DATA BASE FOR WIND RESOURCE IN ICELAND

Rannsóknarþing VoN 2010

(University of Icleand Engineering and Natural Sciences Research Symposium)

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OVERVIEW

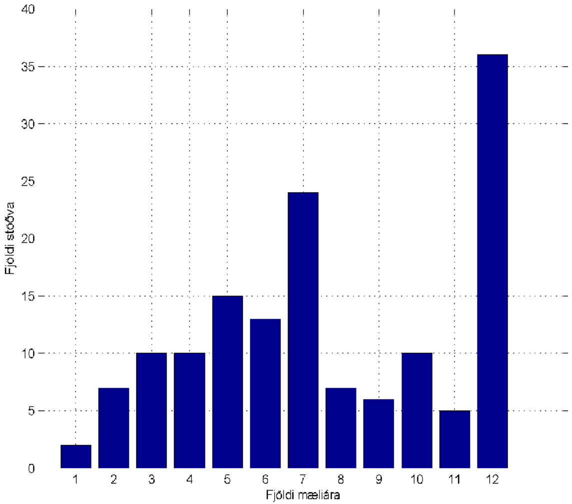
1. Automatic wind measurements in Iceland
2. Measurement error cleaning
3. Wind turbine energy production according to wind speed
4. Wind speed according to height above ground level
5. About the Nordic project IceWind

Automatic wind speed meter (anemometer) measurements in Iceland

- Started just after 1990
- Until 1998 mostly experimental and/or not kept in data base
- Since 1998 there exist 10 minute measurements from ca. 145 stations
- Measured values are: a) 10 minute average speed, b) wind direction, and c) gust (vindhviða)
- Station owners:

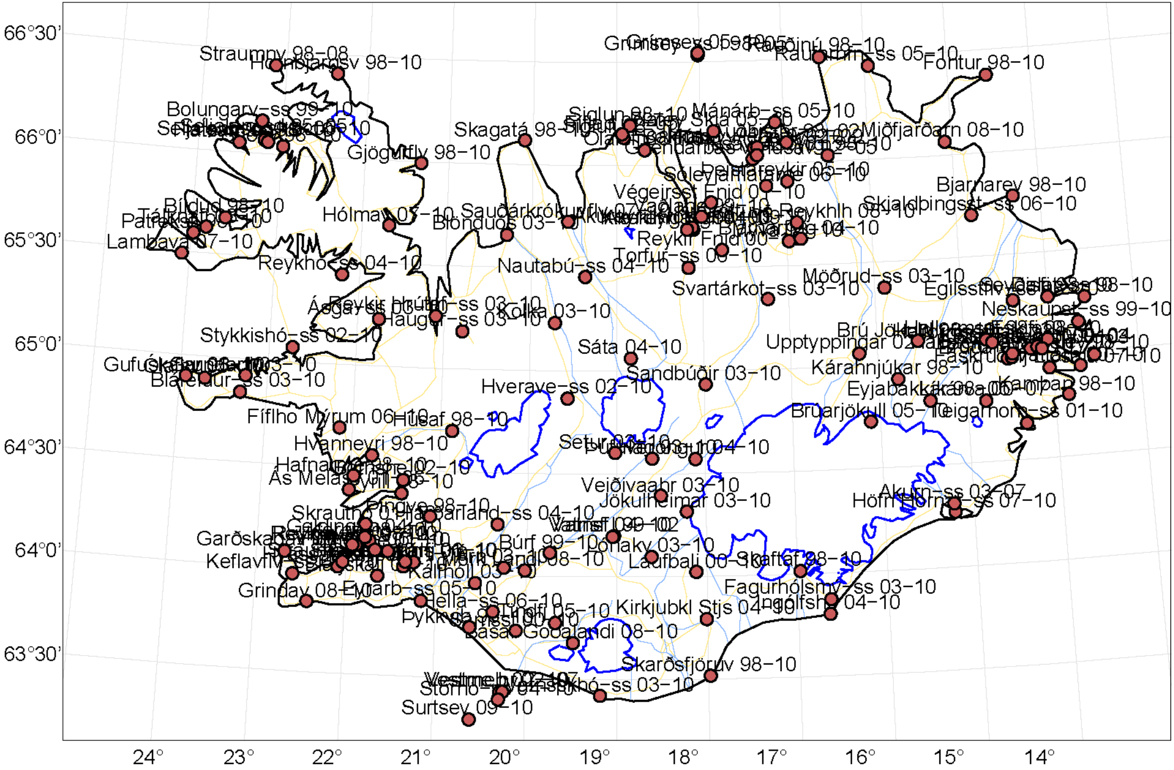
Veðurstofa Íslands (IMO)	118
Landsvirkun/Landsnet	23
Siglingastofnun	9
Orkustofnun	4
Náttúrufræðistofnun	1

- Almost all measure at 10 m above ground level
- Measurements are kept in the IMO database (IMO = Icelandic Meteorological Office)
- 36 stations have measurements for the whole 12 yr period July 1998–July 2010



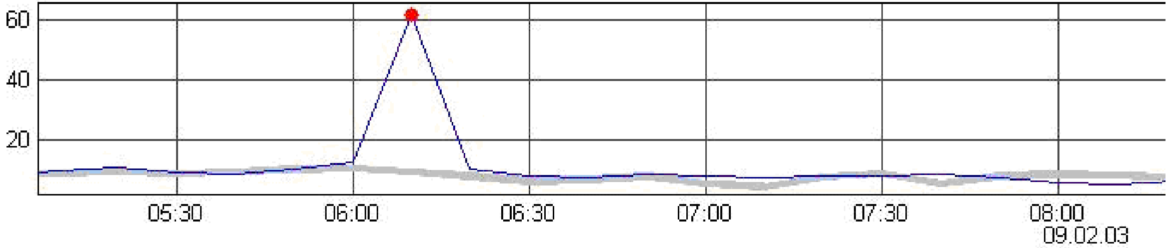
- The remaining 109 stations have on average a 6 yr operational period
- 126 stations are operational in 2010
- Total measurement coverage before error cleaning is 98.2% (this is the total fraction of 10 minute intervals with measurements, added over all the stations, from the first till the last measurement at each one)

Station locations

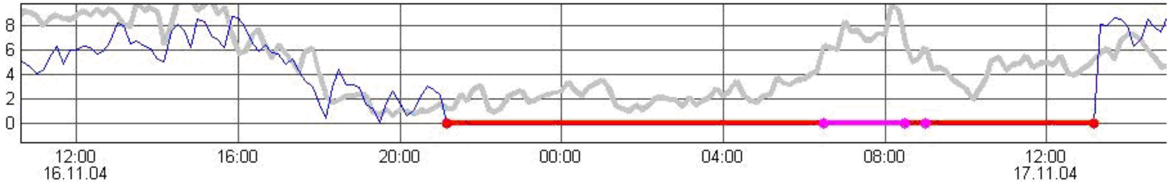


Kinds of errors

Nail (nagli):



Failures:

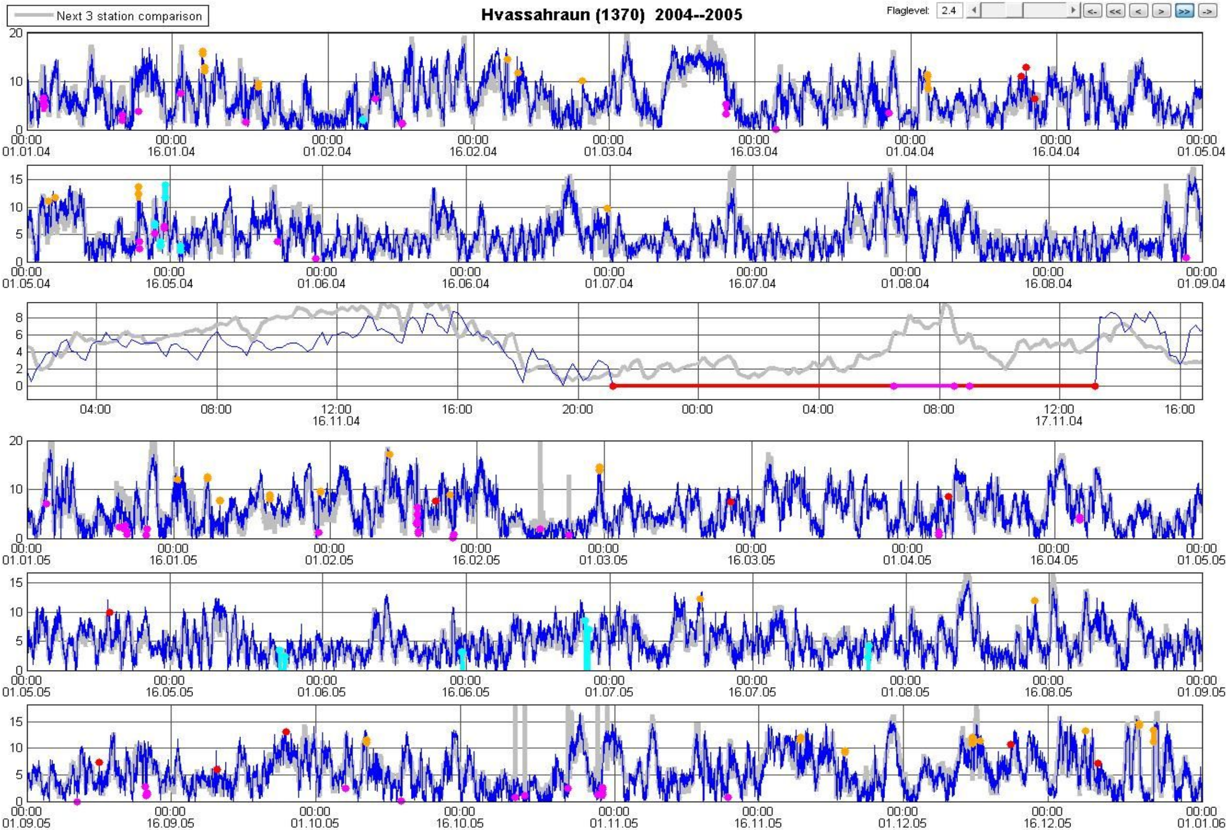


(vertical axis shows wind speed in m/s; gray line is average of nearby stations)

Nails are possibly caused by some electrostatic effect on the registration microcomputer in the anemometer??

Failures are probably mostly caused by mechanical breakdown (e.g. in bearings), storm damage or freezing.

Matlab program to detect and remove nails and failures



Next 3 station comparison
Hvassahraun (1370) 2004--2005
Flaglevel: 2.4
00:00 01.01.04
00:00 16.01.04
00:00 01.02.04
00:00 16.02.04
00:00 01.03.04
00:00 16.03.04
00:00 01.04.04
00:00 16.04.04
00:00 01.05.04
00:00 16.05.04
00:00 01.06.04
00:00 16.06.04
00:00 01.07.04
00:00 16.07.04
00:00 01.08.04
00:00 16.08.04
00:00 01.09.04
04:00
08:00
12:00 16.11.04
16:00
20:00
00:00
04:00
08:00
12:00 17.11.04
16:00
00:00 01.01.05
00:00 16.01.05
00:00 01.02.05
00:00 16.02.05
00:00 01.03.05
00:00 16.03.05
00:00 01.04.05
00:00 16.04.05
00:00 01.05.05
00:00 16.05.05
00:00 01.06.05
00:00 16.06.05
00:00 01.07.05
00:00 16.07.05
00:00 01.08.05
00:00 16.08.05
00:00 01.09.05
00:00 16.09.05
00:00 01.10.05
00:00 16.10.05
00:00 01.11.05
00:00 16.11.05
00:00 01.12.05
00:00 16.12.05
00:00 01.01.06

Result of error detection and cleaning

- Only the 10 minute average values were included in this project (not wind direction and gust)
- A total of 897 nails were discovered and removed by linear interpolation
- 543 failure intervals were found and replaced with "measurement missing"
- After error cleaning the total measurement coverage is 97.0% (was 98.2%)
- The IMO's database has hourly wind speed values (the 10 minutes before each hour), corrected with the help of a different program. The errors detected with help of the Matlab program were compared with this and found to agree for the most part.
- The frequency of both nails and failures was 5–8 times higher at the 29 stations that are more than 500 m asl, than at the 88 stations that are below 100 m asl (with the 100–500 m asl stations falling inbetween)
- As might be expected, both nails and failures are more common in winter than summer
- The resulting corrected and error-cleaned data will be placed online on the University of Iceland Department of Computer Science web site.

Transferring wind speed to 80 m above ground level (agl)

Two commonly used formulae are:

(1) $$V(z) = V_R \left(\frac{z}{z_R} \right)^{\alpha}$$

(2) $$V(z) = V_R \frac{\log(z/z_0)}{\log(z_R/z_0)}$$

where:

$V(z)$ is the wind wind speed at height z (in our case z = 90 m agl)

z_R is the reference height (10 m agl in our case)

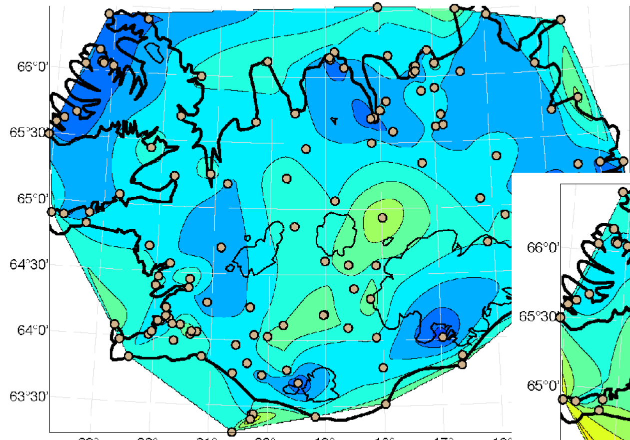
V_R = $V(z_R)$

α is an exponent sometimes said to have typical value 1/7 ≈ 0.143

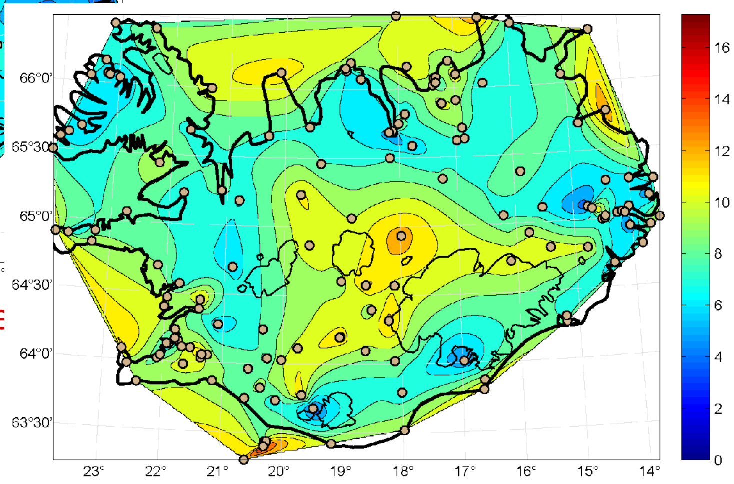
z_0 is a so-called roughness length (typical value sometimes given as 0.01)

These equations with the quoted typical values give a 35% and 30% higher wind speed at 80 m agl than at 10 m agl. The IMO has conducted a limited number of comparison measurements at 10 m and at 30–40 m agl, resulting in α-values ranging from 0.08–0.18 (the lowest value in a location sheltered by a mountain, the rest were 0.11–0.18). Taking all this into consideration we decided to use (1) with $\alpha = 1/7$ in the following.

agl wind speed



summe



winter

Data for several (all ≥ 2 MW rated power) IEC class 1a wind turbines

Windmill	Speed range (m/s)	Speed for 99% power (m/s)	Hub height (m)	Diameter (m)	Efficiency at speeds 6–12 m/s				Max power (MW)
					6	8	10	12	
Gamesa G80-2.0MW	4–25	12.5	60–100	80	14%	35%	65%	91%	2.0
Vestas V80-2.0MW	3.5–25	13.5	60–78	80	15%	34%	64%	90%	2.0
Hitachi 2.0MW	3–25	13.0	60–80	80	15%	35%	62%	97%	2.0
Repower MM82	3.5–25	12.6	59–100	82	16%	38%	70%	94%	2.05
Enercon E70	2–31	14.5	64–80	70	10%	27%	53%	82%	2.31
Nordex N80-2500	3–25	14.3	60–80	80	10%	27%	53%	80%	2.5
Fuhrländer FL 2500	3.5–25	14.5	65–85	80	10%	28%	54%	80%	2.5
W2E W80	4–25	13.8	85	80	10%	27%	53%	83%	2.5
Vestas V90-3.0MW	4–25	14.5	80	90	14%	31%	55%	81%	3.0
Acciona AW-100/3000	4–25	11.7	98	100	10%	30%	70%	100%	3.0
Siemens SWT 3.6	4–25	~13.5	80	107	8%	26%	64%	92%	3.6
Areva Multibrid M5000	4–25	12.0	100–130	116	10%	26%	52%	94%	5.0
Repower 5M	4–30	12.2	120	126	13%	33%	64%	98%	5.0
Average	3.5–25.8	13.3	84	90	11.9%	30.5%	59.9%	89.4%	2.88

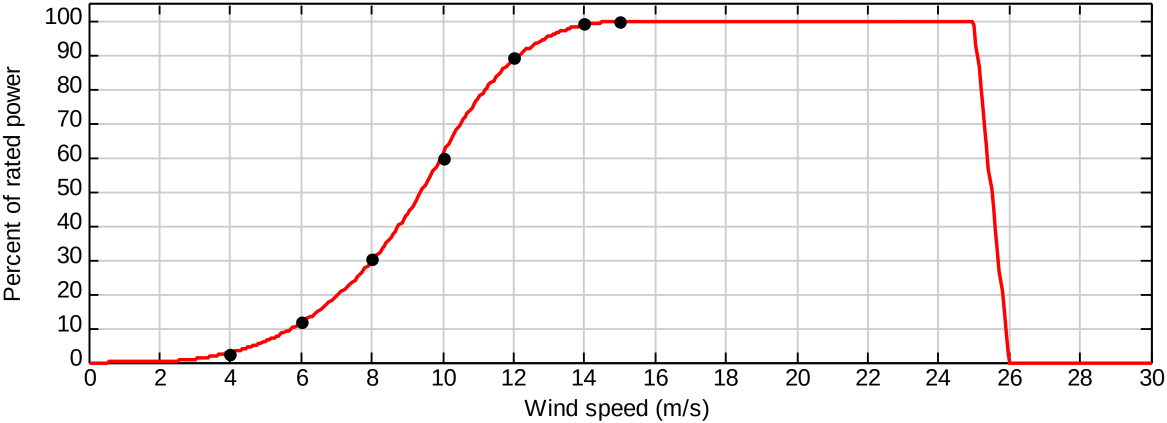
(obtained from manufacturers web sites in May 2009)

IEC = International Electrotechnical Commission, the primary international organization for electrical and electronic related standards

IEC class 1a wind turbines are the ones designed for highest wind speeds

Resulting power curve

$$p(v)=\begin{cases}0 & (v<0.6\text{ m/s})\\ 0.0734(v-0.6)^3 & (0.6\le v<10)\\ 60.95+19.45(v-10)-3.09(v-10)^2+0.153(v-10)^3 & (10\le v<15)\\ 100 & (15\le v<25)\\ 100(26-v) & (25\le v<26)\\ 0 & (26\le v)\end{cases}$$



Percent of rated power
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Wind speed (m/s)

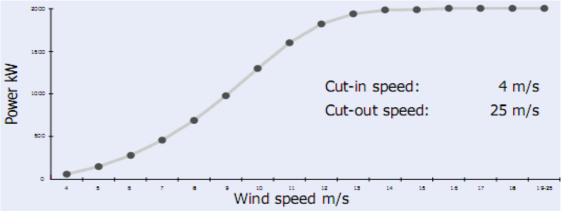
Typical web site information

Power Curve Gamesa G80-2.0 MW

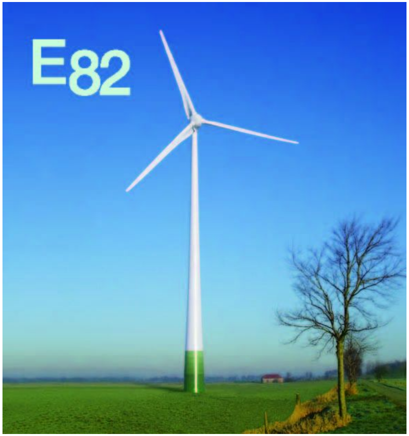
(for an air density of 1.225 kg/m³)

Power curve calculation based on NACA 63.XXX and FFA-W3 airfoils.

Calculation parameters: 50 Hz grid frequency; tip angle pitch regulated; 10% turbulence intensity and a variable rotor speed ranging from 9.0 - 19.0 rpm.



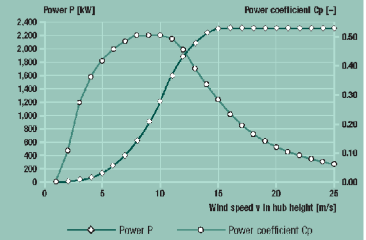
SPEED (m/s)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19-25
POWER (kW)	66.3	152.0	280.0	457.0	690.0	978.0	1,296.0	1,598.0	1,818.0	1,935.0	1,980.0	1,995.0	1,999.0	2,000.0	2,000.0	2,000.0



TECHNICAL DATA

Rated power:	2,300 kW
Rotor diameter:	71 m
Hub height:	64 m – 113 m
Wind class (IEC):	IEC/NVN I and IEC/NVN II (depending on hub height)
Turbine concept:	Gearless, variable speed, variable pitch control
Rotor	
Type:	Upwind rotor with active pitch control
Direction of rotation:	Clockwise
Number of blades:	3
Swept area:	3.959 m²
Blade material:	Fibreglass (epoxy resin); integrated lightning protection
Rotational speed:	Variable, 6 – 21.5 rpm
Pitch control:	ENERCON blade pitch system, one independent pitching system per rotor blade with allocated emergency supply

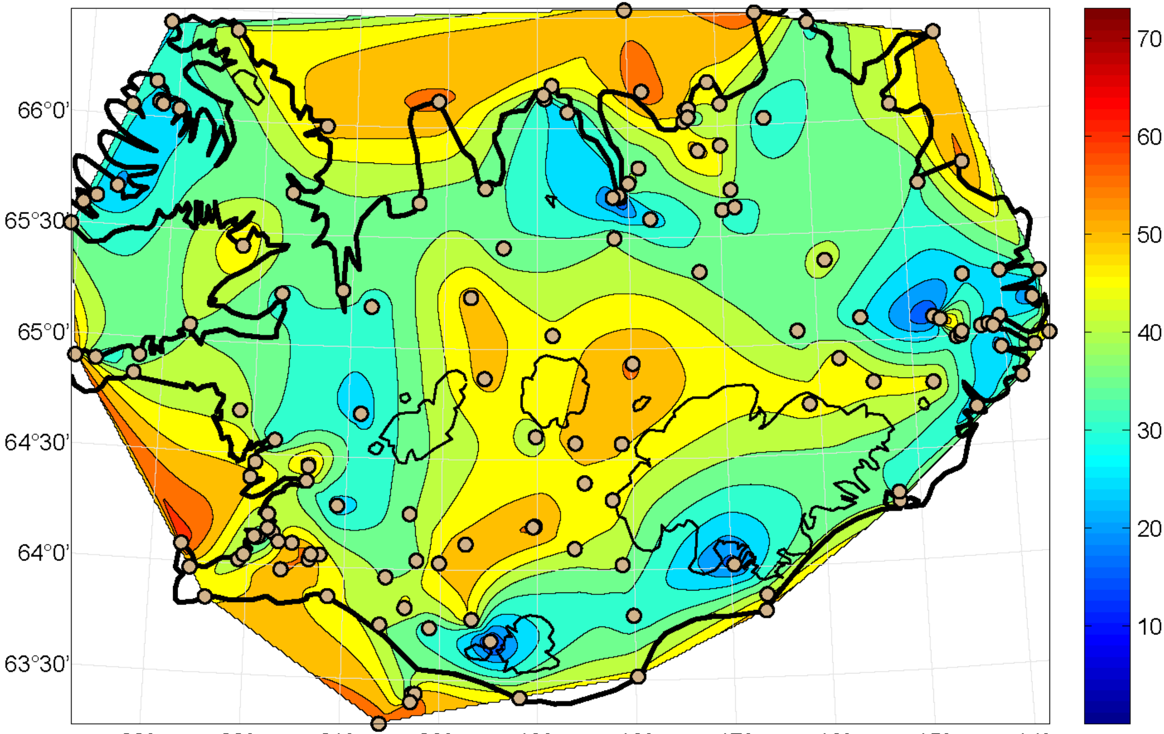
CALCULATED POWER CURVE



Wind [m/s]	Power P [kW]	Power coefficient Cp [-]
1	0.0	0.00
2	2.0	0.10
3	18.0	0.27

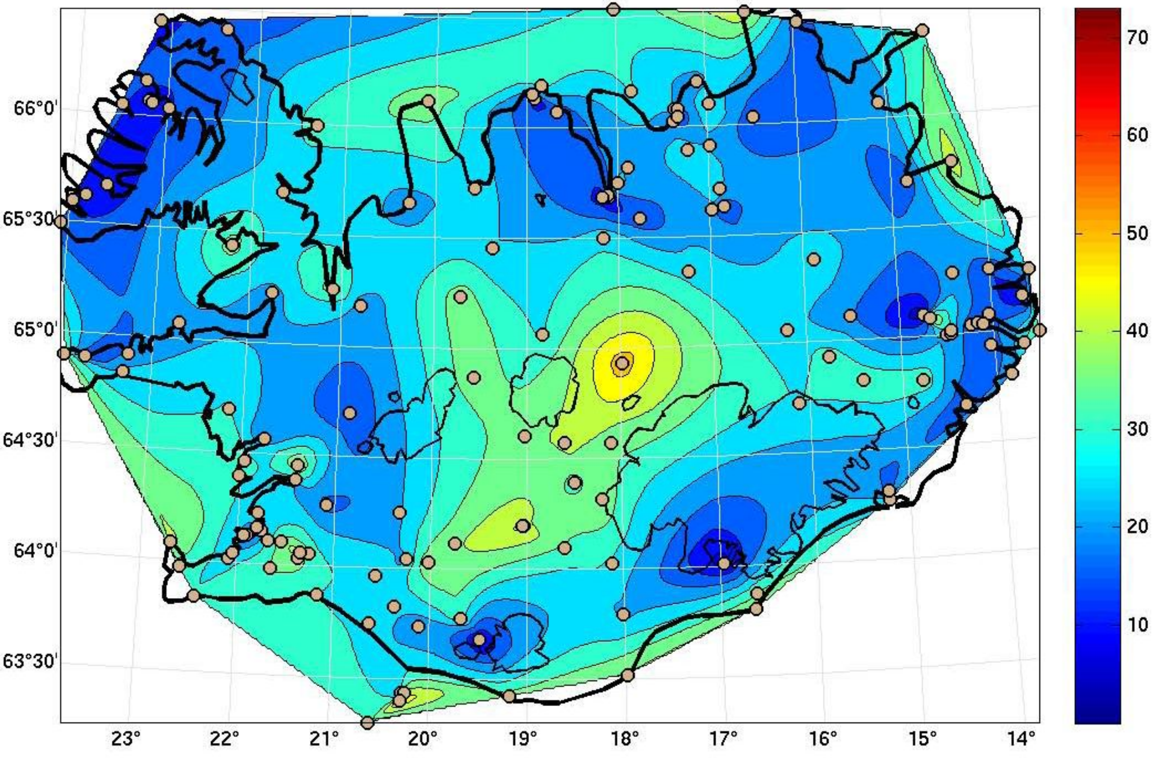
ρ = 1.225 kg/m³

Calculated winter power (percentage of rated power)



66°0'
65°30'
65°0'
64°30'
64°0'
63°30'
23°
22°
21°
20°
19°
18°
17°
16°
15°
14°
70
60
50
40
30
20
10

Calculated summer power (percentage of rated power)



IceWind project

Work package 2. Wind Power in Iceland

Item	Activity	Due date	Responsibility
1.	**Project start date**	1 Sept. 2010	Risø DTU
2.	**2.1 Wind atlas of Iceland (and surrounding seas)**. It shall be a standard wind atlas, with tables with distribtion of wind speed and wind direction, created with the Riso WASP program. The output will be average wind speed and annual energy potential (AEP) at each location	Dec. 2011	Icelandic Meteoroligical Office
3.	**2.2. Siting**. The wind atlas will be used to select 5—10 suitable sites for wind farms in Iceland. This should not be a very time consuming task	June 2012	Icelandic Meteoroligical Office
4.	**2.3a. Generation of time series.** For each of the sites selected in wp 2.2 a typical (or average) wind speed (and direction) time series shall be generated.	Dec. 2012	University of Iceland
5.	**2.3b. Simulation with deterministic time series.** For several scenarios of wind farm sites and several scenarios of installed hydropower potential the models of Landsvirkjun together with the Wilmar model of Riso will be used to determine the energy production potential for Iceland	Dec. 2013	University of Iceland
6.	**E. Simulation with stochastic wind time series.** Parts 2.3a and 2.3b will be repeated using stochastic time series (in effect simulating several years).	June 2014	University of Iceland
7.	**Project end date**	31 August 2014	Risø DTU