Tutorial Energy & Sustainability

Exercise Sheet 5

– Sketch of Solution –

Exercise 1

Average height $H = \frac{165\ d \cdot 5\ m\ +\ 200\ d \cdot 2\ m}{365\ d} = 3.36\ m$

$$P_{el} = 792\,000\ m^3/h \cdot 3.36\ m\ \cdot\ 9.81\ m/s^2 \cdot 1\ t/m^3 \cdot 0.85$$
$$= 22.2 \cdot 10^9 \frac{kg\ m^2}{h \cdot s^2} \frac{1h}{3600s} = 6\,156\,782 \frac{kg\ m^2}{s^3} = 6.16\ MW_{el}$$

Exercise 2

a) $v = 8\ m/s, c_p = 0.5$

$$P_{WEA_1} = 0.5 \cdot 1.184\ kg/m^3 \cdot \pi \cdot (35.5\ m)^2 \cdot (8\ m/s)^3 \cdot 0.5$$
$$= 600\,024.89 \frac{kg\ m^2}{s^3} = 600.025\ kW \text{(Power)}$$
$$\Rightarrow \text{Annual energy generation}$$
$$W_{WEA_1} = P_{WEA_1} \cdot 8760\ h \cdot\ 0.95 = 4993\ MWh$$
$$P_{WEA_2} = 964.13\ kW,\ 90\ m \text{ diameter}$$
$$W_{WEA_2} = 8024\ MWh \approx 8\ GWh$$

b) $v = 4\ m/s, c_p = 0.4$

$$P_{WEA_1} = 0.5 \cdot 1.184\ kg/m^3 \cdot \pi \cdot (35.5\ m)^2 \cdot (4\ m/s)^3 \cdot 0.4$$
$$= 60\ kW$$
$$W_{WEA_1} = 499.3\ MWh$$
$$P_{WEA_2} = 96.41\ kW$$
$$W_{WEA_2} = 802.35\ MWh$$

Exercise 3

a) $VLh_{WEA_1,\text{coast}} = \frac{W_{WEA_1}}{P_{newWEA_1}} = \frac{4\,993\,000\ kWh}{2000\ kW} = 2497\ h$

$\big(\text{alternatively: } 8760\ h \cdot 2000\ kW = 17\,520\,000\ kWh,\ \frac{4\,993\,000\ KWh}{17\,520\,000\ kWh} \cdot 8760\ h = 2497\ h\big)$

$VLh_{WEA_2} = 4012\ h$

b) $VLh_{WEA_1} = 249\ h$ (inland)

c) $VLh_{WEA_2} = 401\ h$ (inland)

Exercise 4

a)

$$\begin{aligned} 465\ EJ/a &= 465 \cdot 10^{18}\ J/a = 465 \cdot 10^{9}\ GJ/a \\ &= 1.29 \cdot 10^{14}\ kWh/a = 129\,270\ TWh/a, \\ P &= \frac{129\,270\ TWh/a}{8760\ h/a} = 14.76\ TW \end{aligned}$$

b) Output $= 1000 \frac{kWh}{m^2 \cdot a} \cdot \eta = 100\ \frac{kWh}{m^2 \cdot a}$

$\frac{100\ kWh/a}{1\ m^2} = \frac{1.29 \cdot 10^{14}\ kWh/a}{x\ m^2} \Rightarrow A = 1.29 \cdot 10^{12}\ m^2$

$\frac{10^6\ m^2}{1\ km^2} = \frac{1.29 \cdot 10^{12}\ m^2}{x\ km^2} \Rightarrow A = 1\,290\,000\ km^2$ (necessary area)

$\frac{1\,290\,000\ km^2}{357\,050\ km^2} = 3.61$ times Germany

Exercise 5

a) $W_{el} = 950 \frac{kWh}{m^2} \cdot 74.93\ m^2 \cdot 0.15 \cdot 0.99 \cdot 0.97 = 10\,254\ kWh_{el}$

b) Specific annual workload $= \frac{10\,254\ kWh}{\frac{74.93\ m^2}{1.27\ m^2} \cdot 0.17\ kW} = 1022\ kWh/kW = 1022\ h$

=full load hours