Renewable electrical self-sufficiency on islands

The need is 600 people * 250 W_e = 150 kW_e power
For a year (8760h) => 150 kW_e * 8760h = 1.314 GWh_e electricity need

Wave power generator :

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 * $(1.3m)^2$ * 6 m/s = 24.84 kW/m

With a generator efficiency of 70% : → 17.4 kW_e/m electricity generation. Assuming 50% equivalent load at these conditions (6 m/s, 1.3 m), a 1 m diameter device would generate 17.4 kWe * 8760h * 50% = 76.2 MWh_{el}. To generate 1.314 GWh electricity, we would need to capture a 1.314 GWhe/76.2 MWhe = 17.2 m wave front. This would obviously be a huge device and rather it would have to be several wave power generators.

Tidal sea-turbine :

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} = 0.5 * 1000 kg/m^3 * C_p * A * peak_tide_current^3 (m/s)^3

Since the average power generated from a sea-turbine is 40% of that generated at peak tidal current, we take this into account by setting the peak power to P = 150 kW_e / 0.4 = 375 kW_e

Average peak tidal current is 1.5 m/s, the sea-turbine's C_p = 30%

To reach 375 kW_e (peak), the turbine swept area is :

A = 375'000 / (0.5 * 1000 * 0.3 * 1.5^3) = 740.74 m^2, i.e. a (very) large sea-turbine with 15.35 m radius would be needed (π * $(15.35)^2$ = 740 m^2).

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 40% :

P = 0.5 * 1.22 (kg/m^3) * 0.4 (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 1.314 GWh_e since the WT unlike the tidal turbine or wave power generator does by far not run year-round.

The WT operates an equivalent 20% time of the year (=1752 h) at rated power, i.e. its rated power is 1.314 GWh_e / 1752 h = 750 kW_e

P (W) = 0.5 * 1.22 * 0.4 * $(12\ m/s)^3$ * A = 421.6 * A

with P = 750 kWe, it follows that A = 1779 m^2 => WT radius R = 23.8 m

(which confirms that for equivalent power generation, a sea turbine is smaller than a wind turbine).

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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.