Developing datasets of tidal and wave energy generation from renewable resource models

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Research objective

Produce reliable datasets of wave, tidal stream and tidal range power output for incorporation into GB power system models
Wave resource

Significant global resource

Wave resource created by offshore winds
- Wind speeds
- Wind duration
- Fetch

Wave energy flux (kW/m wave height)
Tidal resource

Significant global resource

Tidal range created by gravitational pull of the moon & sun

Affected by:
- Funnelling in coastline seabed
- Shoaling of tidal waves
- Resonance in estuaries

Wave

Energy extracted from water motion
- Heave, sway, surge
- Converted to yaw, pitch, roll

No technological convergence:
- Oscillating water column
- Terminator
- Attenuator
- Oscillating wave surge
- Point absorber
- Rotating mass
- Bulge wave
- Overtopping device
Tidal range

Artificial enclosures used to extract energy from tidal elevation

Tide mills survive from Saxon Britain
- e.g. Eling, Christchurch
- Evidence of Roman tide mills

Modern approaches:
- Barrages
- Lagoons

Also: enhanced pumped storage

Illustration of tidal lagoon
Tidal stream

Energy extracted from tidal **current**
- Funnelled by seabed/coastline

Several approaches:
- Horizontal axis turbine
- Vertical axis turbine
- Venturi-based device
- Linear lift-based device

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SeaGen Tidal Turbine

Illustration of tidal stream
Top: Elevation
Bottom: Plan
Challenges in developing wave and tidal energy

CONS

Hostile environment

Technologies under development
  ◦ Costs high/uncertain

Remote from load centres
  ◦ Limited power transmission infrastructure

➢ Limited inclusion in future energy scenarios
➢ Limited guidelines for new projects

PROS

Significant **practical** resource (at certain locations)

Supports system flexibility, energy security
  ◦ Temporal profile complementary to wind and solar
  ◦ Tidal uniquely predictable for a variable renewable resource
Key parameters

Credible installation locations
- Identified in previous work
- Wave:
  - UK Marine Energy Database (UKMED) and previously consented sites\(^1,2\)
- Tidal stream:
  - Critical review of literature supported by further analysis\(^3\)
- Tidal lagoon:
  - Identified by researchers, industry or government\(^4\)

Power conversion technologies:
- Wave – 750 kW Pelamis WEC\(^2\)
- Tidal stream – Representative 2MW floating horizontal axis tidal turbine\(^2\)
- Tidal lagoon – Andritz double-regulated bulb turbine\(^4\)

Note: References provided at end of presentation
Data development

**WAVE POWER**
- Not predictable for long time horizons
- Based on historical reanalysis data as per Struthers et al\(^2\)
  - ERA5 dataset\(^5\) 1990 to 2019
  - Hourly resolution
  - Significant wave height (H\(_s\))
  - Peak period (T\(_p\))
  - Conversion to energy period (T\(_e\))
- Pelamis power matrix

**TIDAL STREAM**
- Predictable over long time horizons
- Based on Thetis\(^6\) coastal ocean flow model of **velocities** as per Jordan et al\(^7\)
  - 2025, 2030, 2035, 2040, 2045, 2050
  - Hourly resolution
- Representative floating turbine power curve

**TIDAL LAGOON**
- Predictable over long time horizons
- Based on Thetis\(^6\) coastal ocean model of **elevation** as per Mackie et al\(^4\)
  - 2025, 2030, 2035, 2040, 2045, 2050
  - Hourly resolution
- Turbine hill chart and 0D operation model\(^4\)

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**Process Diagram**

- **Resource data**
- **Power performance data**
- **Power time series**
- **Calculate output as ratio of rated power**
- **Capacity factor series**
Resource fluctuation – 21st March

WAVE (2018)

TIDAL STREAM (2050)

TIDAL LAGOON (2050)
Resource fluctuation – 21st March

WAVE (2018)

TIDAL STREAM (2050)

TIDAL LAGOON (2050)
Resource fluctuation – 21st March

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TIDAL LAGOON (2050)
Resource fluctuation – 21st March

WAVE (2018)

TIDAL STREAM (2050)

TIDAL LAGOON (2050)
Resulting power output profiles

Power output dependent on installed capacity

Capacity factor:
  - Power output as a ratio of rated power

Tidal stream and tidal range usually complementary

Wave energy output at selected locations 27th Jan 2018
SW Peninsula – 18th Jan
SW Peninsula – 26th Jan

**Key**
- Tidal stream
- S.W. Peninsula
- Tidal lagoon
- S.W. Peninsula Wave
- S.W. Peninsula

![Map of SW Peninsula with markers for different locations]

![Graph showing capacity factor over time for various locations]

- Wave @ Penzance
- Wave @ St Mary's Point
- Wave @ Wave Hub
- Tidal stream @ Alderney Race
- Tidal stream @ Portland Bill
- Tidal lagoon @ Watchet
Example application (1)

Datasets applied in PyPSA GB

Dispatch of National Grid Future Energy Scenarios 2022
- System Transformation scenario
- Limited marine energy capacity

SW PENINSULA NODE:
- Measurable **tidal stream** output

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**SW Peninsula Node - 21st March 2045**

- Nuclear
- Tidal lagoon
- Solar Photovoltaics
- Wind Onshore
- CCS Biomass
- Biomass
- Tidal stream
- Wave power
- Hydrogen

Power (GW)

00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00
Example application (2)

MELKSHAM NODE:
- Measurable **tidal lagoon** output

Key
- Tidal stream
- CCS Biomass
- Biomass
- Wave power
- Wind Onshore
- Nuclear
- Tidal lagoon
- Tidal Stream
- Solar Photovoltaics
- Hydrogen

Melksham Node - 21st March 2045

Datasets applied in PyPSA GB

Dispatch of National Grid Future Energy Scenarios [ref]
**Conclusion**

**SUMMARY**

- **Significant practical marine resource**
  - Low carbon
  - Complementary to wind & solar
  - Better system flexibility & energy security

- **Energy modelling**
  - Forecast deployment limited
  - Reliable time-series of wave and tidal needed

- **Capacity factor time-series**
  - Can be used to explore potential benefits
  - Support informed investment and policy decision-making

**LIMITATIONS & FURTHER WORK**

**Energy conversion technologies:**
- Alternative archetypes
- Developments in individual efficiency
- Uncertainty over feasible capacity

**Temporal consistency:**
- Wind, wave & solar based on historical resource measurements
- Tidal based on predictive models for future years

**Climate change impacts, such as:**
- Implications for weather patterns
- Sea level rise

Paper reference 113
References


5. ERA5 hourly data on single levels from 1979 to present: https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysisera5-single-levels?tab=form


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