Icelandic Meteorological Office

An Icelandic Wind Atlas

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Introduction

Wind power is an important source of low-impact renewable energy. This is especially true at high latitudes in winter, when the highest average wind speeds coincide with reduced streamflow and sunshine hours. Unlike solar energy, wind power can therefore be used throughout the year. In this study, a wind atlas for Iceland was produced, to allow for a regional comparison of the wind energy potential across the island, and an identification of suitable wind farm sites.

Data and Methodology

The data used for this study was produced with the mesoscale Weather Research and Forecasting (WRF) Model. Data is available for the 1995 – 2008 period. Grid points are spaced at 3 km. Due to the strong dependence of wind power density on terrain elevation, together with the limited spatial resolution, small-scale variability, particularly local maxima, are underestimated in the WRF model. For a more precise assessment of the wind conditions within a limited region around specific test sites (Figure 1), the Wind Atlas Analysis and Application Program (WAsP), developed by the Wind Energy and Atmospheric Physics Department at Risø National Laboratory (Troen and Petersen, 1989), was used.

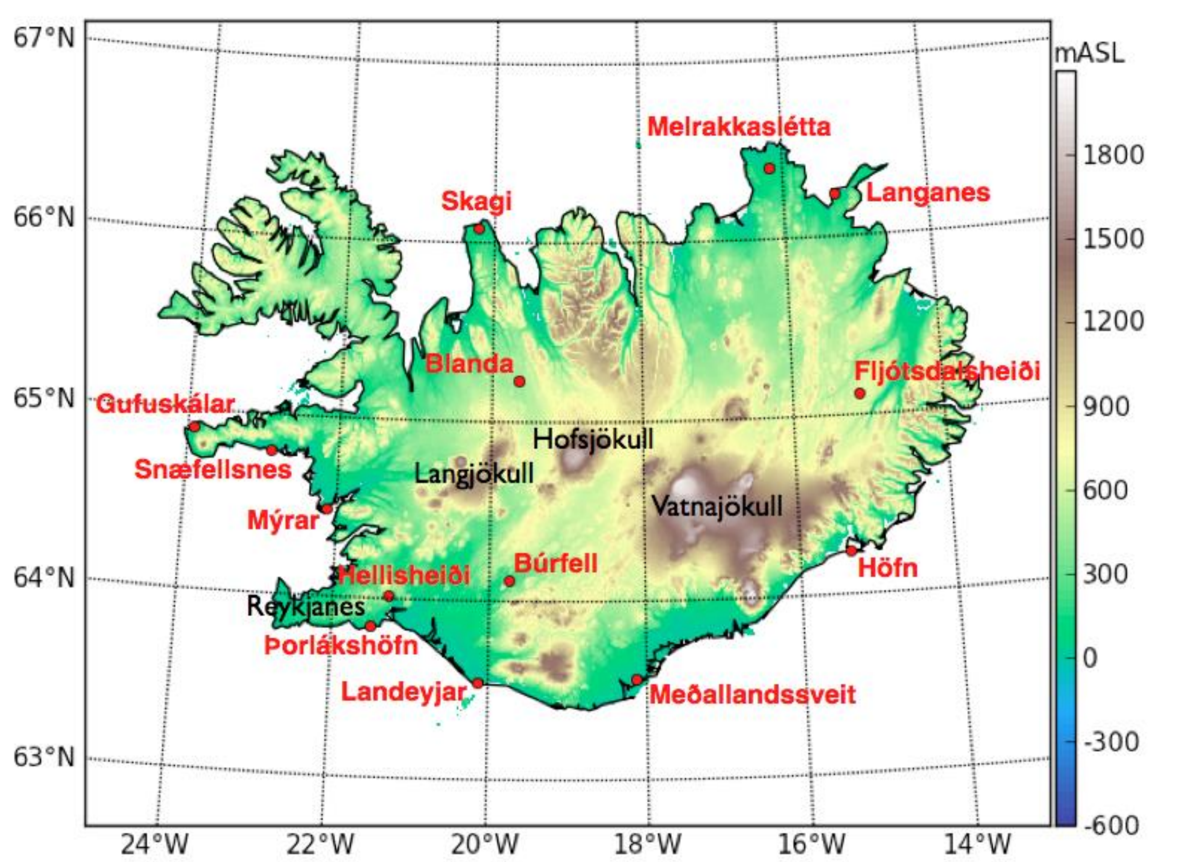

Figure 1: Topographic map of Iceland, with the locations of test sites, for which detailed analyses were performed. Terrain elevation is given in metres above mean sea level (mASL).

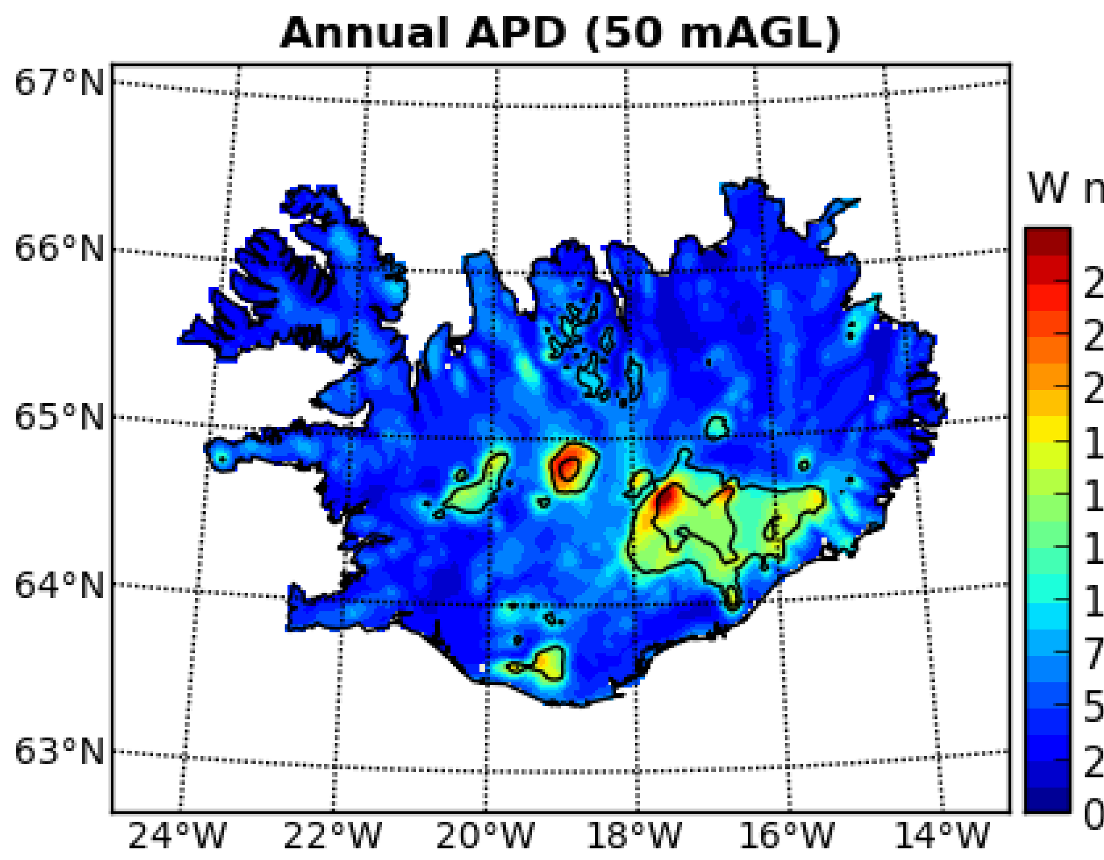

Figure 2: Annual average wind power density (APD) at 50 metres above ground level (mAGL), based on WRF model data.

The Wind Energy Potential of Iceland

Comparing Figures 1 and 2 it is apparent, that the large-scale spatial variability of average wind power density primarily depends on terrain elevation, following essentially a linear profile with height. Relative to the average value within 10 km of the coast, power density across Iceland varies by a factor of 0.5 – 4.5. The largest reduction relative to the near-coastal average occurs in low-lying regions of the southwest and northeast.
At intermediate elevations of 500 – 1000 mASL, independent of the distance to the coast, power density is within a factor of 2.0 – 2.5 of the near-coastal average. However, away from the coast, and on higher terrain, accessibility is generally reduced, and icing may become a serious issue for wind power production.
The highest wind speeds at low elevations are found over the most exposed peninsulas, along the coast of the southernmost part of the island, as well as around Höfn.
Compared with summer, average power density in winter is increased throughout the island by a factor of 2.0 – 5.5, with the largest increases on the lower slopes of Vatnajökull, along the complex coastline of the Westfjords, and over the low-lying areas in the northeast.

Figure 3: Two Enercon E44 wind turbines near Búrfell.

Test Sites

Fourteen test sites (Figure 1) were chosen for detailed WAsP analyses. Average values of power density and available power at each location are shown in Table 1. Wintertime increases in energy production are between a factor of 1.5 – 2.5 of the summer averages. Based on annual wind conditions at 55 mAGL, Skagi has 58% higher power density than Hellisheiði. However, to be able to fully exploit a given wind energy potential, the cut-out speed and rated power of the turbine must be sufficiently high. On Skagi, despite the higher values of average power density, the technical limitations of the relatively small Enercon E44 turbine result in 11% lower average available power than on Hellisheiði. This is primarily the result of the higher proportion of above cut-out speeds. Much of the power density at above-rated speeds is also lost through various breaking mechanism to protect the turbine.

Table 1: Winter (DJF) / annual / summer (JJA) values of average wind power density (APD), average available power (AAP), and efficiency of power generation at 55 mAGL, for the Enercon E44 turbine. Efficiency is defined as AAP / (APD x rotor area).

Location	APD [W m^{-2}]	AAP [kW]	Efficiency [%]
Blanda	2990 / 1610 / 650	510 / 450 / 320	11 / 19 / 32
Búrfell	2010 / 1230 / 510	520 / 440 / 290	17 / 23 / 38
Fljótsdalsheiði	1470 / 740 / 280	490 / 360 / 200	22 / 32 / 46
Gufuskálar	2370 / 1410 / 700	590 / 470 / 330	16 / 22 / 31
Hellisheiði	2210 / 1600 / 750	630 / 540 / 400	19 / 22 / 35
Höfn	1750 / 1070 / 390	460 / 340 / 180	17 / 21 / 31
Landeyjar	2140 / 1620 / 920	550 / 470 / 360	17 / 19 / 26
Langanes	1850 / 1130 / 460	570 / 440 / 260	20 / 26 / 37
Meðallandssveit	1810 / 1630 / 1200	520 / 500 / 430	19 / 20 / 23
Melrakkaslétta	1690 / 1030 / 450	570 / 440 / 280	22 / 28 / 41
Mýrar	1670 / 1040 / 460	540 / 430 / 280	21 / 27 / 40
Skagi	4400 / 2530 / 1470	550 / 480 / 370	8 / 12 / 17
Snæfellsnes	1690 / 1150 / 510	500 / 400 / 250	19 / 23 / 32
Þorlákshöfn	1870 / 1240 / 530	580 / 470 / 290	20 / 25 / 37

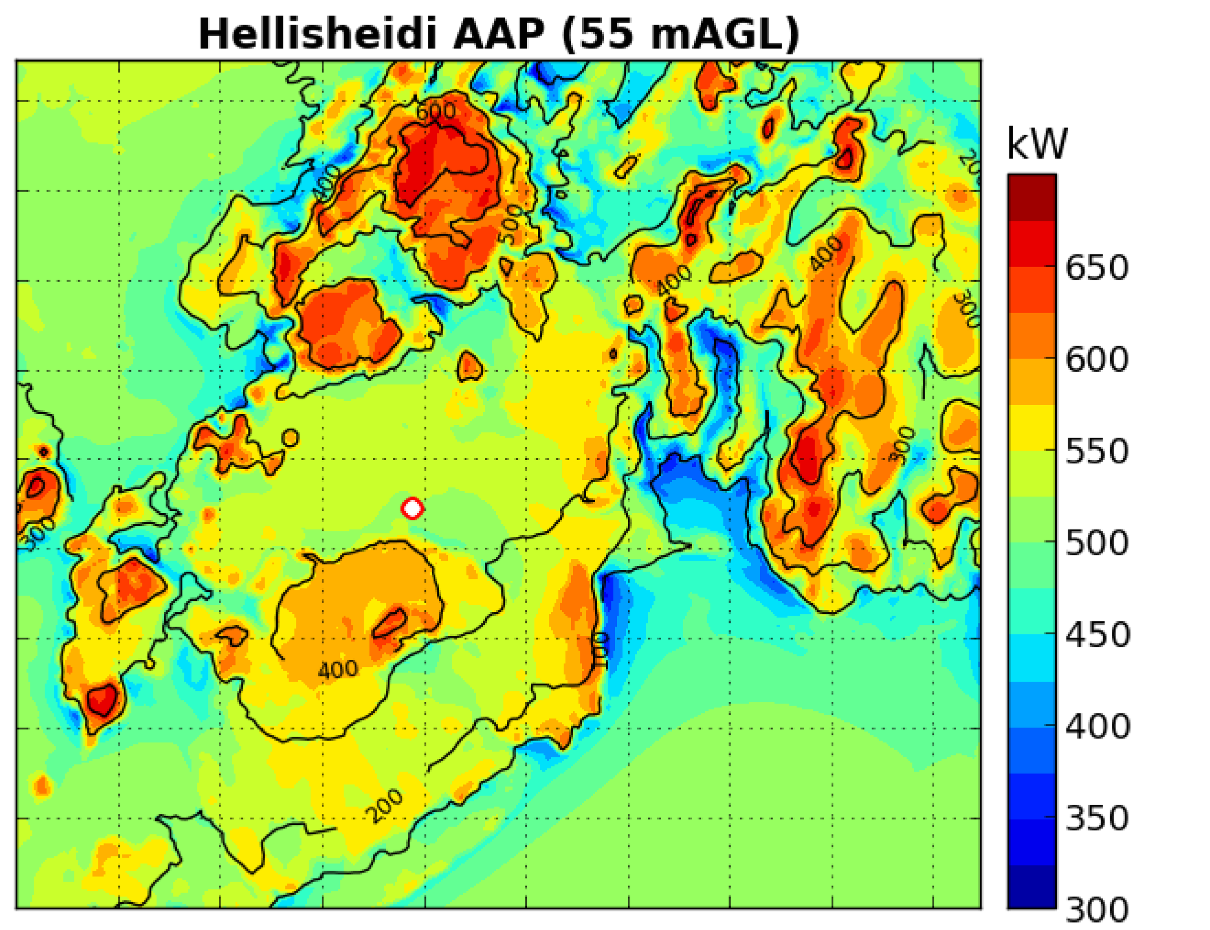

Figure 4: Annual average available power (AAP) at 55 mAGL within the Hellisheiði region, based on a WAsP analysis with WRF model input data.

Conclusions

According to the categories established in the European Wind Atlas (Troen and Petersen, 1989), the wind energy potential of Iceland is in the highest class. Although wind energy cannot be expected to replace hydro- and geothermal energy, it can be a valuable addition. For example, a modest wind farm of 15 Enercon E44 turbines installed on Hellisheiði would produce more energy than the smallest currently operational hydro- and geothermal power plants in Iceland together.
As seen in Figure 4, even small relative increases in terrain elevation can lead to a doubling of the annually available wind power. Considering problems with accessibility and icing at high altitudes, small isolated hills in otherwise flat and low-lying terrain, possibly near the coast, are therefore preferable for the installation of wind turbines.
For a given average wind power density and a particular wind turbine, the actually produced wind power strongly depends on the local wind speed distribution between cut-in and cut-out speed. In a strong-wind environment such as Iceland, wind turbines with a high rated power, and especially with a high cut-out speed, are required to be able to extract the wind energy potential efficiently.

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The data is made available through an online wind atlas. Follow the link from the IMO webpages on the wind energy potential of Iceland at http://www.vedur.is/vedur/vedurfar/vindorka/.

References:
Nawri, N., G. N. Petersen, H. Björnsson, and K. Jónasson, 2013: The wind energy potential of Iceland. Report VÍ 2013-001, Icelandic Meteorological Office, Reykjavik, Iceland.
Troen, I., and E. L. Petersen, 1989: European Wind Atlas. Risø National Laboratory, Roskilde, Denmark.