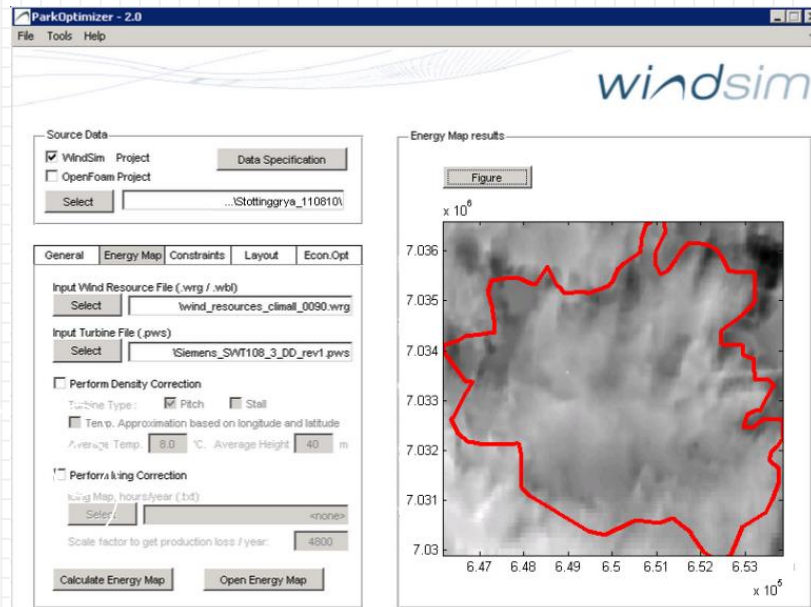


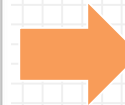
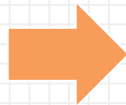
ParkOptimizer 2.0

Maximising energy, minimising loads

by Klaus Vogstad
klaus@windfarmdesigns.com



CFD
results



Final
layout

Project
constraints

1

IEC
compliance

2

Optimise
turbine
layout

3

Optimise
size

4

1. Overview of new features in 2.0
 - a. Energy map
 - b. IEC maps
 - c. Optimisation
2. ParkOptimizer 2.0 integration with WindFarmDesigns.com (WFD)
 - a. ParkOptimizer 2.0 can seamlessly run more sophisticated layout optimisation algorithms through WFD API
3. Using ParkOptimizer for site suitability and turbine tenders

X Energy map

- X Density correction
- X Icing map correction

X Crossprediction graphs

- X per sector & per wind speed
 - Wind speed
 - Shear
 - Turbulence

X IEC constraints

- X Faster computations
- X Turbulence and effective turbulence maps & per wind speed bins
- X Options for turbulence extrapolation
 - from CFD results
 - from Mast
 - combining both

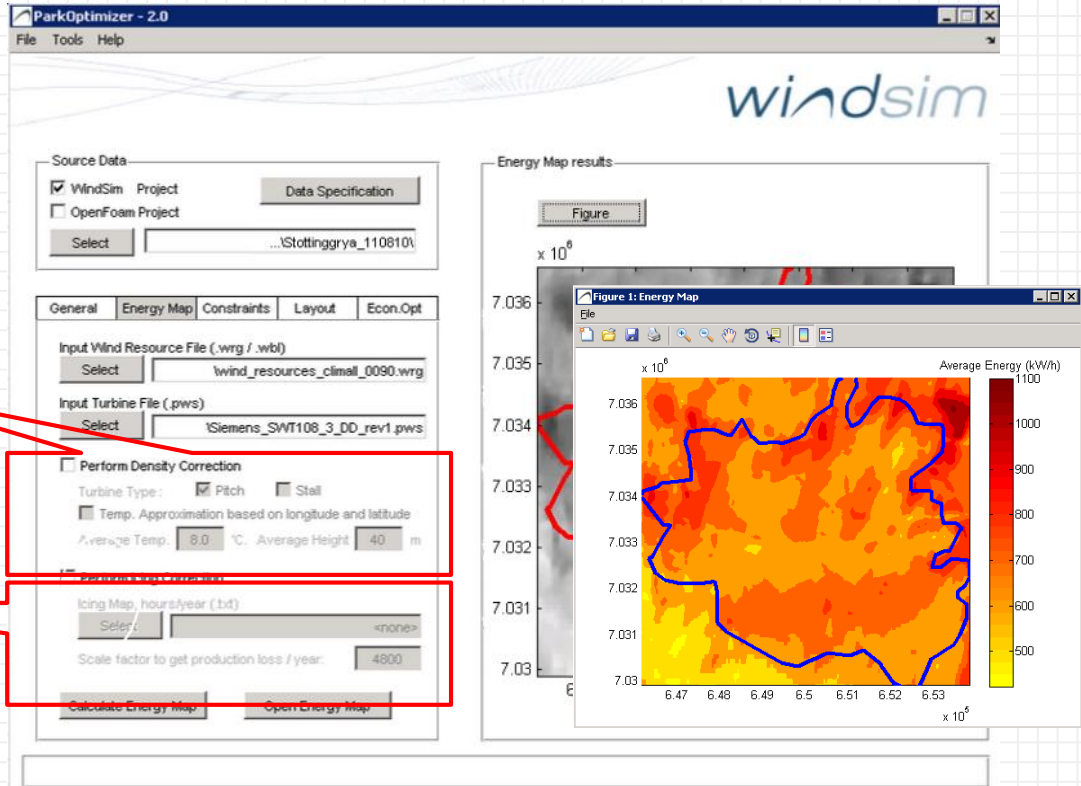
X Optimisation

- X Elliptic constraints optimisation via WindFarmDesigns API
- X API for optimisation - can be integrated into other services

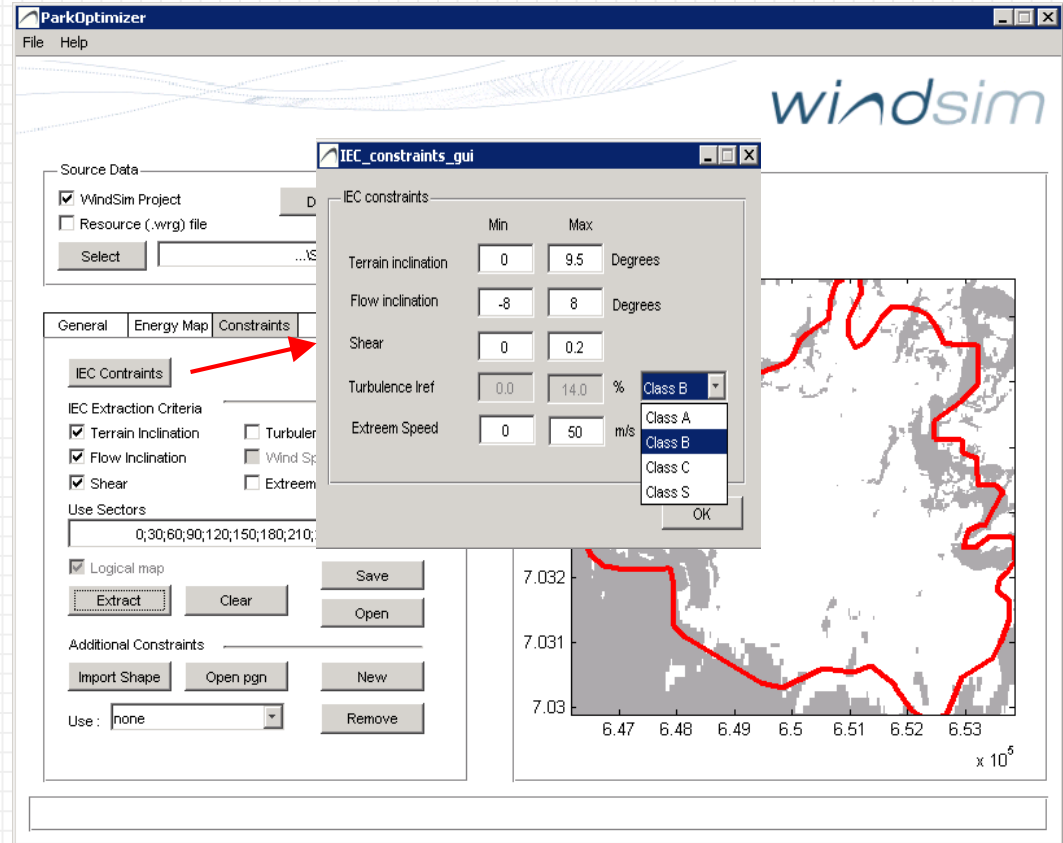
1. New Energy map features

Density correction based
on lat/lon and weather
data

Correction from icing
losses if ice maps are
available
(file upload)



X Defined classes for turbulence and extreme wind exclusion maps



The screenshot shows the ParkOptimizer software interface. The main window displays a map with a red boundary. A dialog box titled "IEC_constraints_gui" is open, showing the following constraints:

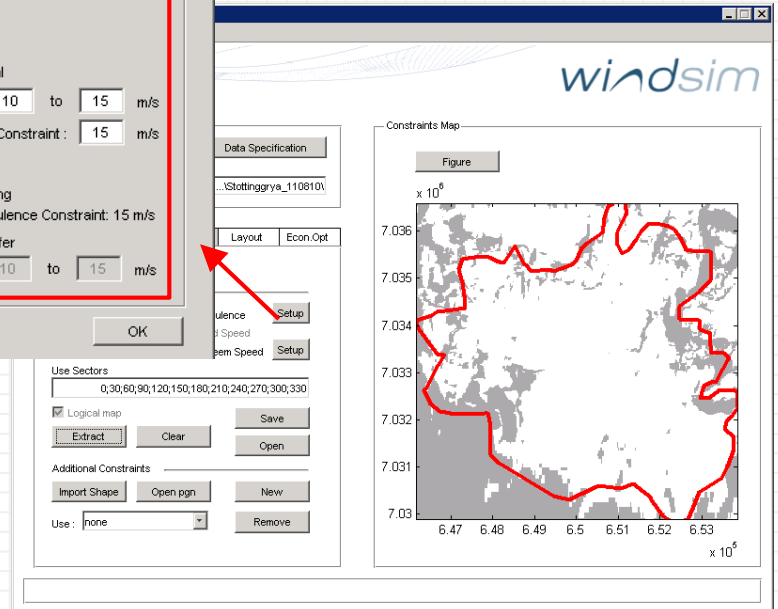
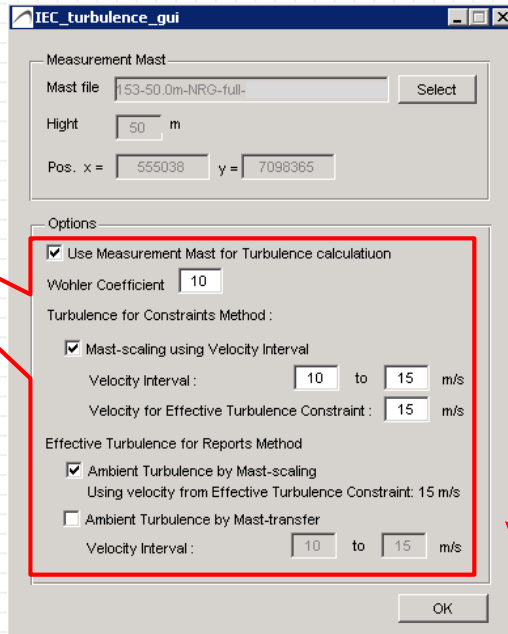
Constraint	Min	Max	Unit
Terrain inclination	0	9.5	Degrees
Flow inclination	-8	8	Degrees
Shear	0	0.2	
Turbulence Iref	0.0	14.0	%
Extrem Speed	0	50	m/s

The "Turbulence Iref" dropdown menu is open, showing the following options: Class B (selected), Class A, Class C, and Class S. The "Use Sectors" field is set to "0,30;60;90;120;150;180;210;". The "Logical map" checkbox is checked. The "Extract" button is highlighted with a red arrow.

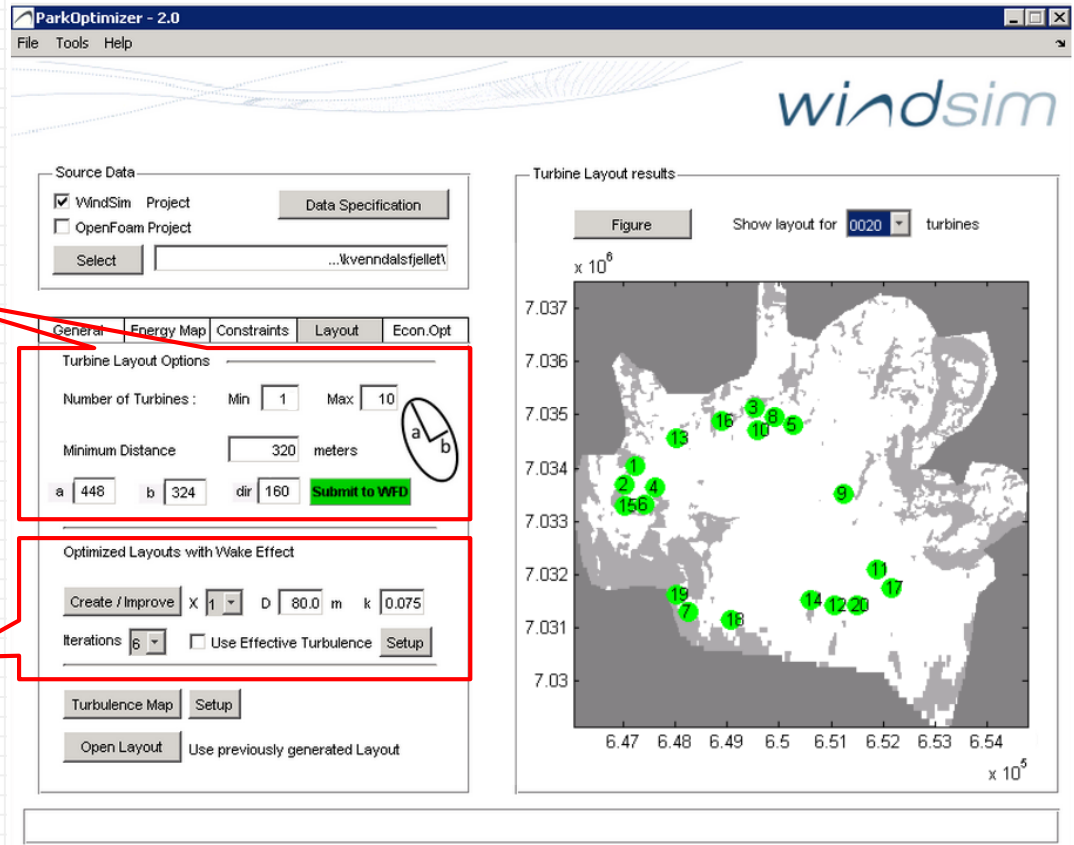
X Turbulence and effective turbulence maps & per wind speed bins

X Options for turbulence extrapolation

- from CFD results
- from Mast
- combining both



- X New optimisation option with elliptic distance constraint.
 - X Global optimum using operations research techniques
 - X Fast computations in the cloud - integrated service with WindFarmDesigns
 - X Provides a range of layouts
- X Old heuristic optimisation still available (simulated annealing)

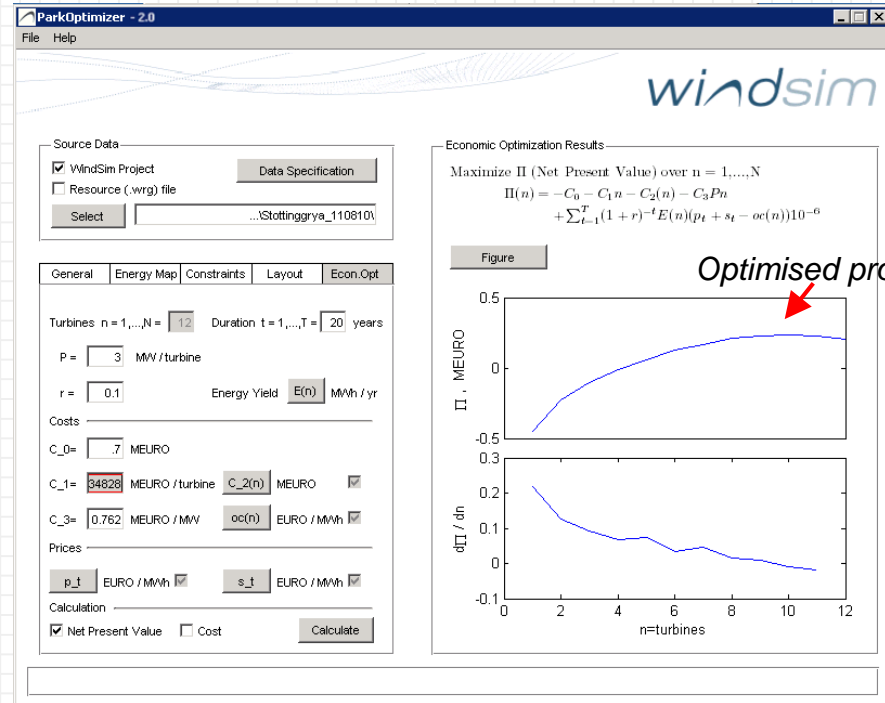


The screenshot shows the ParkOptimizer - 2.0 software interface. The window title is "ParkOptimizer - 2.0" and it has a menu bar with "File", "Tools", and "Help". The interface is divided into several sections:

- Source Data:** Includes a "Data Specification" button and a "Select" button with a file path "...\kvenndalsfjellet\".
- General Tab:** Contains "Turbine Layout Options" and "Optimized Layouts with Wake Effect".
 - Turbine Layout Options:** Includes "Number of Turbines" (Min: 1, Max: 10), "Minimum Distance" (320 meters), and a diagram showing an elliptical distance constraint with parameters 'a' (448), 'b' (324), and 'dir' (160). A "Submit to WFD" button is present.
 - Optimized Layouts with Wake Effect:** Includes a "Create / Improve" button, a dropdown menu set to 'X', a "D" field set to 80.0 m, a "k" field set to 0.075, an "Iterations" dropdown set to 6, and a "Use Effective Turbulence" checkbox with a "Setup" button.
- Other Buttons:** "Turbulence Map" with a "Setup" button, and "Open Layout" with the text "Use previously generated Layout".

On the right side, the "windsim" logo is visible above the "Turbine Layout results" section. This section includes a "Figure" button, a "Show layout for" dropdown set to "0020" turbines, and a plot area. The plot shows a map of the turbine layout with 20 numbered green dots representing turbine positions. The axes are labeled with coordinates in units of 10^6 and 10^5 .

- X Size matters:
 - X Optimizing for a range of layout sizes provides you with an energy curve $E(n)$ for project sizes of $n=1..N$ turbines
 - X Project size is important for profitability considerations, and even more for risk-return
 - X NPV or LCOE as optimisation criteria



X IEC reports for site suitability of layouts, i.e flow inclination, shear, I_a , I_{eff} , extreme wind

layout0022_lect.txt

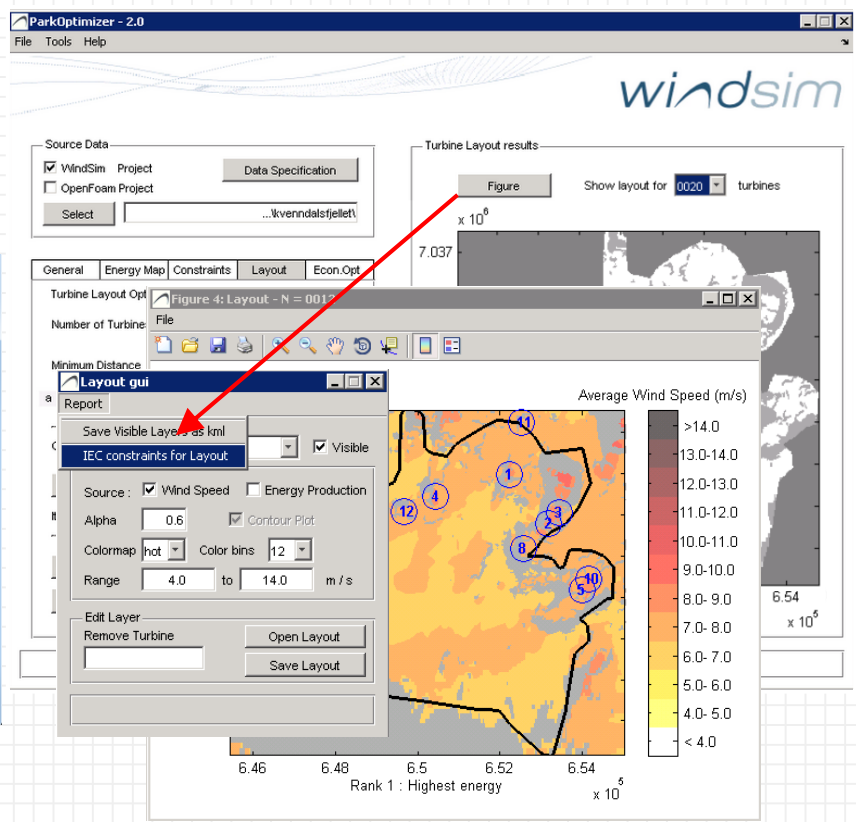
IEC constraints, max or mean (based on frequency distribution of Wind Resource file) over Used Sectors :

Turbine	x	y	z	A	k	V _{mean}	V _{wake}	Terrain	Incl.	Flow Incl.	Shear	Ambient turbulence	Effective turbulence	Extreme speed
um	um	m	Weibull		m/s	m/s	degr.		degr.	(max)	(mean)	% (mean)	%	m/s
1	287763.0	6798988.0	NaN	8.97	1.83	7.93	7.77	10.03	7.81	0.11	16.88	20.08	41.07	
2	287738.0	6797063.0	NaN	9.34	1.80	8.28	7.87	10.52	4.14	0.06	14.28	19.82	44.24	
3	288188.0	6799163.0	NaN	8.94	1.83	7.91	7.59	8.65	6.77	0.11	14.13	20.92	43.27	
4	288038.0	6799313.0	NaN	9.28	1.84	8.21	7.46	5.76	7.94	0.07	12.90	19.30	43.39	
5	288163.0	6797063.0	NaN	8.87	1.81	7.86	7.43	9.05	4.98	0.08	15.88	20.82	37.81	
6	290013.0	6796763.0	NaN	8.34	1.83	7.39	7.26	6.54	7.60	0.05	17.88	20.22	58.45	
7	288488.0	6796813.0	NaN	8.34	1.84	7.38	7.14	11.75	5.72	0.11	16.78	21.91	35.04	
8	288338.0	6796338.0	NaN	8.33	1.82	7.37	7.15	7.13	4.08	0.09	16.13	20.18	45.84	
9	288438.0	6796663.0	NaN	8.79	1.83	7.77	7.08	11.37	5.10	0.11	15.29	20.94	53.54	
10	289563.0	6796738.0	NaN	8.08	1.83	7.16	7.00	0.03	7.45	0.10	18.55	21.06	51.36	
11	288888.0	6799613.0	NaN	8.21	1.83	7.27	6.98	9.27	6.89	0.13	16.29	21.24	44.02	
12	290138.0	6797963.0	NaN	8.03	1.84	7.12	7.00	10.44	7.04	0.06	17.45	20.43	63.99	
13	289063.0	6797888.0	NaN	8.10	1.84	7.18	6.92	8.96	7.99	0.10	16.52	19.55	47.10	
14	288913.0	6796863.0	NaN	8.12	1.83	7.18	6.90	9.13	4.68	0.10	15.87	21.40	38.63	
15	288638.0	6797238.0	NaN	8.45	1.82	7.49	6.87	5.94	6.59	0.09	14.82	20.58	45.10	
16	289938.0	6797588.0	NaN	8.02	1.83	7.10	6.80	4.05	4.26	0.03	17.79	20.87	46.88	
17	287738.0	6799413.0	NaN	8.34	1.83	7.39	6.73	0.00	7.79	0.15	18.20	22.03	40.78	
18	288613.0	6799288.0	NaN	8.11	1.83	7.18	6.65	8.62	6.28	0.17	17.40	22.49	52.90	
19	287388.0	6796688.0	NaN	7.69	1.81	6.82	6.63	9.69	5.24	0.20	18.76	22.90	37.59	
20	287338.0	6797138.0	NaN	7.98	1.82	7.06	6.58	11.02	7.55	0.20	18.85	23.12	43.14	
21	289763.0	6798938.0	NaN	7.44	1.83	6.59	6.54	10.80	5.63	0.10	17.26	18.09	37.71	
22	289188.0	6798313.0	NaN	7.55	1.83	6.68	6.52	2.62	6.46	0.11	18.40	21.06	43.03	

Sector wise IEC constraints:

Turbine	x(utm)	y(utm)	z(m)
1	287763.0	6798988.0	NaN

Sector	A	k	f	Shear	Ambient turbulence	Effective turbulence	Flow inclination
1							



ParkOptimizer - 2.0

File Tools Help

windsim

Source Data

WindSim Project OpenFoam Project

Data Specification

Select ...\kvenndatsfjellet\

Turbine Layout results

Figure Show layout for 0020 turbines

x 10⁸

7.037

General Energy Map Constraints Layout Econ.Opt

Turbine Layout Opt Figure 4: Layout - N = 0012

Number of Turbine File

Minimum Distance

Layout gui

Report

Save Visible Layers as kmz Visible

IEC constraints for Layout

Source: Wind Speed Energy Production

Alpha 0.6 Contour Plot

Colormap hot Color bins 12

Range 4.0 to 14.0 m/s

Edit Layer

Remove Turbine Open Layout Save Layout

Average Wind Speed (m/s)

>14.0

13.0-14.0

12.0-13.0

11.0-12.0

10.0-11.0

9.0-10.0

8.0-9.0

7.0-8.0

6.0-7.0

5.0-6.0

4.0-5.0

< 4.0

6.46 6.48 6.5 6.52 6.54

Rank 1 : Highest energy

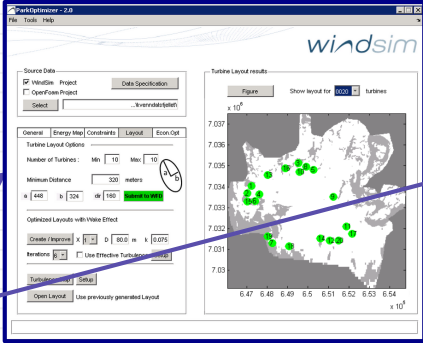
x 10⁵

2. ParkOptimizer integration with WFD

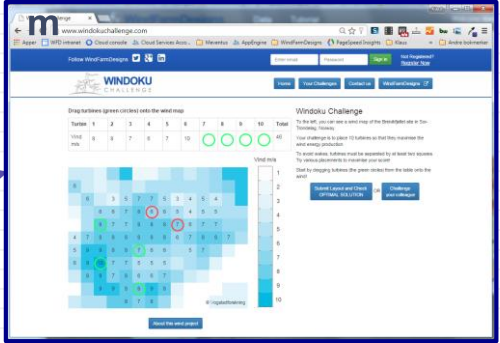
WindFarmDesigns Engine
-optimisation algorithms and other cloud based wind farm design services

API

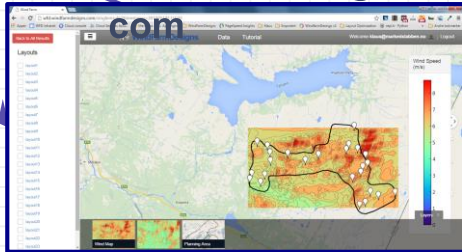
ParkOptimizer



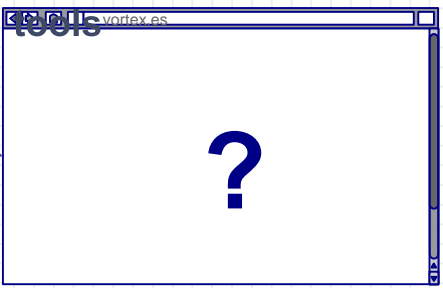
www.windokuchallenge.co



windfarmdesigns.com




3rd party & client in-house tools



Important criteria for turbine selection is Levelised Cost of Energy - LCOE

Turbine manufactureres compete on:

- X Turbine price (Turbine Supply Agreement)
- X O&M (Turbine service agreement)
- X AEP (Annual Energy Production)

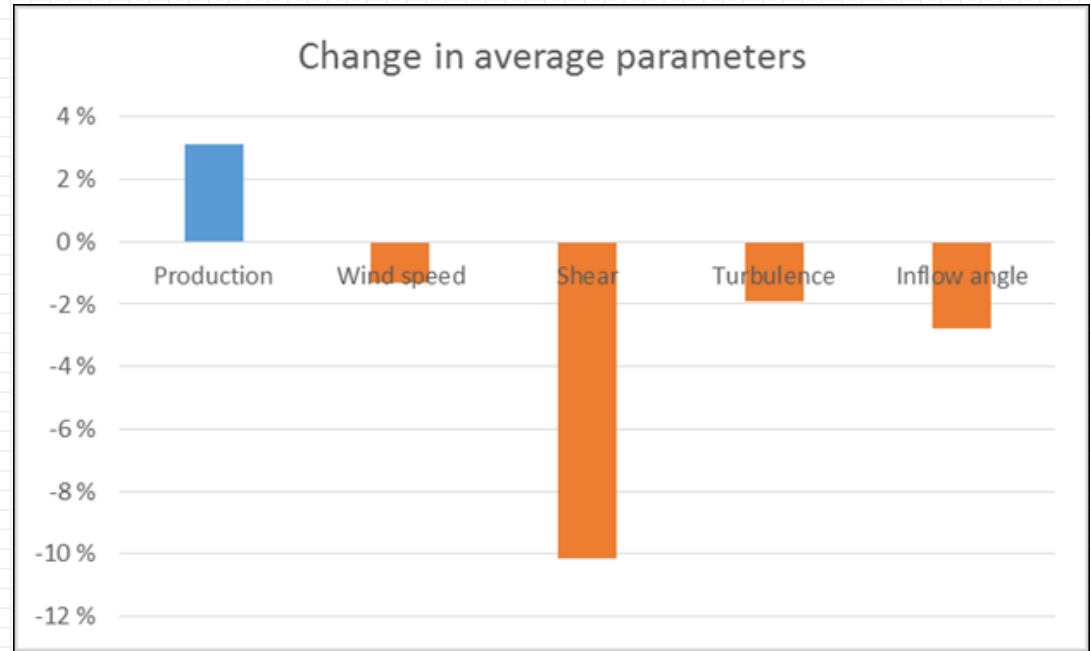
$$LCOE = \frac{\textit{Turbine price} + a \cdot \textit{O\&M}}{a \cdot \textit{AEP}}$$


While price reductions are often focused in negotiations, layout optimisations can substantially improve LCOE !

$$a = \sum_{t=1}^T (1+r)^{-t} - \text{annuity factor with interest rate } r \text{ and lifetime } T$$

Example of results obtained using ParkOptimizer

- X Layout improved *after* turbine suppliers proposed layout
- X Turbine supplier reviewed the improved layout agreed to the changes (with respect to loads)
- X **Energy maximised**, improving LCOE
- X **Loads minimised**; IEC parameters such as wind speed, shear, turbulence, inflow angle etc. were all reduced



- X Similar cases has shown improvements in AEP by 2.75%, 3%, 4% and up to 10% during turbine tenders.
- X Such improvements are decisive in winning turbine tenders

- X New features in ParkOptimizer 2.0 presented
- X ParkOptimizer can be used to optimise turbine layouts in order to
 - X Maximise energy
 - X Minimise loads
 - X Improve profitability
- X ParkOptimizer can be used to design IEC compliant layouts as part of
 - X Project development
 - X Site suitability studies
 - X Turbine tenders

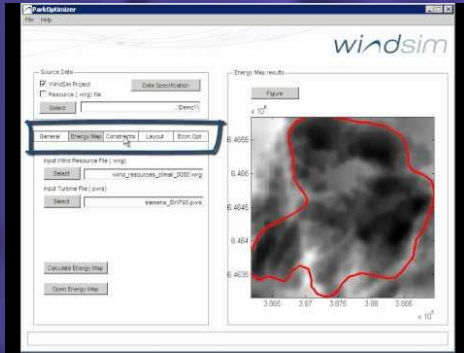
- X New features in ParkOptimizer 2.0 presented
- X ParkOptimizer can be used to optimise turbine layouts in order to
 - X Maximise energy
 - X Minimise loads
 - X Improve profitability
- X ParkOptimizer can be used to design IEC compliant layouts as part of
 - X Project development
 - X Site suitability studies
 - X Turbine tenders

Any questions?

For more information contact :

- X klaus@windfarmdesigns.com
- X www.windfarmdesigns.com

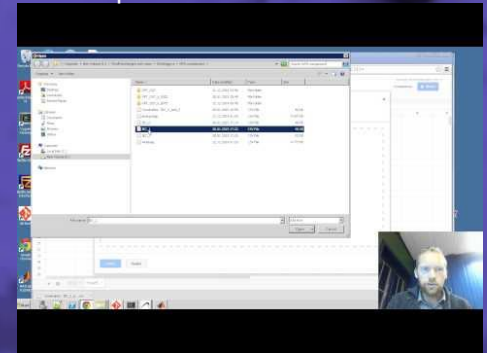
Introducing ParkOptimizer



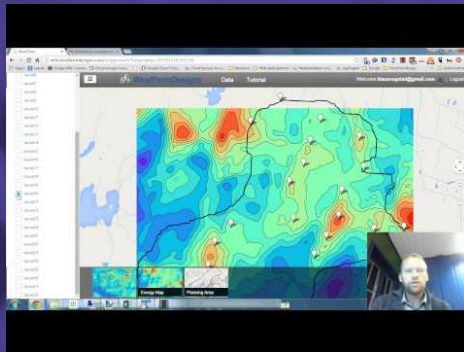
WindSim webinar on ParkOptimizer



How to combine multiple IEC constraint sets in ParkOptimizer



Introducing WindFarmDesigns



Google hangout on air - WindFarmDesigns

