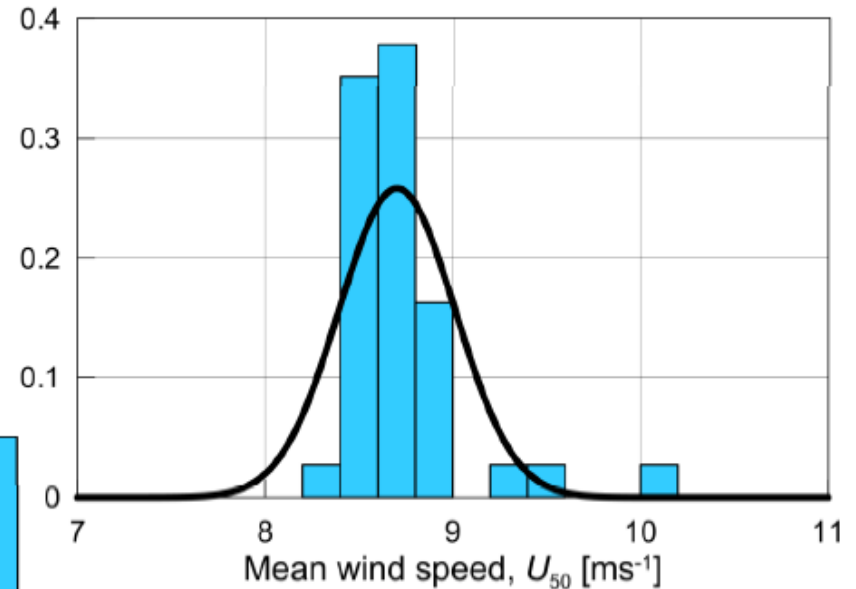
All teams report results

Mean wind speed = **8.7 ms⁻¹**

Std. deviation = **0.2 ms⁻¹** (2.5%)

Range = 8.3 to 9.4 ms⁻¹ (13%)

(statistics without single high outlier)



Results - long-term wind speed @ 60m

LT mean wind speed @ 60 m

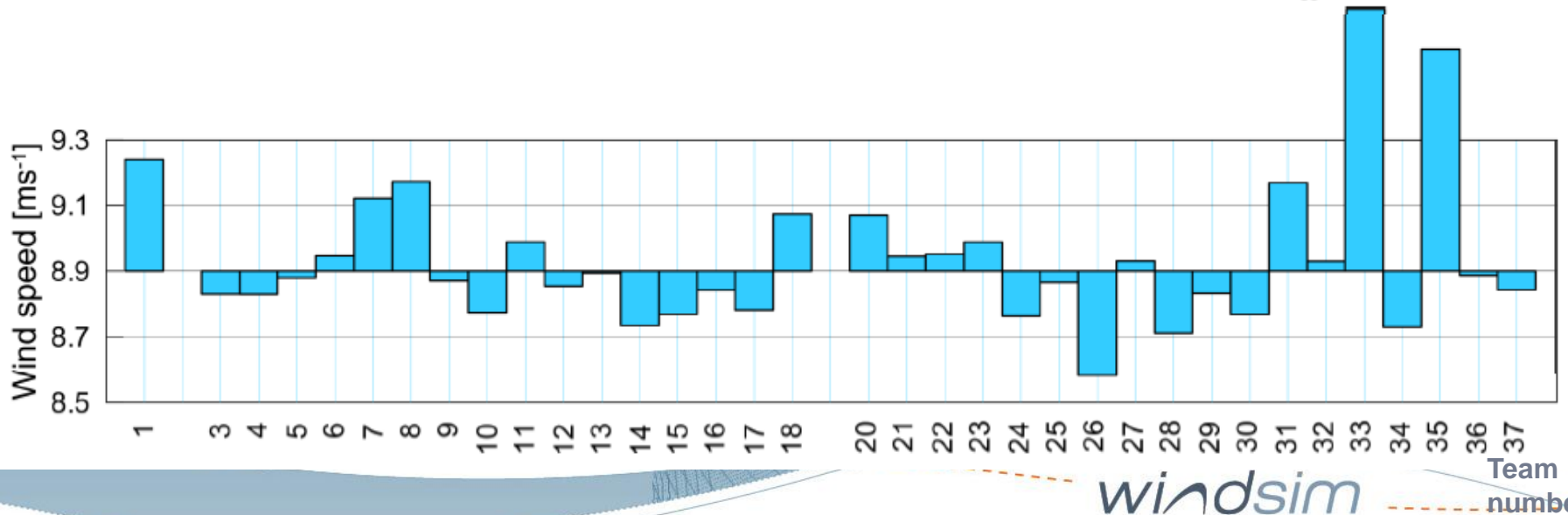
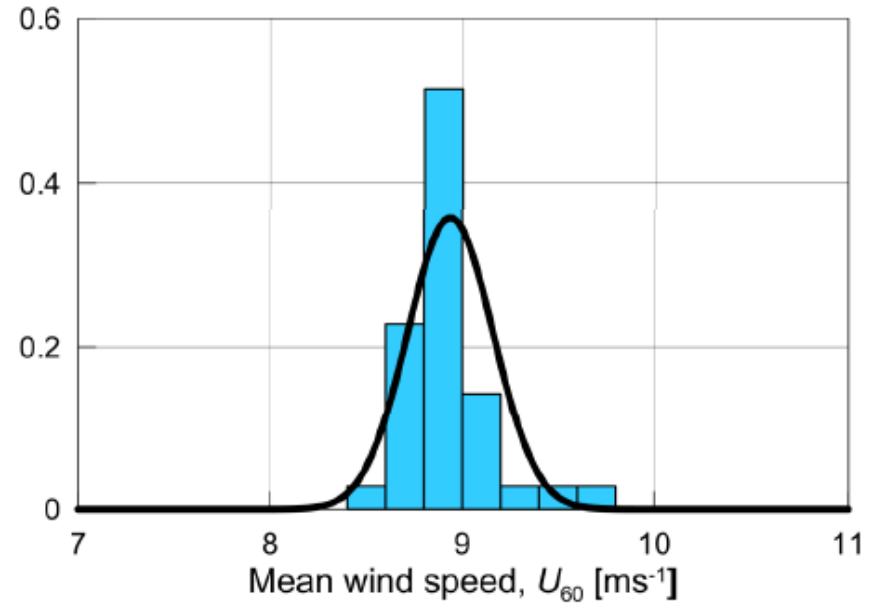
Data points used = 35 (of 37)

Team 2 and 19 report no results

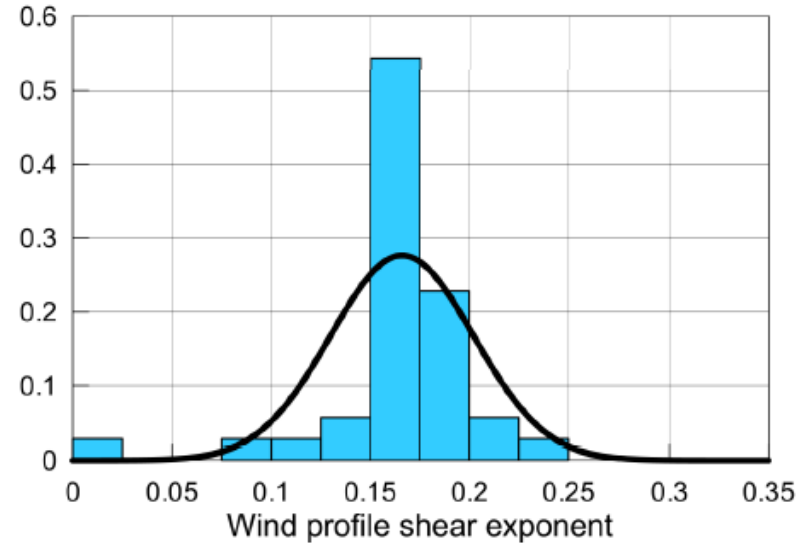
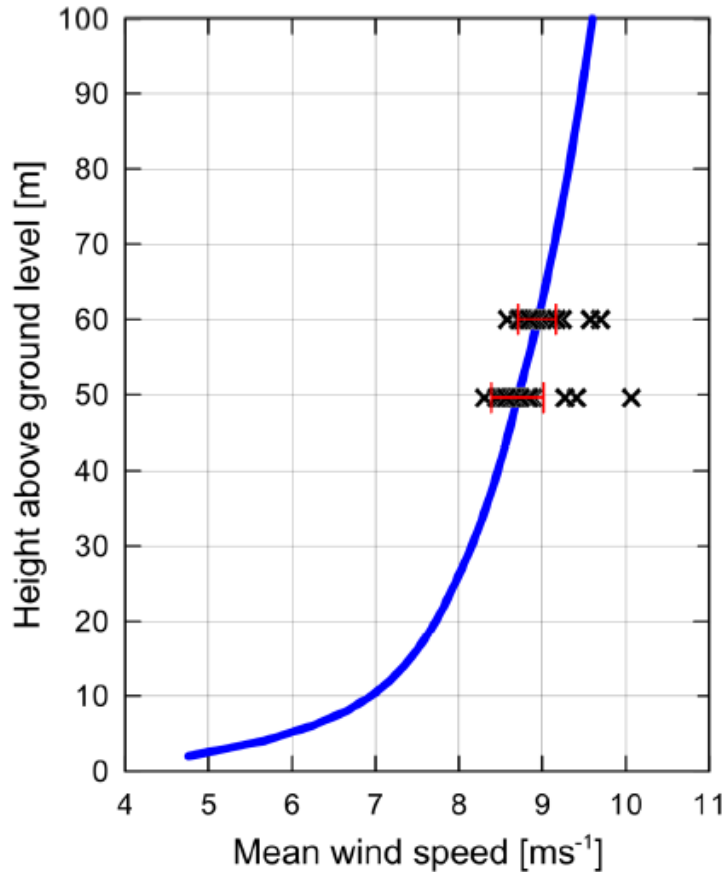
Mean wind speed = **8.9 ms⁻¹**

Std. deviation = **0.2 ms⁻¹** (2.5%)

Range = 8.6 to 9.7 ms⁻¹ (13%)



Results – Wind Shear



Data points used = 35 (of 37)

Team 2 and 19 report no results

Mean shear exponent = **0.166** (1/6)

Std. deviation = **0.037** (22%)

Range = 0.015 to 0.237 (133%)

Windsim Alpha=0.134

Results - long-term turbulence intensity @ 50m

Turbulence intensity @ 49.6 m

Data points used = 35 (of 37)

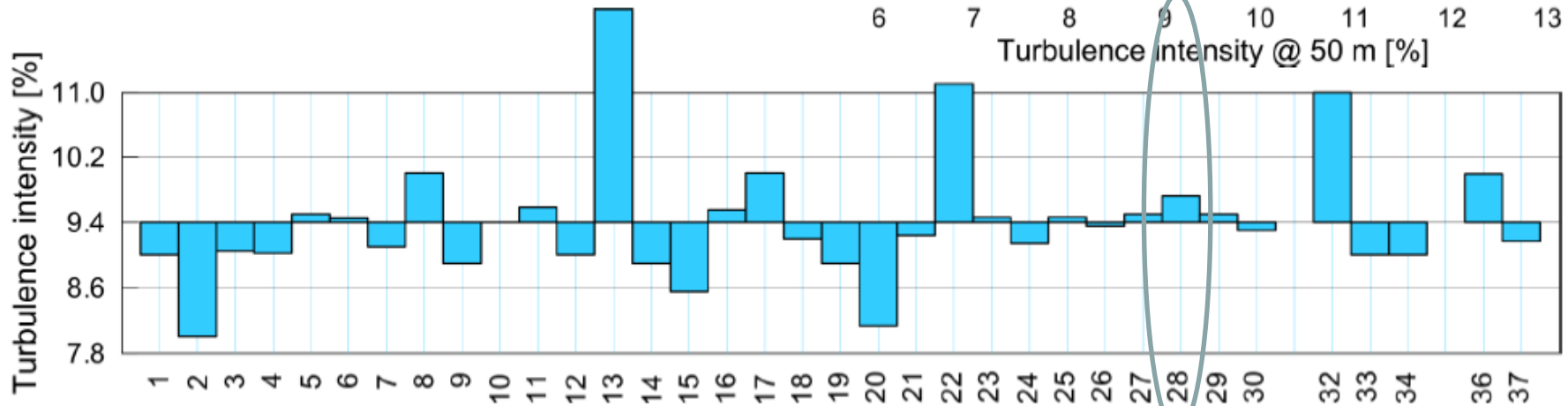
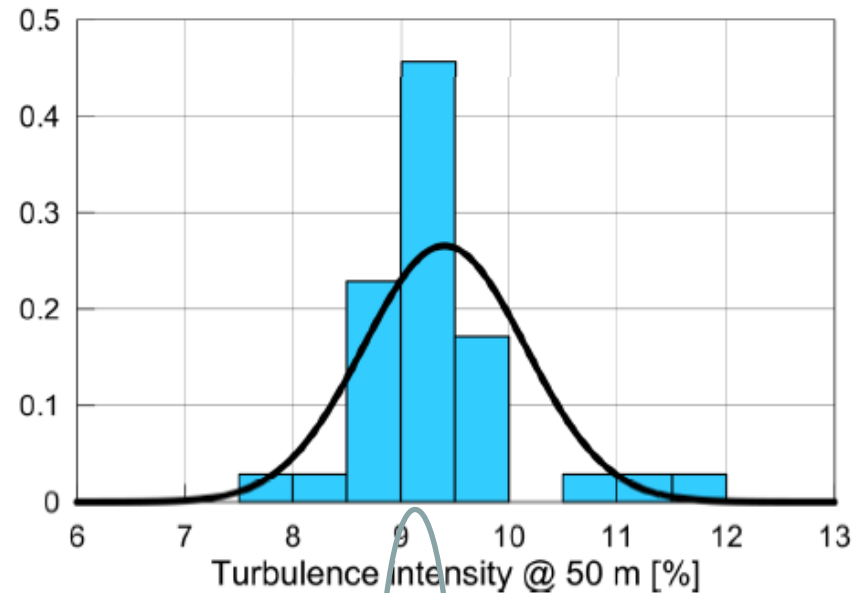
Team 31 and 35 report no results

Mean turb. intensity = **9.4%**

Std. deviation = **0.8%** (8%)

Range = 8% to 12% (43%)

WindSim = 9.72% (site measurements)



Results - long-term turbulence intensity @ 60m

Turbulence intensity @ 60 m

Data points used = 29 (of 37)

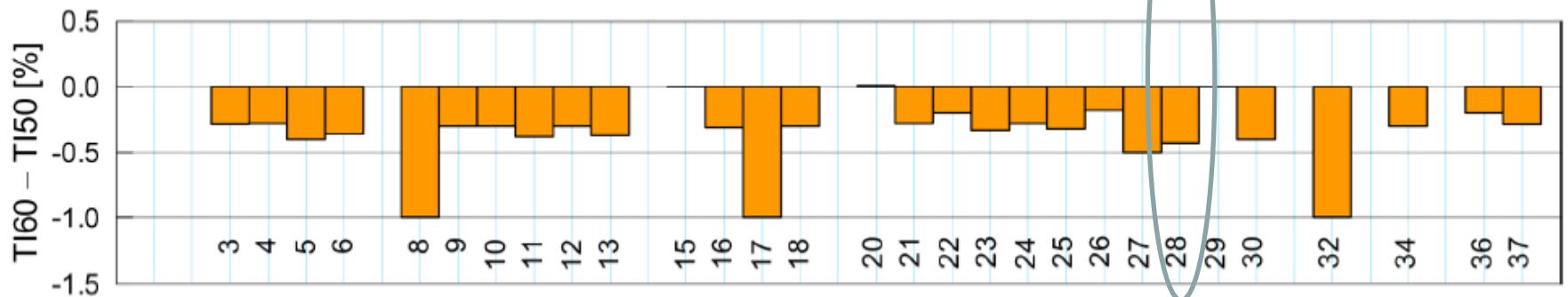
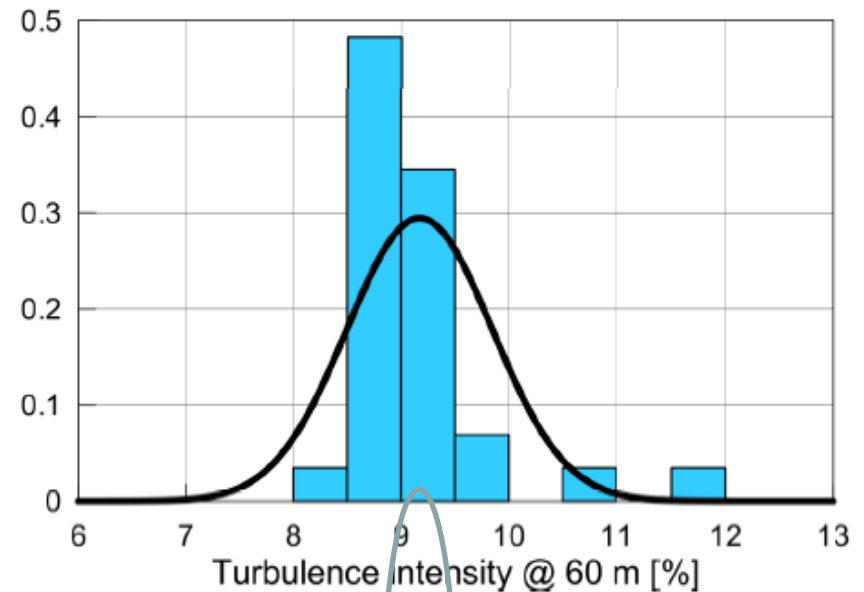
Eight teams report no results

Mean turb. intensity = **9.2%**

Std. deviation = **0.7%** (7.8%)

Range = 8.1% to 12% (38%)

WindSim = 9.29% (transferred .tws)



Results – gross energy yield

Gross energy yield of wind farm

Data points used = 36 (of 37)

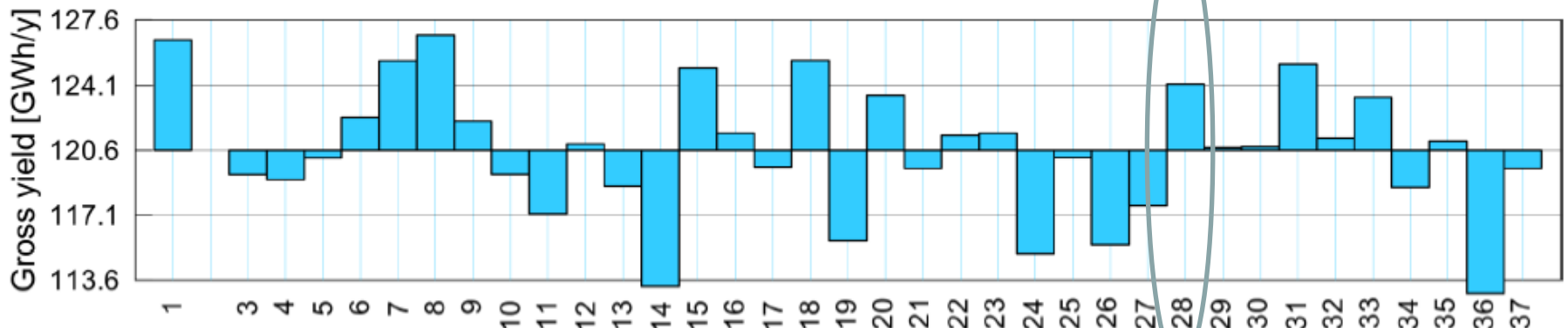
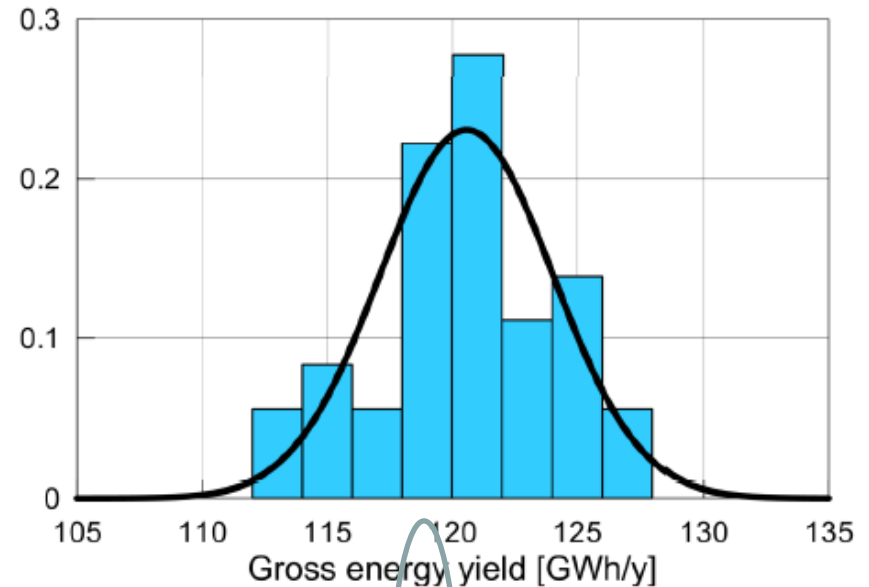
Team 2 reports no result

Mean gross yield = **121 GWh**

Std. deviation = **3.5 GWh (2.9%)**

Range = 113 to 127 GWh (12%)

WindSim = 118GWh*1.054=124GWh (2.6%)



Results – wake losses

Wake losses

Data points used = 36 (of 37)

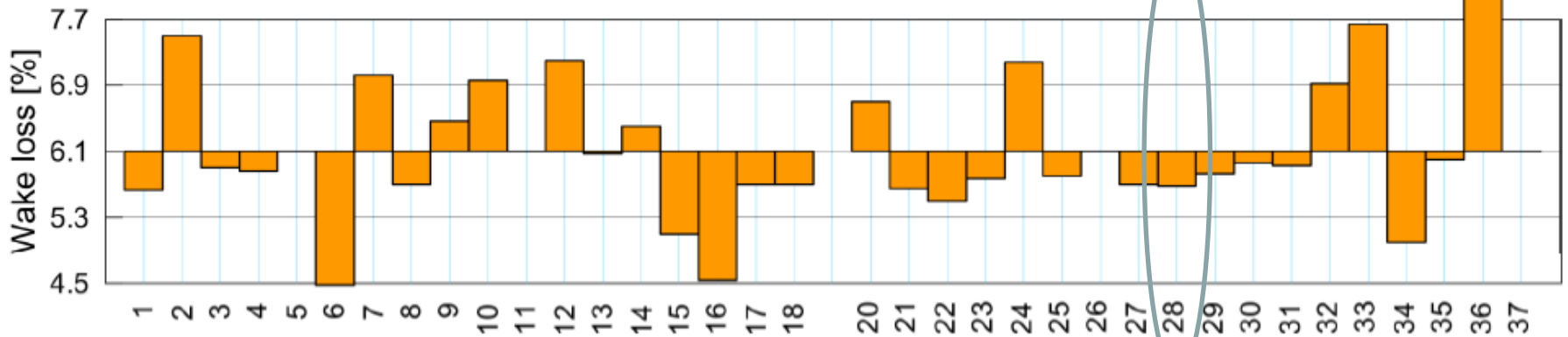
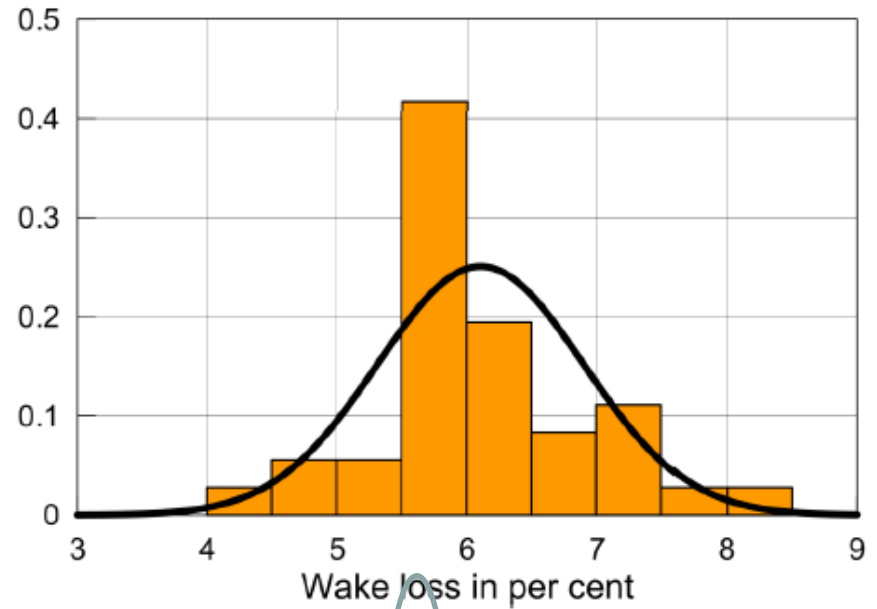
Team 19 reports no result

Mean wake loss = **6.1%**

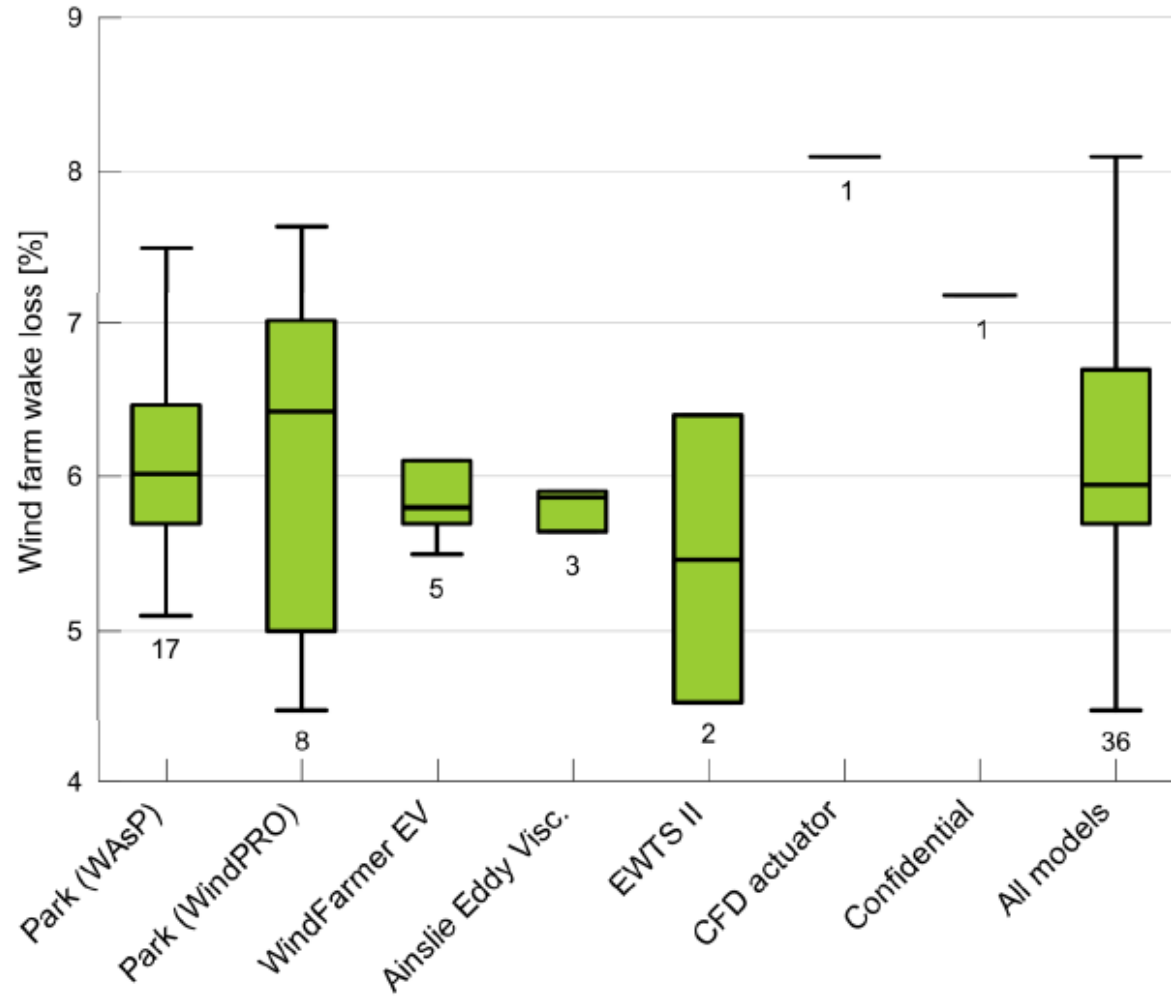
Std. deviation = **0.8%** (13%)

Range = 4.5% to 8.1% (59%)

WindSim = 5.68% (6.9%)



Comparison of wake models



Results – potential energy yield

Potential energy yield of wind farm

Data points used = 35 (of 37)

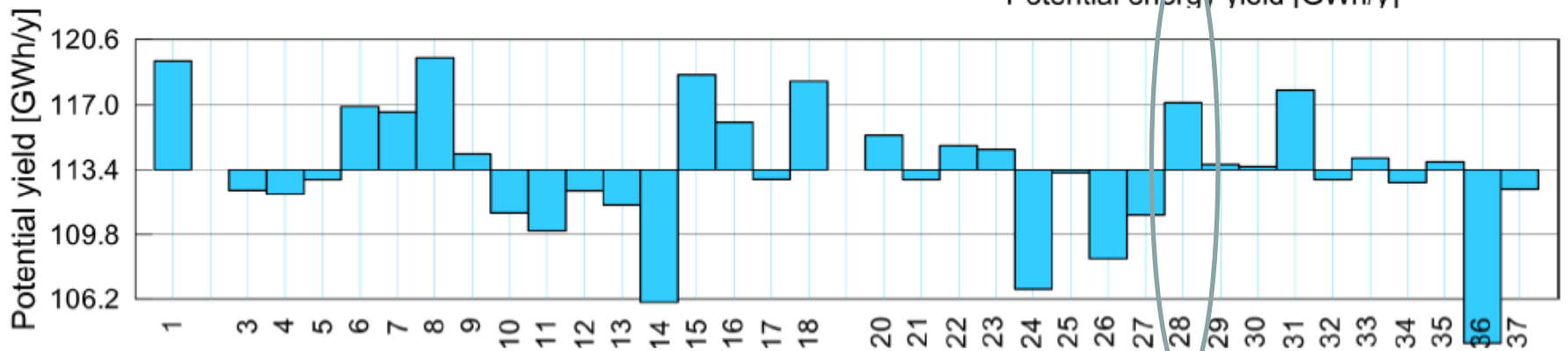
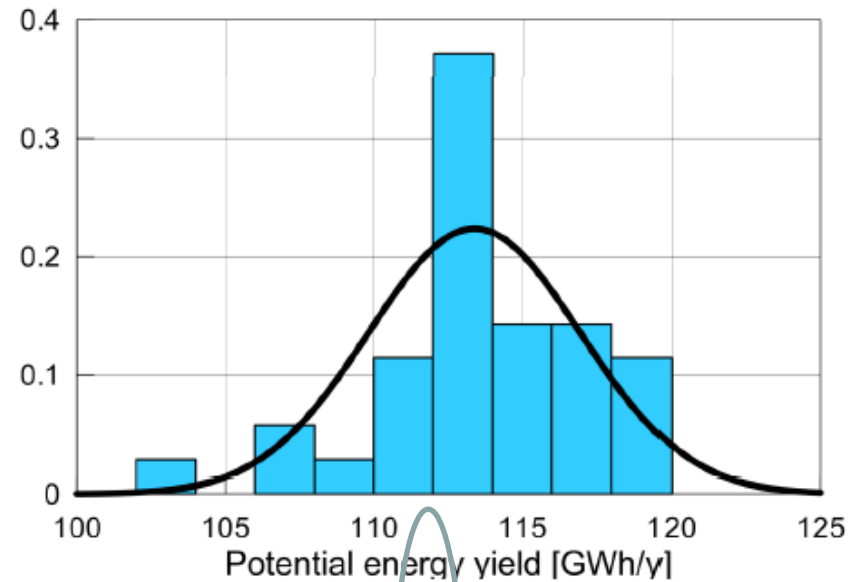
Team 2 and 19 report no results

Mean potential yield = **113 GWh**

Std. deviation = **3.6 GWh (3.2%)**

Range = 104 to 120 GWh (14%)

WindSim = 117GWh (3.5%)



Results – technical losses

Technical losses

Data points used = 34 (of 37)

Team 2, 8 and 9 report no results

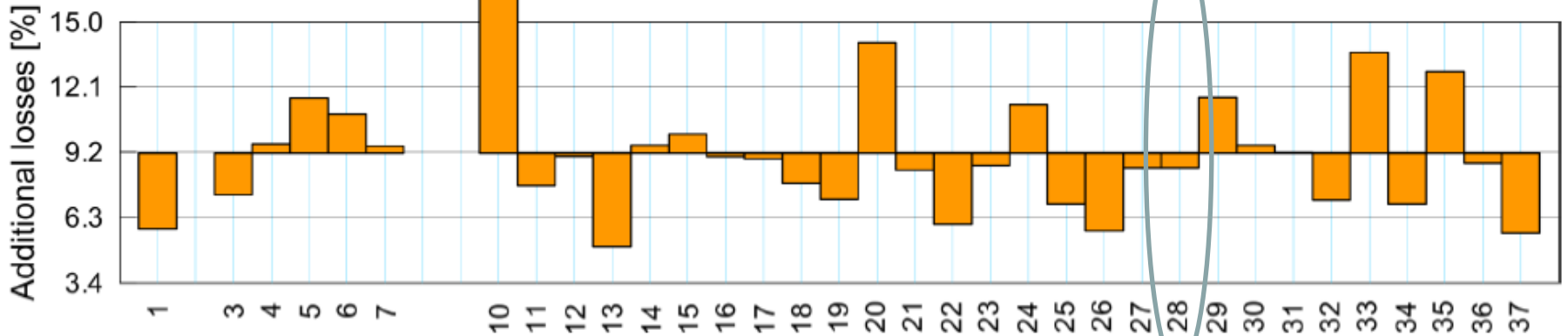
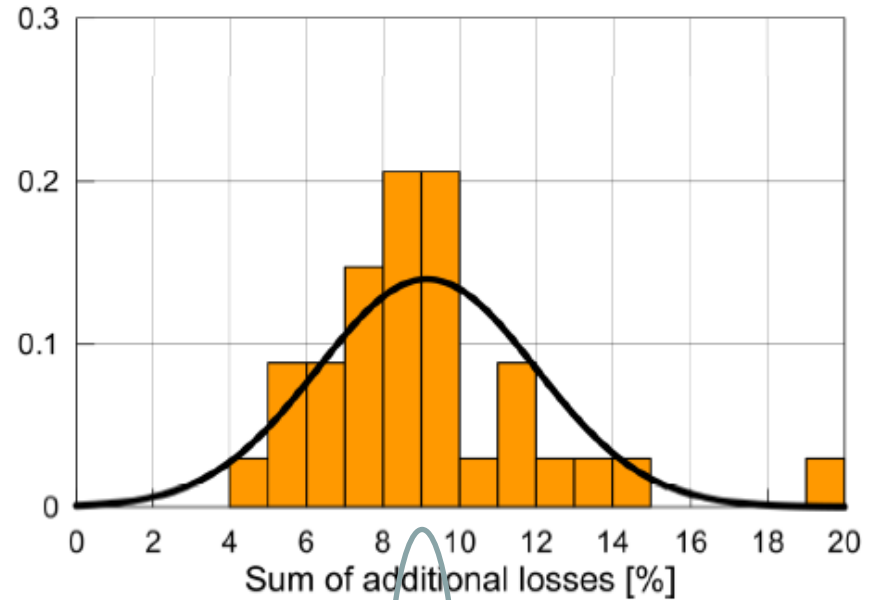
Mean total loss = **9.2%**

Std. deviation = **2.9%** (32%)

Range = 5 to 20% (159%)

Median value = 8.8%

WindSim = 8.5% (7.6%)



Results – net energy yield (P50)

Net energy yield of wind farm (P50)

Data points used = 34 (of 37)

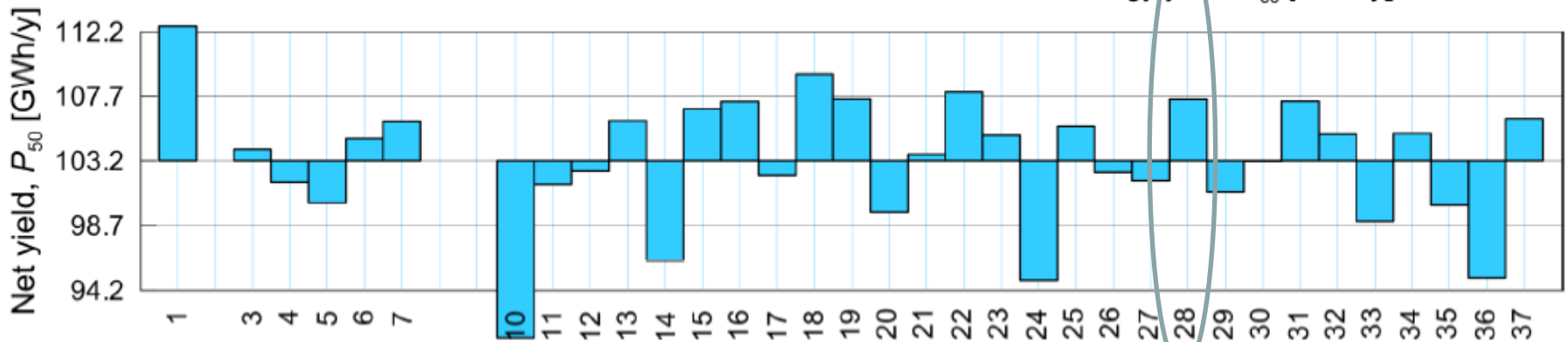
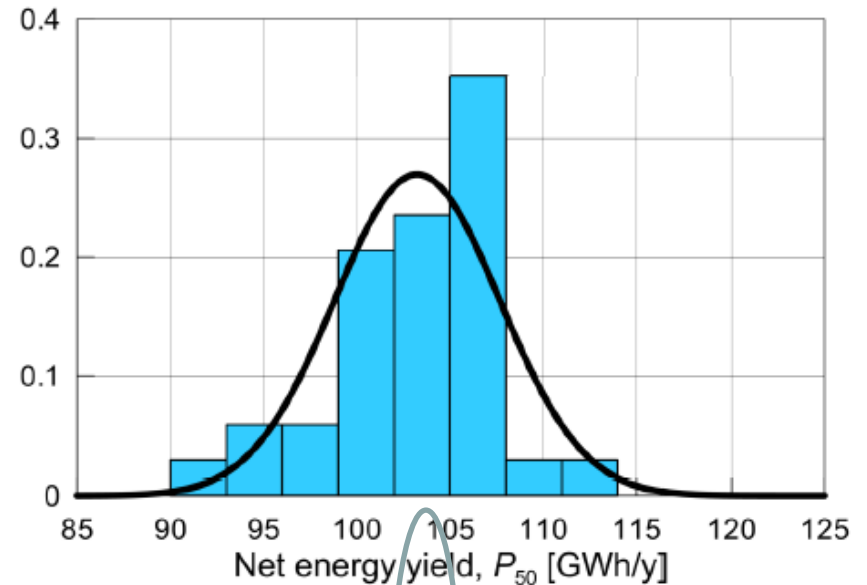
Team 2, 8 and 9 report no results

Mean net yield = **103 GWh**

Std. deviation = **4.5 GWh (4.4%)**

Range = 91 to 113 GWh (21%)

WindSim = 107GWh (4.3%)



Team number

windsim

Results – uncertainty

Uncertainty estimates

Data points used = 35 (of 37)

Team 2 and 9 report no results

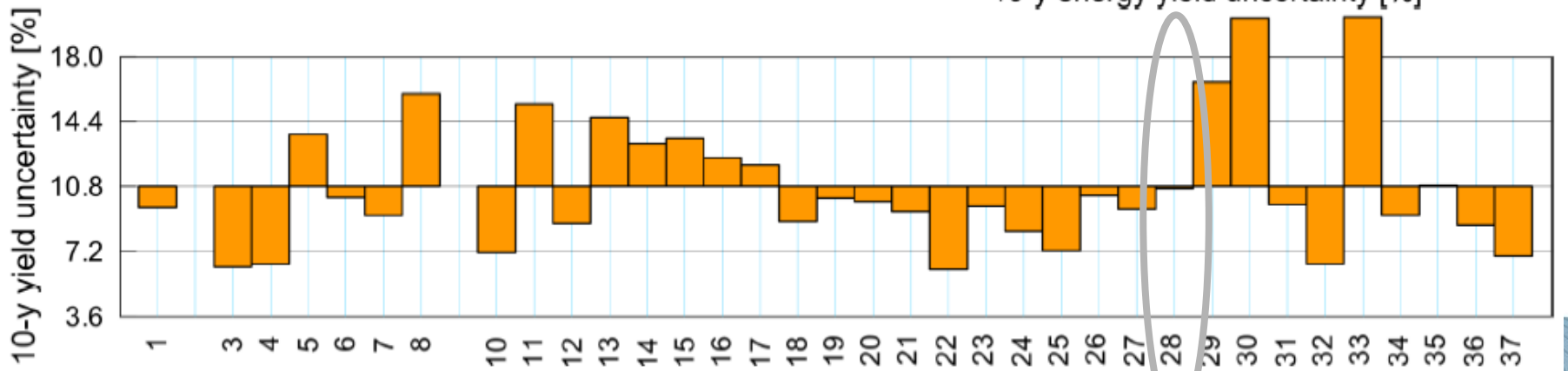
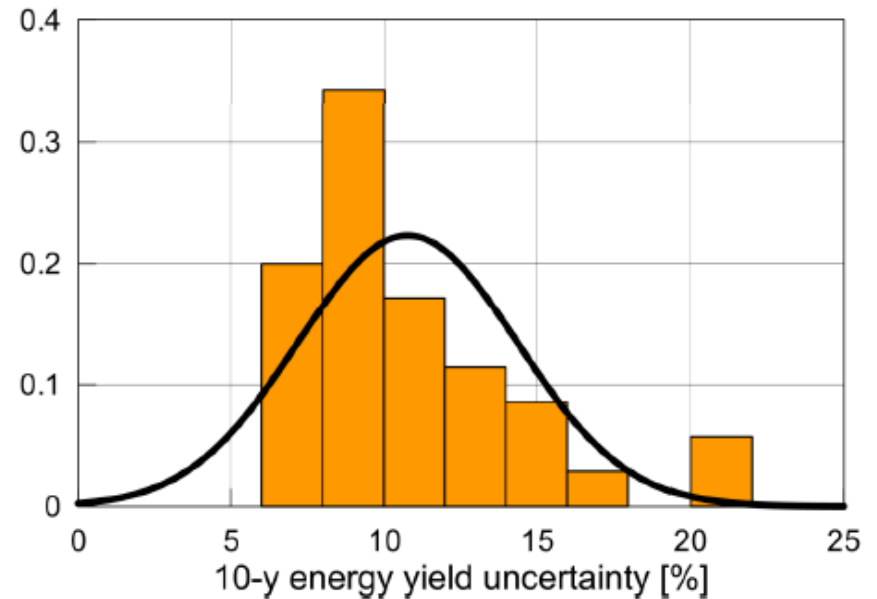
Mean uncertainty = **11%**

Std. deviation = **3.6%** (34%)

Range = 6 to 20% (129%)

(Calculated from *P50* and *P90*)

WindSim = 10.7% (2.7%)



Results – net energy yield (P90)

Net energy yield of wind farm (P90)

Data points used = 35 (of 37)

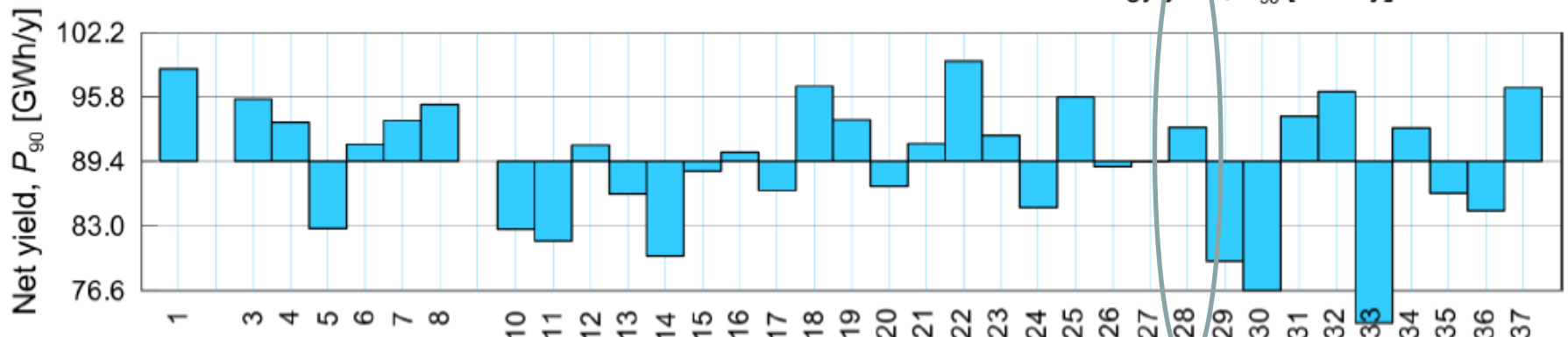
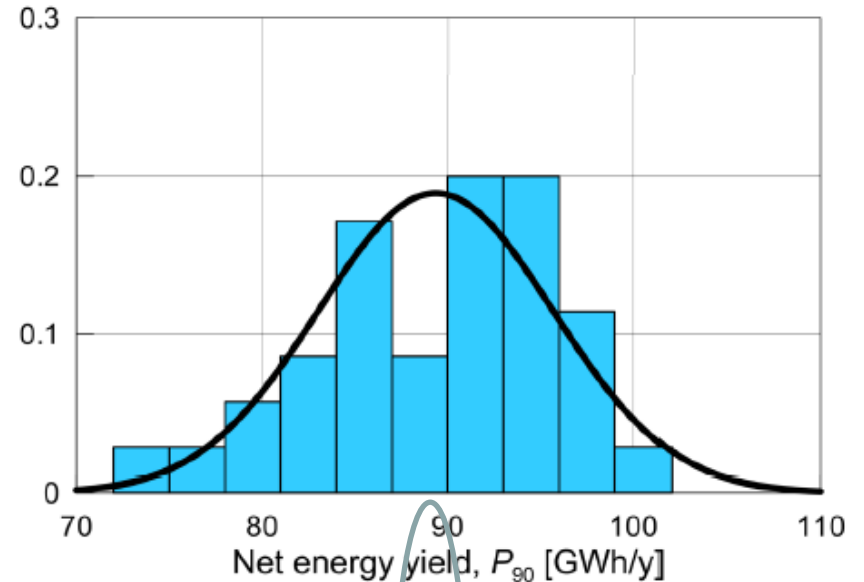
Team 2 and 9 report no results

Mean net yield = **89 GWh**

Std. deviation = **6.4 GWh (7.2%)**

Range = 73 to 99 GWh (29%)

WindSim = 92.8 GWh (4.2%)



WindSim Losses & Uncertainties tool

Losses And Uncertainties
X

Losses

AEP GROSS	111,42 GWh/y
AEP (inc. wake effects)	107,15 GWh/y
AEP NET	99,81 GWh/y

Other losses (6,85%)

Description	%	
Availability	3	✕
Grid	3	✕
Icing	1	✕

Uncertainties

P50	50 %	99,81 GWh/y
P75	75 %	90,44 GWh/y
P90	90 %	82,00 GWh/y
Uncertainties		13,92%

Uncertainties wind (6,78%)

Description	%	
Wind variability	3	✕
Wind measuremnts	1	✕
WindSim	6	✕

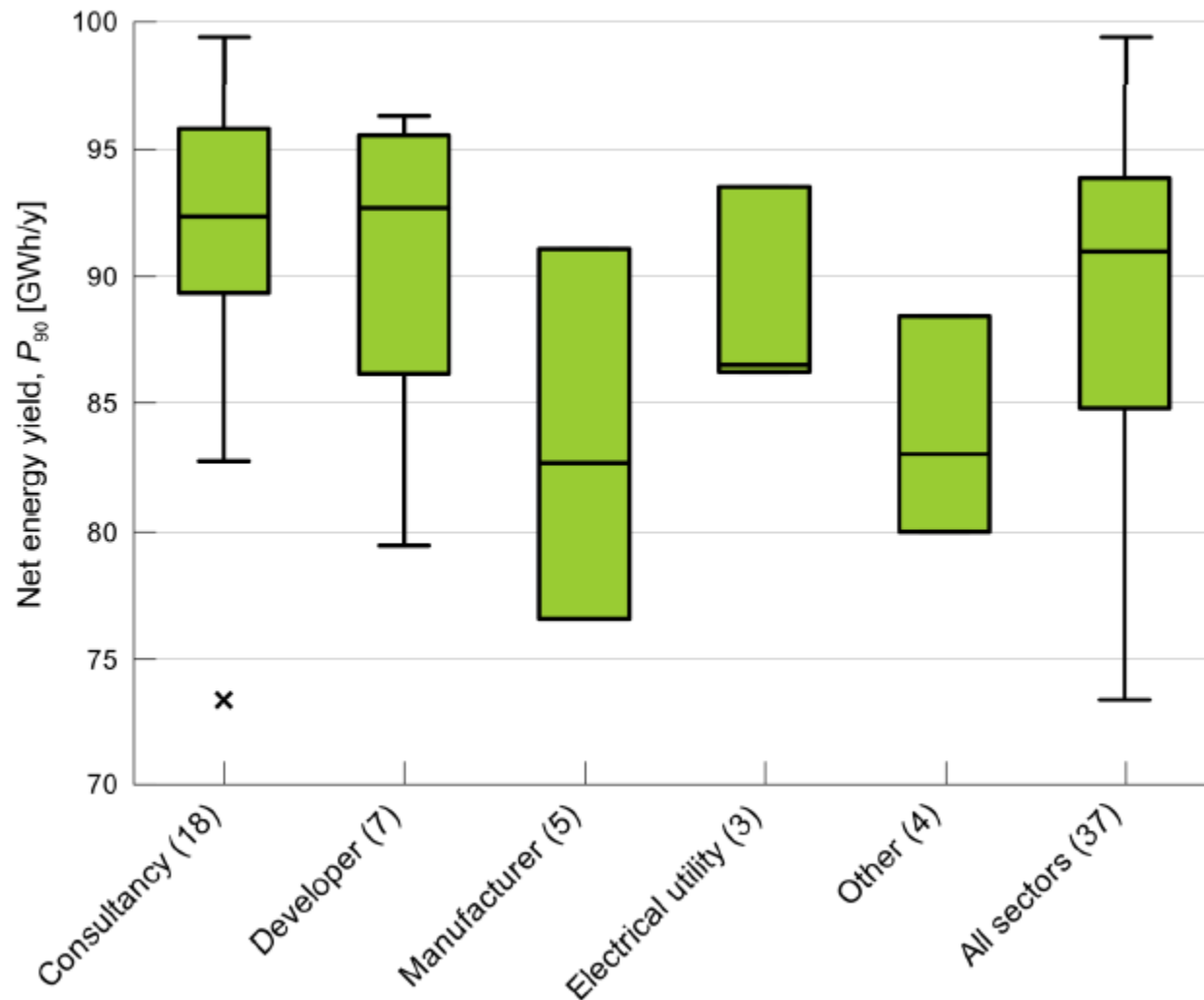
Uncertainties energy (6,71%)

Description	%	
Power curve	6	✕
Losses	3	✕

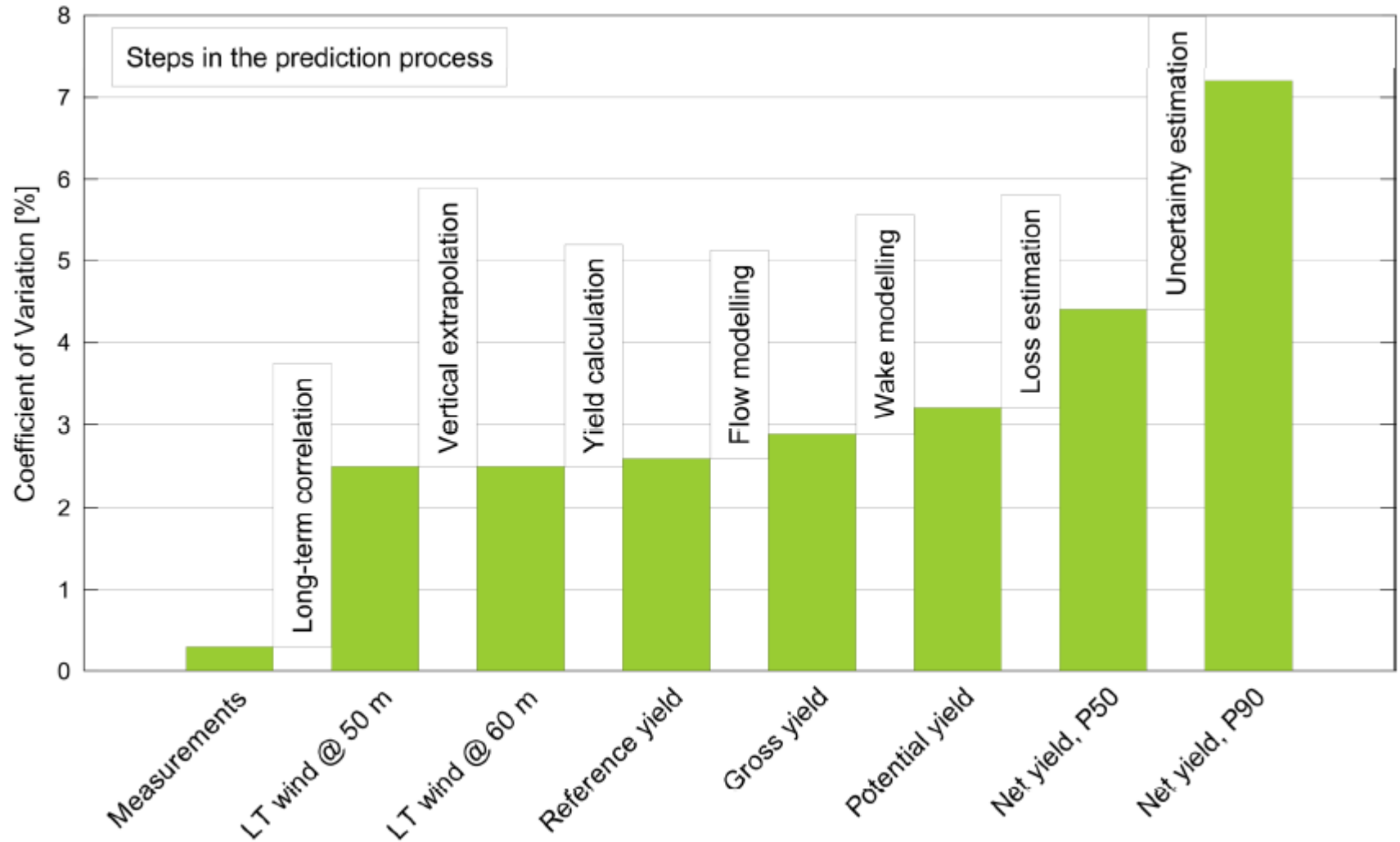
(Sensitivity factor 1,80%)

Export
Need Help?

Comparison of P_{90} versus business sector



Steps in the prediction process



"Accuracy "

Comparison of Resource and Energy Yield Assessment Procedures (EWEA)

as indicator for the performance of the consulting team

4.2 %

Difference between P90 calculated by WindSim and the average
amongst all the participants



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THANKS QUESTIONS?

MORE QUESTIONS? CONTACT

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Li Di, di@windsim.com

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