Thorne Island – Micro Tidal Lagoon Initial Assessment

Site Description:

This report presents first principle calculations and a basic assessment of the proposed micro tidal lagoon along with other alternative suggestions for renewable energy at Thorne Island, Pembrokeshire.

Thorne Island is situated approximately 250-300m off the headland at Angle, on the South side of the Milford Haven Estuary. The tidal range at Thorne Island varies typically between 6m during a spring tide and 3m during a neap tide.

The cave on the North-East side of the island has an enclosed area of approximately 260m^2 and a narrow opening, approximately 2.6m across.

Lagoon Capacity Calculation:

Local Tidal Range values according to MHPA[1] are as follows:

Table 1 – Tide height and range values

	High Water Height*	Low Water Height*	Tidal Range
Spring Tide	7.39 m	0.77 m	6.6 m
Neap Tide	5.32 m	2.66 m	2.7 m
Mean Tide	6.33 m	1.71 m	4.6 m

Using this data and the cave measurements taken during the site visit on the 18th Jan 2022, Figure 2 was produced to show an approximation of the volume of water inside the lagoon at varying water depths. For this calculation the tidal lagoon boundary included the entire cave and the mouth to the cave up to the metal bridge, as illustrated in Figure 1 below, therefore aligning with the proposed jetty designs.

Figure 1 - Thorne Island lagoon boundary

[1] https://www.mhpa.co.uk/uploads/2021-12-13-58-1-2022-tide-tables.pdf - 14/01/2022

The lagoon water volume, V, measured in m³, has been calculated for spring, neap and mean tides by applying the tidal height and range values to the curve in Figure 2. These values are shown in the 'Water volume' column in
Table 2 below.

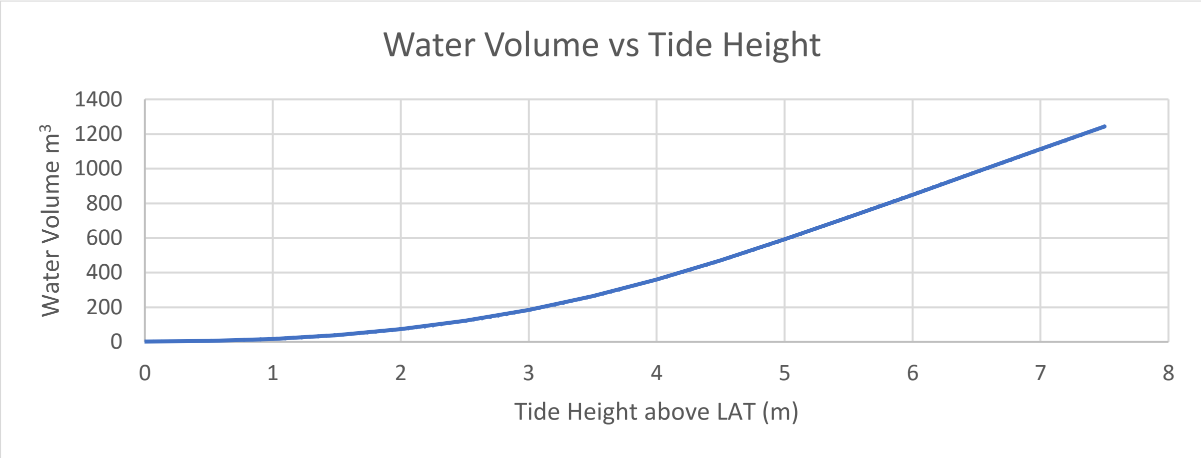

Figure 2 - Lagoon water volume at varying tide heights

Power Output Calculation:

Assumptions for power output calculation:

- Efficiency factor = 0.7. This is an optimistic value for a small scale system, product of turbine efficiency, generator efficiency and pipe losses.
- Constant head difference across the barrage of 2m during ebb/flood; to create sufficient flow across the turbine for electrical energy generation.
- There is sufficient flow across turbines such that the full tidal range is utilised within the lagoon (i.e. lagoon height = sea height at high and low tides)
- There are no "off the shelf" products for this system, so it is assumed that the system can be purchased and operates reliably long term.

The total energy that can be produced during a half-tide (6hrs period) can be calculated in Joules using the potential energy formula, $E = mg\Delta h$,. In this formula m is the total mass of the water passing in/out of the lagoon (i.e. $V * 1029kg/m^3$), g is the gravitational constant ($9.81m/s^2$) and Δh is the head difference inside and outside of the lagoon, which for the purposes of this study has been set to 2m. The head difference is also applied to the volume calculation. Applying a factor of 0.8 for the turbine/generator efficiency and converting from Joules to kWh gives the following formula:

$$E = mg\Delta h * \frac{0.8}{3,600,000}$$

Applying this to the water volumes for spring, neap and mean tides produces approximations for the electrical energy that could be produced from this tidal lagoon system.

Table 2 shows the largest and smallest tide from the sample data set (one month analysed) with power output predictions in kWh for that tide.

Table 3 gives the results of the analysis. The energy generated by the sample data set is scaled up to an annual equivalent value. Using a generous electricity price of 30p/unit the system could generate energy worth £840 per year. Using the two 10kW heat pumps as a reference use of electricity, they could be powered for 140 hours per year, around 1.6% of the time. A photovoltaic system with approximately the same power output would be around 3.5kW peak. This is slightly smaller than the 4kW systems typically installed on UK houses.

Table 2 – Water Volume and Power Output Values

Tide type	Water volume	Head	Energy per half tide
Spring	1048 m^3	2 m	4.1 kWh
Neap	122 m^3	2 m	0.48 kWh

Table 3 - Summary Results

	Unit	**Value**
Annual equivalent energy	kWh/pa	2799
Energy price	£/kWh	0.30
Value of energy	£	840
Load from heat pumps	kW	20
Total time heat pumps can be powered from tidal	hours/pa	140
%run time		1.6%
Comparison with Solar		
Typical yield per kW installed	kWh/pa	800
Equivalent installation	kW	3.50

Environmental and Planning Issues

- JNCC list Pembrokeshire Marine as a Special Area of Conservation (SAC). Sea caves are listed as “Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site” https://sac.jncc.gov.uk/site/UK0013116. As a result of this significant effort will be required to secure a marine licence.
- Permits/licences will be required from the Port and NRW.
- The legal boundary of the property will need to be established to determine if Crown Estate owned seabed is required. If this is the case a lease will have to be negotiated and ground rent paid.
- CADW will be consulted as part of the permit process.
- The permit process will require an environmental consultant, scientific survey and legal costs. It could take 2 years and due to the SAC designation, NRW could still say no at the end of the process.

Evaluation:

- Permits will be expensive and slow to obtain.
- Very limited amount of energy available due to the size/water holding capacity of the cave
- Would not be sufficient to solely power Thorne Island for a prolonged amount of time.
- Would be beneficial during spells with no solar or wind in providing a small amount of energy
- Not profitable, when factoring in likely costs for servicing and maintenance.

Alternative suggestions for sustainable energy generation:

The channel between Thorne Island and Thorne Point could potentially be an ideal location a tidal stream device. Below are a number of potentially viable options to be considered:

Tidal Stream Devices:

- Floating/seabed mounted Devices currently exist and can be off-the-shelf products
- An assessment of the flow velocities would provide a good indication of this site's potential
- Consideration would need to be given to significant forces on the moorings and the device itself during extreme weather conditions
- Interference from mariners would need to be well managed. It may be difficult for the Port to sign off a navigational risk assessment due to the local beaches.
- The channel's limited depth rules out most existing tidal stream devices; a small-scale device would be required. One potential supplier has a base in Milford Haven: https://qednaval.co.uk/

Floating PV Farm:

- Low cost installation
- Positioned on the sheltered side of the island
- May not be suitable for extreme weather conditions at Thorne Island
- Ocean specific mooring systems are under development

Small floating wind turbine

- Turbines are low cost and reliable
- Bespoke platform to be designed, storm effects should be manageable
- Environmental permits required, less challenging requirements

Hydropower from rainwater tank

- The water tank can supply a high head turbine which would produce more energy per L of water in comparison with a tidal lagoon
- Could naturally provide energy during times when solar energy is unavailable and there is surplus rainfall
- As a rough approximation, a hydropower system with a 50,000 gallon reserve, a 20m head and an efficiency factor of 0.8 would produce 9.8kWh (enough to power 1 UK home for 1 day)
- This would use up months of rainwater collection that could not be used for other purposes.

Traditional renewable energy systems on the island

- A significant number of solar panels would be the cheapest option. Heritage, planning and aesthetic issues would set the upper limit on the number
- An onshore wind turbine (of suitable size) would provide plenty of energy. This may be too noisy for residents. Impacts on the bird population would need to be surveyed.

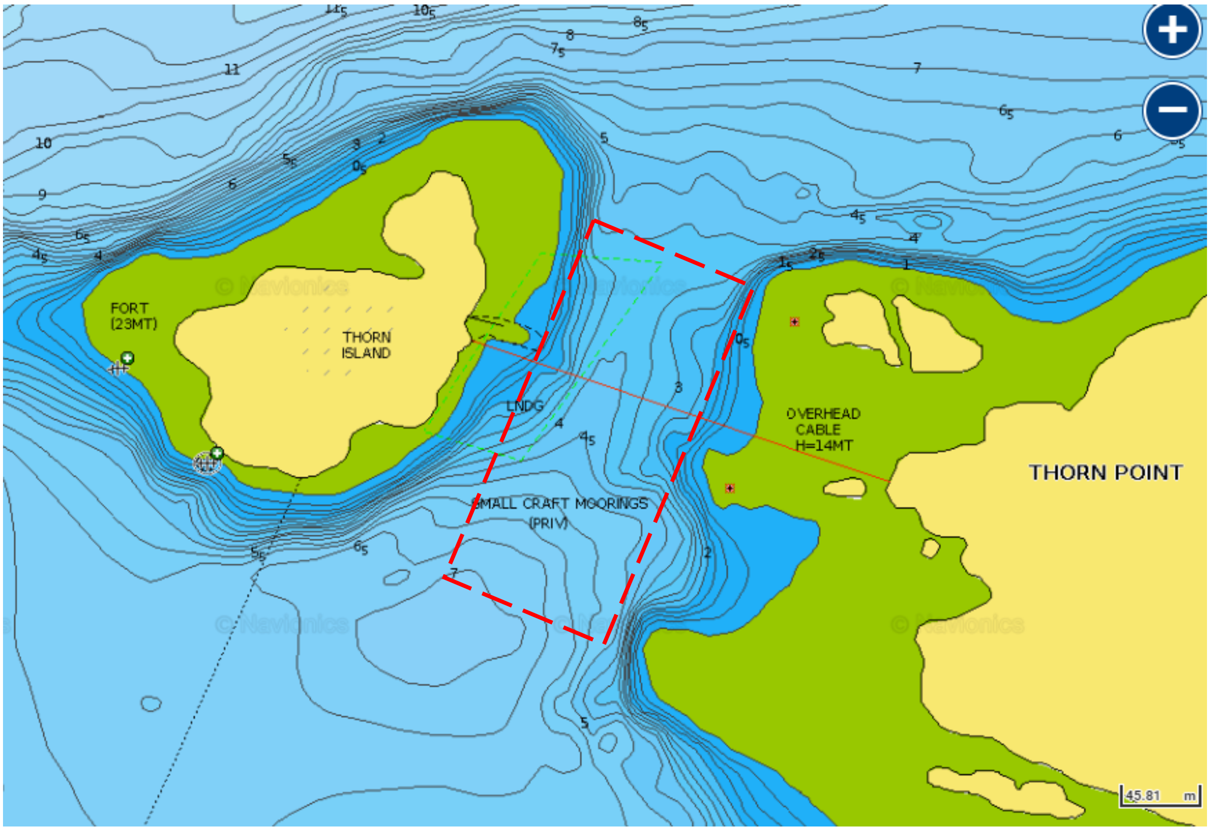

Figure 3 - Thorne Island bathymetry chart

Conclusion

A micro-tidal lagoon would be a novel project and potentially beneficial in promoting tidal range energy in Wales and in the UK.

The lagoon would reliably produce a very small amount of energy that would be beneficial in powering some essentials when solar and wind are not available. However, it would also not be sufficient as a stand-alone source of electrical energy to the Island. Due to the size of the cave, the amount of energy that this lagoon is capable of producing is limited and would therefore not be a cost-effective way of generating electricity when compared to solar or wind.

Through other funding sources available under the MEECE project, it may be possible to conduct a feasibility study into one of the three projects identified: small floating wind, tidal stream or floating PV.

The most effective solution would be to increase significantly the installed solar panels on the island.