

Assignment 4 (Wind resource prediction, site assessment, & real-world questions).

The assignment is divided in two parts: wind resource assessment, and site assessment; each covers important aspects of the course material. First, we estimate the Annual Energy Production (AEP) at two hypothetical/potential turbine sites; hereafter the extreme winds are estimated for these sites.

We consider two locations for our assessment (wind turbine siting):

- A) in the western Great Belt, close to Nyborg;
- B) in the eastern Great Belt, close to Korsør.

These are basically on either side of the Great Belt bridge¹, where the island ‘Sprog’ (Sprogø) is in the middle between the two. Look on a map to check the relevant geography (one may also inspect e.g. the New European Wind Atlas online).

In this exercise, you may assume constant roughness lengths of $z_0 = 0.02$ cm over water and $z_0 = 2$ cm for the land. For the wind turbine hub heights here, use $z_{\text{hub}} = 120$ m.

The AEP in one directional sector (denoted by index i) is

$$E_i = T f_i \int_0^\infty p_i(U) P(U) dU \quad (5)$$

where T is the length of one year (typically expressed in hours), f_i is the frequency of occurrence of wind directions in sector i , and $p_i(U)$ is the pdf of wind in the i^{th} sector. The power curve $P(U)$ is given by the simple expression

$$P(U) = P_{\text{rated}} \times \begin{cases} (U/U_{\text{rp}})^3 & \text{for } U \leq U_{\text{rp}} \\ 1 & \text{for } U_{\text{rp}} < U < 25 \text{ m/s} \\ 0 & \text{for } U > 25 \text{ m/s} \end{cases} \quad (6)$$

where $U_{\text{rp}} = 12$ m/s is the speed where a rated power $P_{\text{rated}} = 13$ MW is achieved.

1. Calculate the AEP in units of MWh for a turbine having the power curve given by eqn. (6), at each of the two sites; do this using the data from Sprogø (file `sprogo_1.zip` from Assignment 1). You may use the Weibull- k and k parameters from the distributions obtained in Assignment 1, and assume that k does not change when going from Sprogø to the two sites.
 - (a) You are, in effect, ‘vertically extrapolating’ from $z = 70$ m to $z_{\text{hub}} = 120$ m. If the Weibull- k parameter actually decreases by 15% over this vertical extent, then are you justified in ignoring its variation? (Support this quantitatively!)
 - (b) Now find the least-windy and most windy years, respectively, from this dataset; repeat your AEP calculation for each of these two years.
 - i. How different are the windiest and ‘weakest’ years, respectively, compared to the mean you found above? What % AEP variation does this correspond to?
 - ii. Your boss says that at their previous company, for uncertainty estimates they “just used an inter-annual variability of 2 m/s for Denmark”. Given what you just found above for the windiest/caldest mean years, does this make sense? How do you respond to him/her about this?

¹E.g. see <https://www.google.com/maps/place/The+Great+Belt+Bridge/>

- iii. A colleague does MCP analysis (long-term correction) on the long Sprogø data that you have here, based on a 50-year global re-analysis dataset at a resolution of ~ 40 km; they say that “*your wind data seems to be 30% too high*”. Is this reasonable? Whose number do you trust, and why?
 - (c) Another colleague tells you that mesoscale modelling results of the Great Belt area (from WRF with 3 km grid-spacing, for 15 years) show that: for mean winds above 15 m/s at z_{hub} , the geostrophic wind at Korsør differs from that at Nyborg, by an amount that increases linearly from 0% for $U|_{z=120\text{m}} = 15$ m/s up to 10% for $U|_{z=120\text{m}}$ at cut-out. Your colleague is skeptical about the GDL, and claims that it thus can't be trusted for your analysis. What is your (numerically-based) response to this?
2. Estimate V_{50} at Sprogø (i.e. for $z=70$ m), using PWM and two other methods.
- (a) Use the results from PWM, to then extrapolate the extremes from Sprogø to Nyborg and Korsør.
 - (b) How are the individual events at Nyborg different than those expected at Korsør? From which directions do the strongest winds ‘blow’ for each?
 - (c) Examine and discuss the results from the three methods you've used. Include which is best, and why...
 - (d) What would you do, if you only had only 1 year of measured data?
 - (e) What turbine class would you use at Sprogø? Would the Nyborg or Korsør sites require a different turbine class?