ParkOptimizer 2.0
Maximising energy, minimising loads

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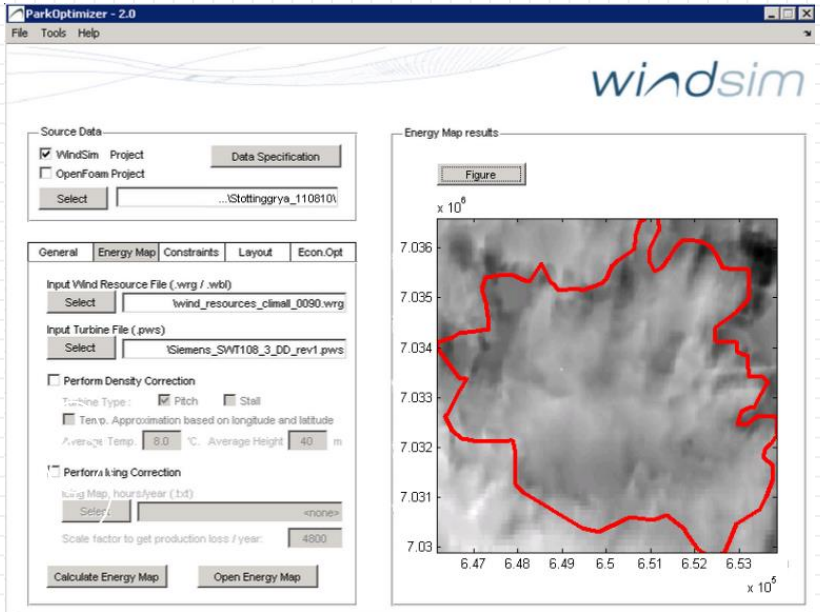
Overview of ParkOptimizer

CFD results



Final layout

Project constraints **1**

IEC compliance **2**

Optimise turbine layout **3**

Optimise size **4**

Presentation outline

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

New features summary

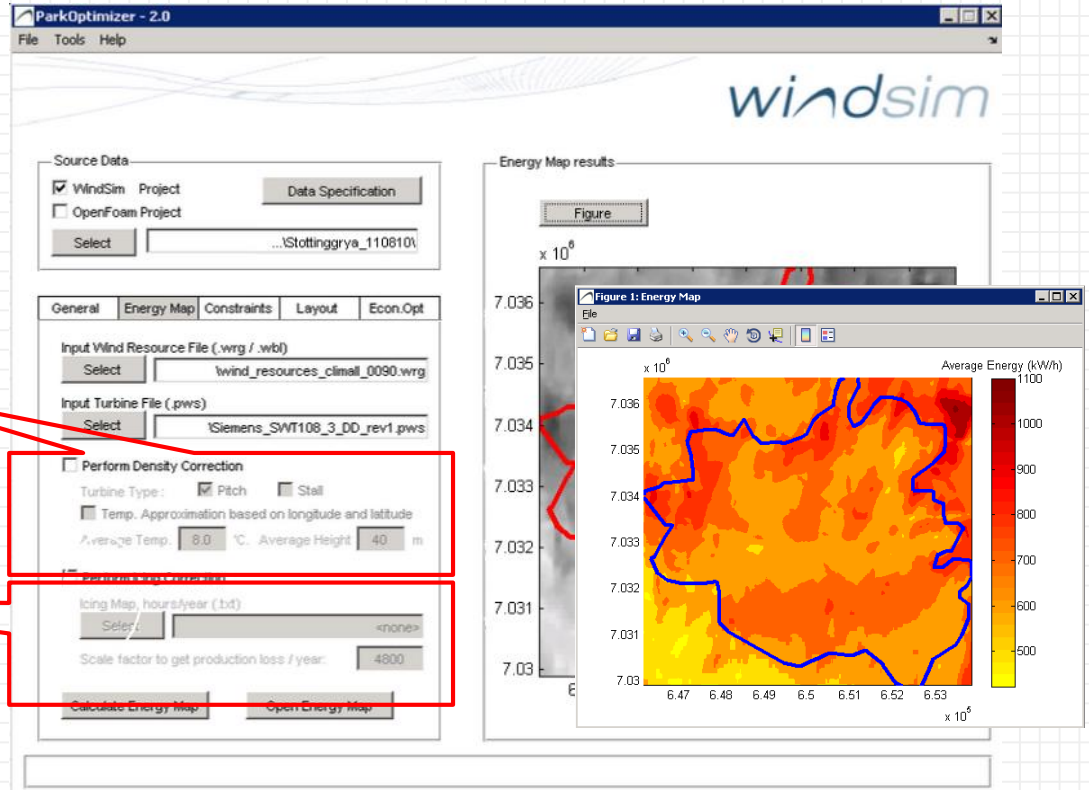
- ✗ **Energy map**
  - ✗ Density correction
  - ✗ Icing map correction
- ✗ **Crossprediction graphs**
  - ✗ per sector & per wind speed
    - Wind speed
    - Shear
    - Turbulence
- ✗ **IEC constraints**
  - ✗ Faster computations
  - ✗ Turbulence and effective turbulence maps & per wind speed bins
  - ✗ Options for turbulence extrapolation
    - from CFD results
    - from Mast
    - combining both
- ✗ **Optimisation**
  - ✗ Elliptic constraints optimisation via WindFarmDesigns API
  - ✗ API for optimisation - can be integrated into other services

1. New Energy map features

Density correction based on lat/lon and weather data

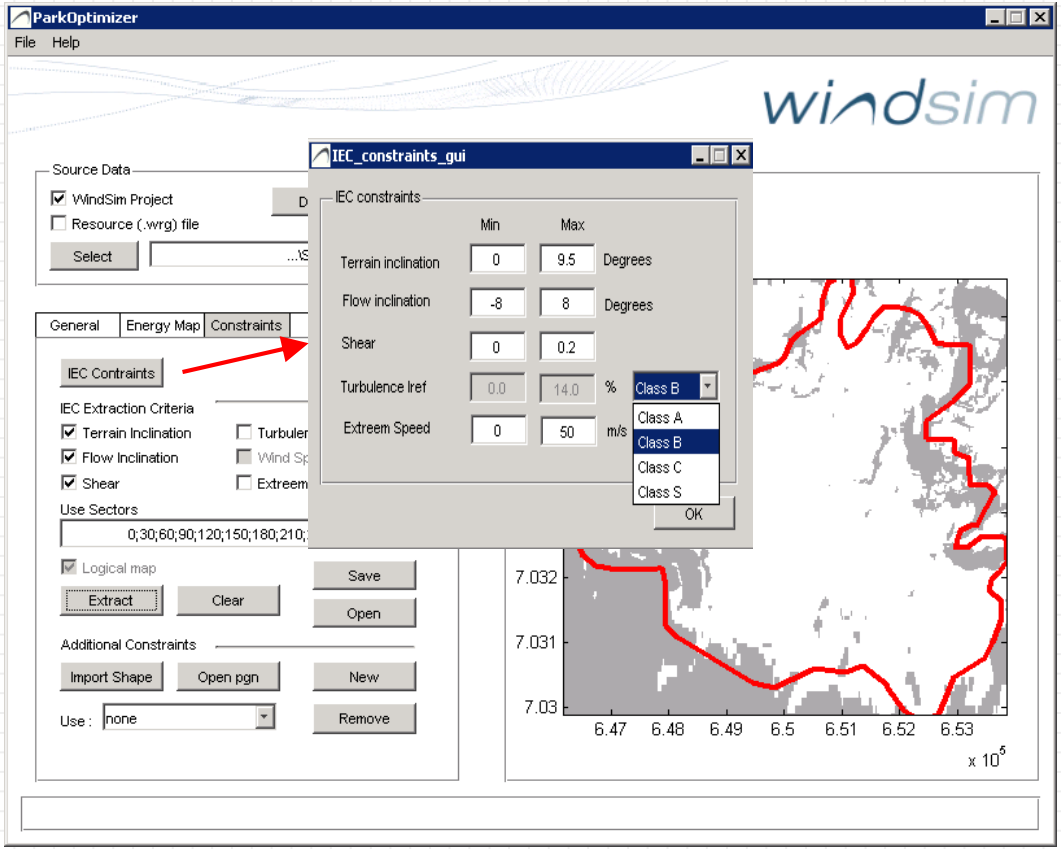
Correction from icing losses if ice maps are available

(file upload)



IEC maps update

- **Defined classes for turbulence and extreme wind exclusion maps**



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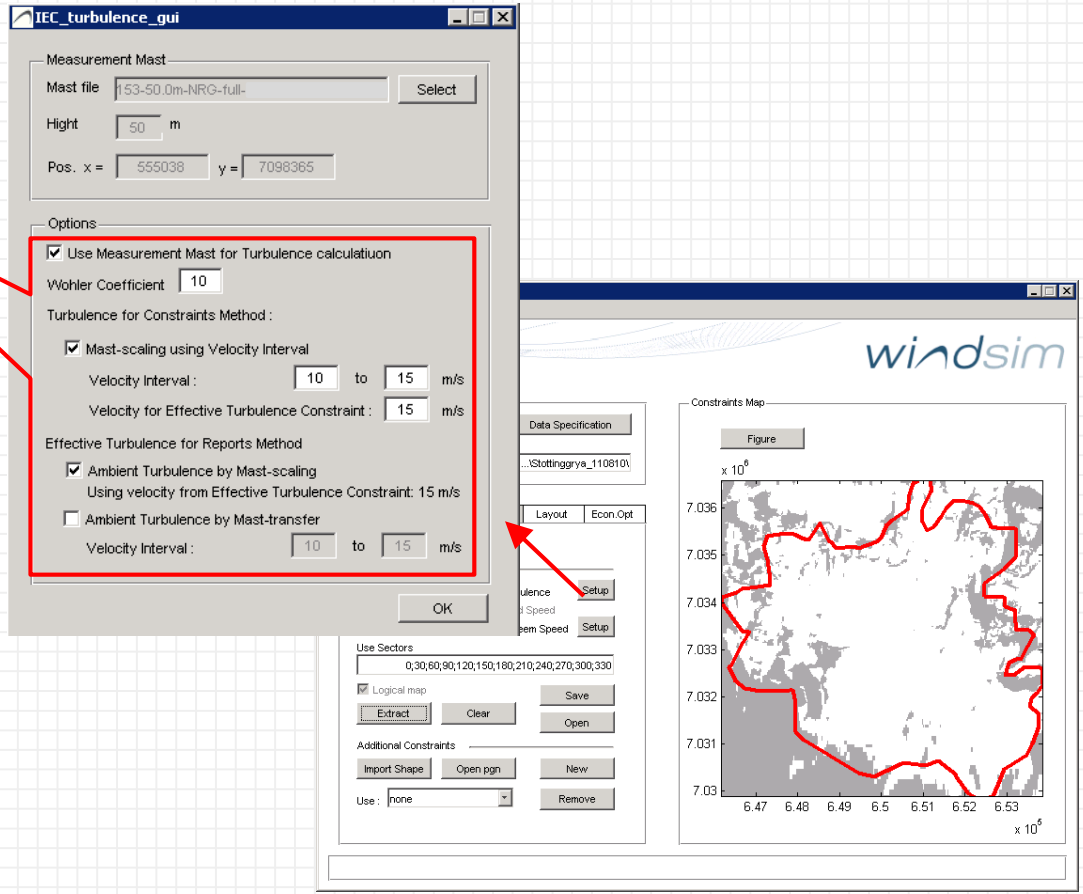
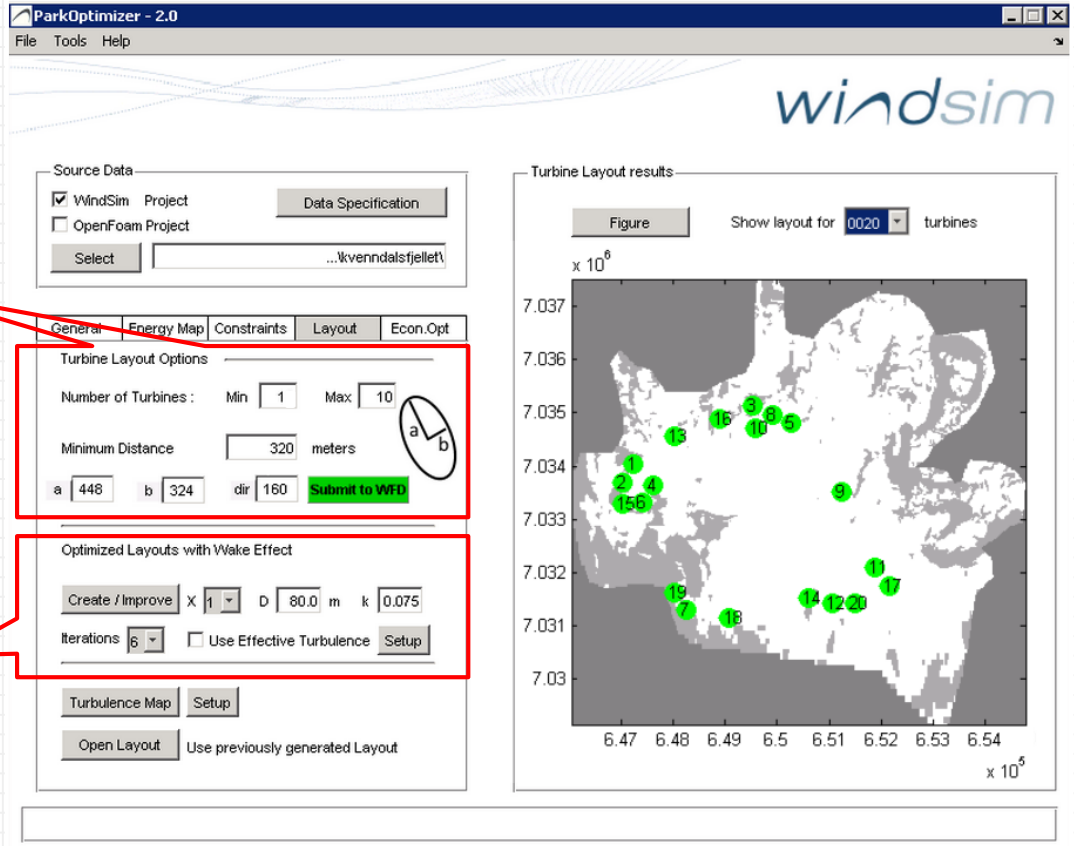


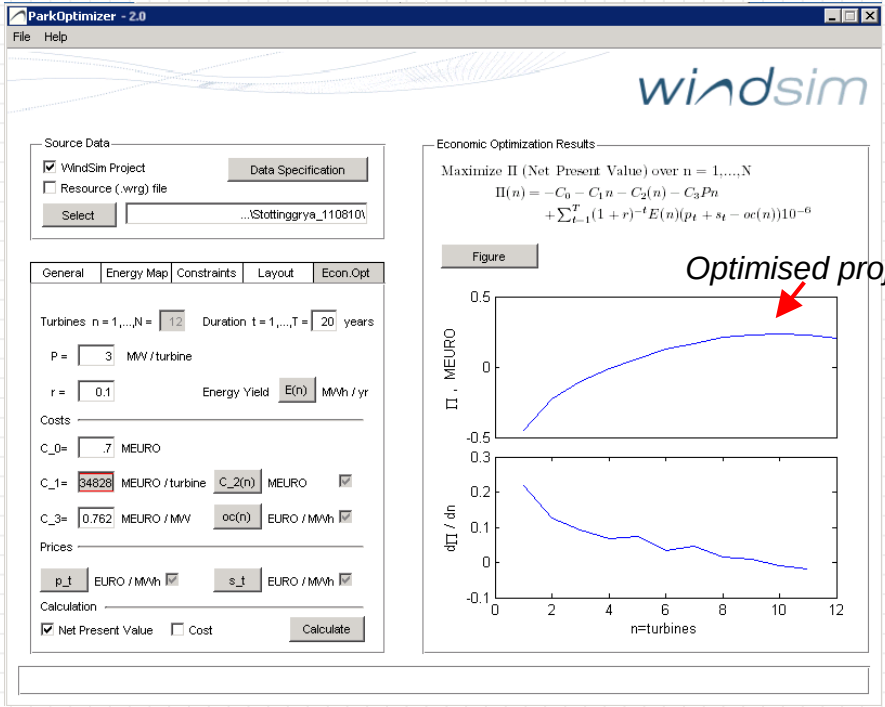
IEC-compliant layout optimisation

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



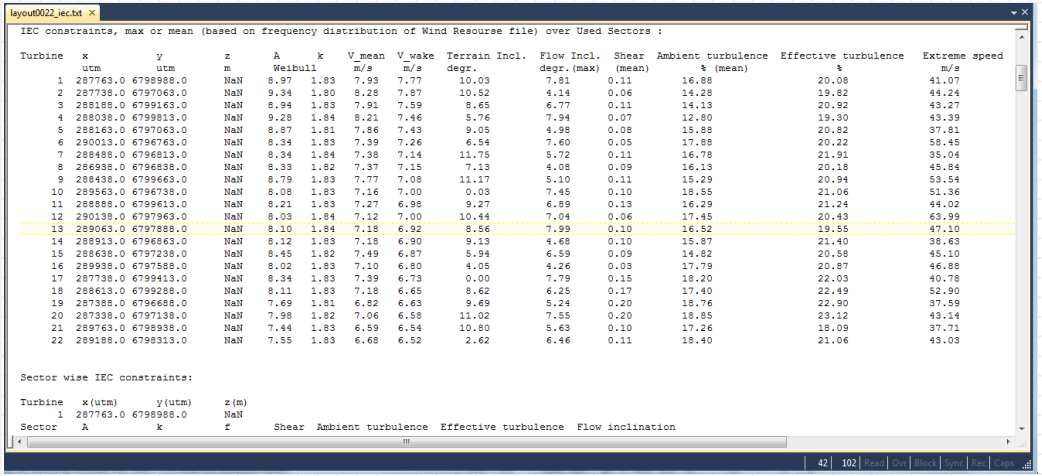
Optimise project size

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



IEC report including effective turbulence

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



layout0022_iec.txt

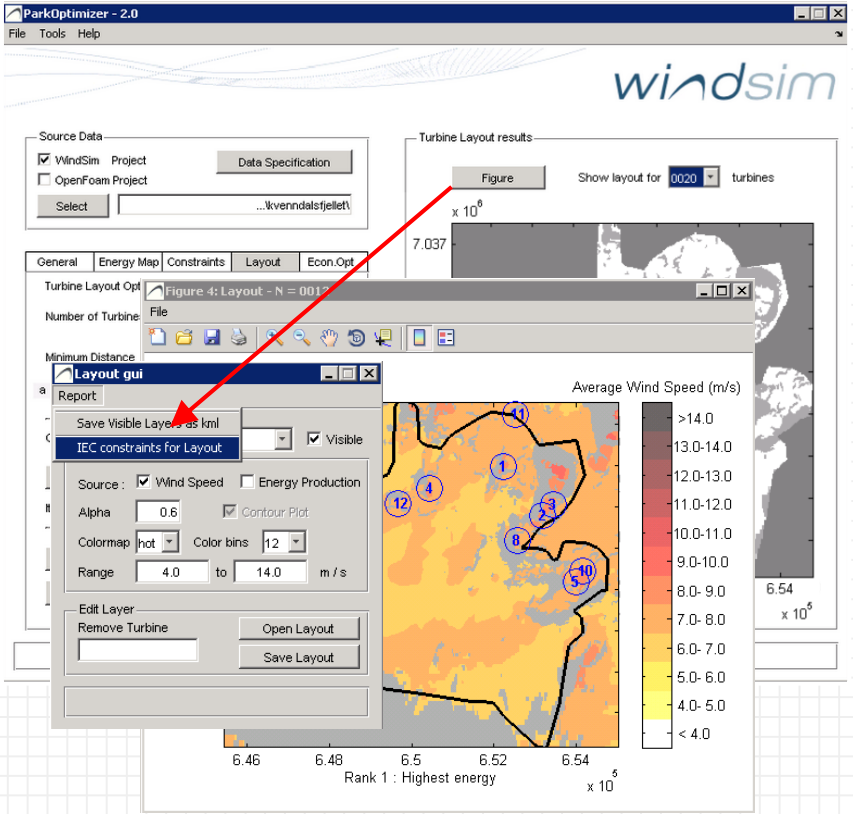
IEC constraints, max or mean (based on frequency distribution of Wind Resourse file) over Used Sectors :

Turbine	x utm	y utm	z m	A Weibull	k	V_mean m/s	V_wake m/s	Terrain Incl. degr.	Flow Incl. degr.(max)	Shear (mean)	Ambient turbulence % (mean)	Effective turbulence %	Extreme speed 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	6799813.0	NaN	9.28	1.84	8.21	7.46	5.76	7.94	0.07	12.80	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	286938.0	6796838.0	NaN	8.33	1.82	7.37	7.15	7.13	4.08	0.09	16.13	20.18	45.84
9	288438.0	6799663.0	NaN	8.79	1.83	7.77	7.08	11.17	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	8.56	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	6.25	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

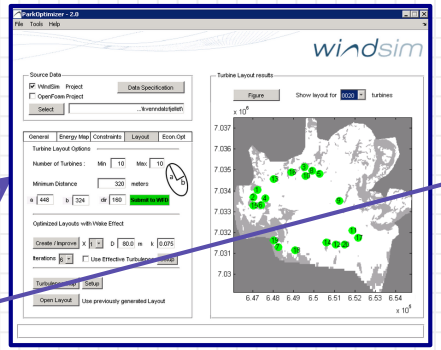


2. ParkOptimizer integration with WFD

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

API

ParkOptimizer



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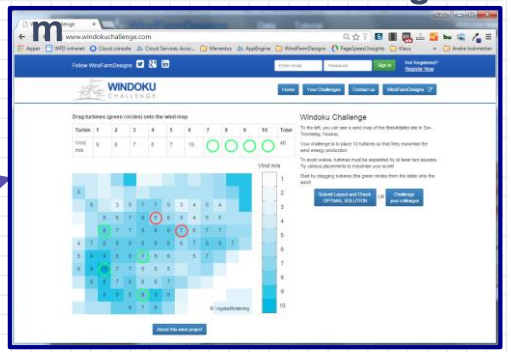
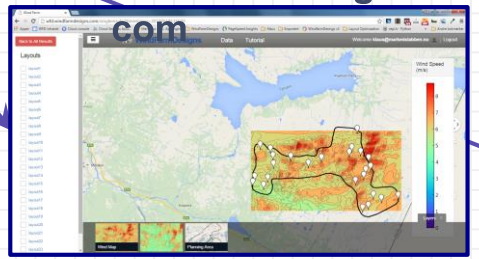
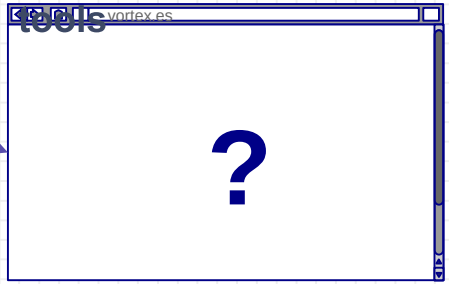


windfarmdesigns.com



3rd party & client in-house tools



3. ParkOptimizer for site suitability & turbine tenders

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

Turbine manufatureres compete on:

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

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

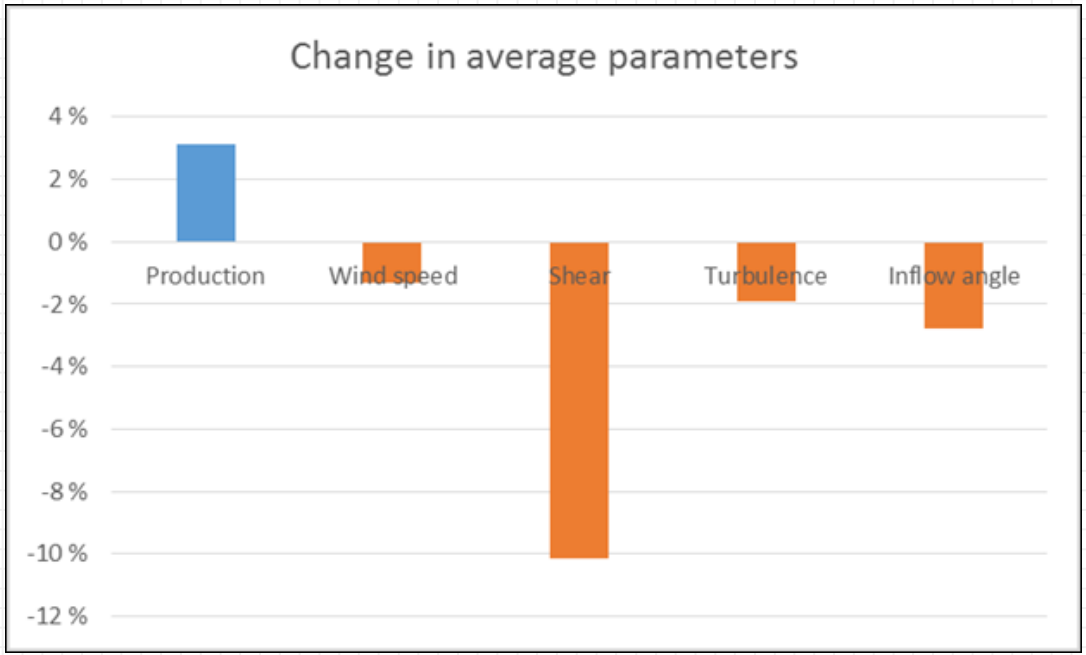
While price reductions are often focused in negotiations, layout optimisations can substantially improve LCOE !

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

3. ParkOptimizer for site suitability & turbine tenders

Example of results obtained using ParkOptimizer

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



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

Conclusion

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

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  - Site suitability studies
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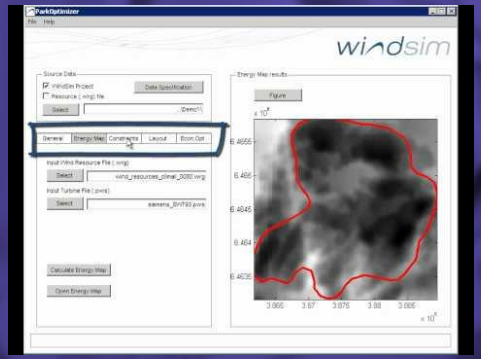
Any questions?

For more information contact :

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

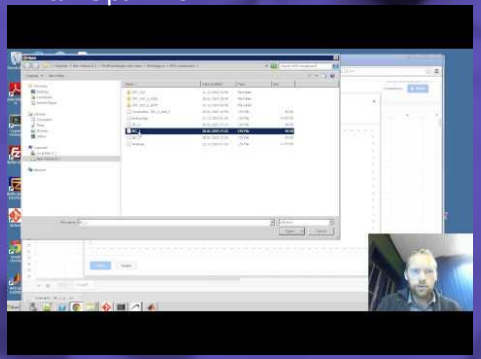
Resources

Introducing ParkOptimizer

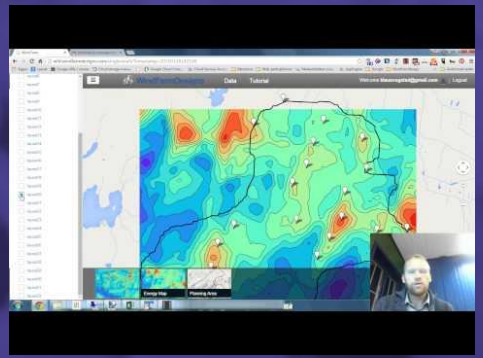


WindSim webinar on ParkOptimizer

How to combine multiple IEC constraint sets in ParkOptimzier



Introducing WindFarmDesigns



Google hangout on air - WindFarmDesigns