Q3 Power density of air $P_{total} = \frac{1}{2}\rho u^3$

$$= \frac{1}{2} \times 1.225 \times (8)^3$$

$$= 313.6 \, W/m^2$$

if the gearbox eff. is 90%, generator eff. 95%,

$C_p = 0.4$,

over all loss factor $= 0.9 \times .95 \times .4$

$$= 0.342$$

Actual power density $= 313.6 \times 0.342 = 107.251 \, W/m^2$

Annual Energy density $=$ Power density $\times$ Hours in year

$$= 107.251 \times 8760 = 939520.51$$
$$wh/m^2$$

$$= 939.52 \, kWh/m^2$$

Swept area of the rotor $= \dfrac{Total\ annual\ energy\ reqn.}{useful\ energy\ density}$

$$\pi R^2 = \frac{2000000}{939.52} \, m^2$$

$$R = \sqrt{\frac{2128.75}{3.14}} = 26.04 \, m$$

WPP power rating $=$ Actual Power density $\times$ Area of the rotor

$$= \frac{107.251 \times 2182.75 \, (\pi R^2)}{1000}$$ → for your reference

$\pi R^2 = 2182.75$

$$= 228.31 \, kW$$

This value is on the assumption ⇒ wind is available for 8760 hours of the year, which actually does not happen, hence the concept of PLF has to be applied

Actual WPP rated Power $= \dfrac{228.31}{0.3}$

$$= 761.0 \, \simeq \, 760 kW$$

4 Power required to pump the water (3)

$$= \frac{5 \times 1000}{3600} \times 9.8 \times 9 = 122.5 \, W$$

Power required at the rotor

$$= \frac{122.5}{0.55 \times 0.75} = 296.97 \, W$$

$P_{max} = C_p \times P_{total}$

$$296.97 = 0.28 \times \left(\frac{1}{2} \times 1.225 \times \pi R^2 \times 7^3 \right)$$

$$R = \left(\frac{296.67}{0.28 \times 659.67} \right)^{1/2} = 1.27 \, m$$

Diameter $D = 2.54 \, m$.

from the graph, TSR, $\lambda = 1$
already with you
from PPT   Tip Speed Ratio

$\lambda = \omega R / u_0 \rightarrow$ undistribed speed

$$\omega = \frac{\lambda u_0}{R} = \frac{1 \times 7}{1.27} = 5.51 \, rad/s$$

RPM of the designed rotor is

$$= \frac{\omega \times 60}{2\pi} = \frac{5.51 \times 60}{2\pi}$$

$$= 52.64 \approx \underline{53}$$