Renewable electrical self-sufficiency on islands

The need is 2000 people * 350 W_e = 700 kW_e power
For a year (8760h) => 700 kW_e * 8760h = 6.132 GWh_e electricity need

<u>Wave power generator :</u>

wavespeed = windspeed !

The power per 1 m width of incoming wavefront is given by :

P (kW/m) = 2.45 * wave-amplitude^2 * wavespeed = 2.45 * $(1.4m)^2$ * 6 m/s = 28.8 kW/m

With a generator efficiency of 70% : → 20.17 kW_e/m electricity generation. Assuming 50% equivalent load at these conditions (6 m/s, 1.4 m), a 1 m diameter device would generate 20.17 kWe * 8760h * 50% = 88.33 MWh_{el}. To generate 6132 MWh electricity, we would need to capture a 6132 MWhe/88.33 MWhe = 69.4 m wave front. This would be an impossibly huge device and rather it would have to be many wave power generators. Taking a Pelamis snake of 3.5 m diameter, some 20 of these would be needed.

<u>Tidal turbine :</u>

The power formula which applies is like that for a wind turbine, but using as density that of water (1000 kg/m^3) instead of air and the tidal current instead of the windspeed :

P_{peak_spring} = 0.5 * 1000 kg/m^3 * C_p * A * spring_peak_tide_current^3 (m/s)^3

P_{peak_neap} = 0.5 * 1000 kg/m^3 * C_p * A * neap_peak_tide_current^3 (m/s)^3

With spring_peak_tide_current = 1.6 m/s and neap_peak_tide_current = 1.1 m/s, the ratio neap/spring = 1.1 / 1.6 = 0.6875, which has to be raised to the 3rd power, giving a power ratio of P_{peak_neap} / P_{peak_spring} = 0.325. The average <u>peak</u> power is then ½ .(1 + 0.325) = 0.6625 of the P_{peak_spring} power. Finally the average <u>actual</u> power is 39% of this value, or 0.39 * 0.6625 = 0.258 of P_{peak_spring} power.

Since the island needs a power provision of 700 kWe, we take this into account by setting the spring tide peak power to P = 700 kW_e / 0.258 = 2709.24 kW_e

To reach this peak power at spring tide, the turbine swept area would need to be:

A = 2'709'240 / (0.5 * 1000 * 0.3 * 1.6^3) = 4409.6 m^2, i.e. again an impossibly huge tidal turbine with 75 m diameter would be needed (π * (37.5 m radius)^2 = 4410 m^2). Note that as a wind turbine, this would be a relatively normal size. Hence again a series of smaller tidal turbines would be needed to cover the minimal average electrical needs of the island. Taking a 10 m more conventional radius tidal turbine, about 14 of those would be needed.

Wind turbine:

The power formula for a wind turbine applies, using as density that of air (1.22 kg/m^3) and the windspeed, with a C_p of 35% :

P = 0.5 * 1.22 (kg/m^3) * 0.35 (C_p) * A * v^3

The average wind speed v (on land and sea) is 6 m/s. The rated wind speed is twice the average wind speed, i.e. 12 m/s.

We have to consider the annual electricity need of 6.132 GWh_e since the WT unlike the tidal turbine or wave power generator does by far not run year-round at rated power.

As given, the WT operates an equivalent 2500h time of the year at this rated power, i.e. the rated power from a single turbine would need to be 6.132 GWh_e / 2500 h = 2.45 MW_e

P (W) = 0.5 * 1.22 * 0.35 * (12 m/s)^3 * A = 421.6 * A

with P = 2.45 MWe, it follows that A = 6648.5 m^2 => WT diameter = 92 m

This would hence be doable with a single turbine. Note that the equivalent tidal turbine is a bit smaller. Note also that we have taken a very 'windy' case (6 m/s average wind on the location)!

2)

Every case will of course have to be overdimensioned to take into account peak consumption on the island, not just the annual average. Also electricity transport and distribution losses on the island from the point of generation obviously need to be taken into account.

Wind: needs a large amount of electricity storage and a back-up solution to deal with wind cuts.

Sea turbine: in the research stage, issues with corrosion etc; power is also not constant as the tidal current changes all the time between 0 and peak current; therefore it also needs a buffer system to smoothen out and store the electricity supply.

Wave power generator: requires heavy cost for overdimensioning, to take on big waves.

Globally the exercise illustrates that the required power for the considered case might be covered by, say, 2 large wind turbines (90 m diameter), about 15 tidal turbines (10 m radius), and about 20 wave generators (3.5 m diameter).