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

Iain A. Struthers*[1], *Lucas Mackie*[2], *Gareth P. Harrison*[1], *Daniel Coles*[3], *Athanasios Angeloudis*[1], ***R. Camilla Thomson[1]

[1]School of Engineering, The University of Edinburgh, Edinburgh EH9 3DW, UK
[2]Department of Earth Science and Engineering, Imperial College, London, UK
[3]School of Engineering, Computing and Mathematics, University of Plymouth, Plymouth PL4 8AA, UK

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Research objective

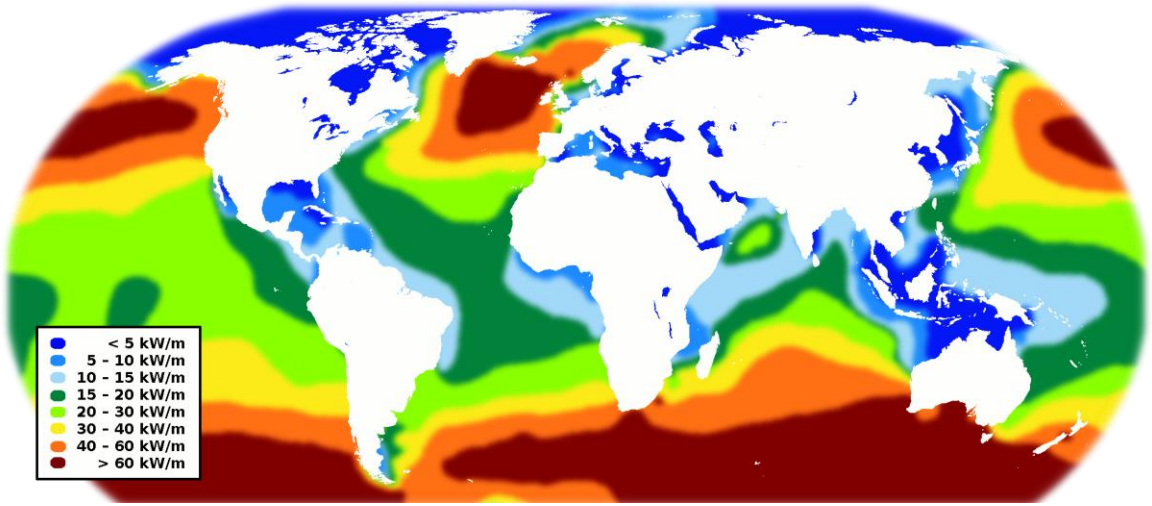
Produce reliable datasets of wave, tidal stream and tidal range power output for incorporation into GB power system models

Wave resource

Significant global resource

Wave resource created by offshore winds

- Wind speeds
- Wind duration
- Fetch



Wave energy flux (kW/m wave height)

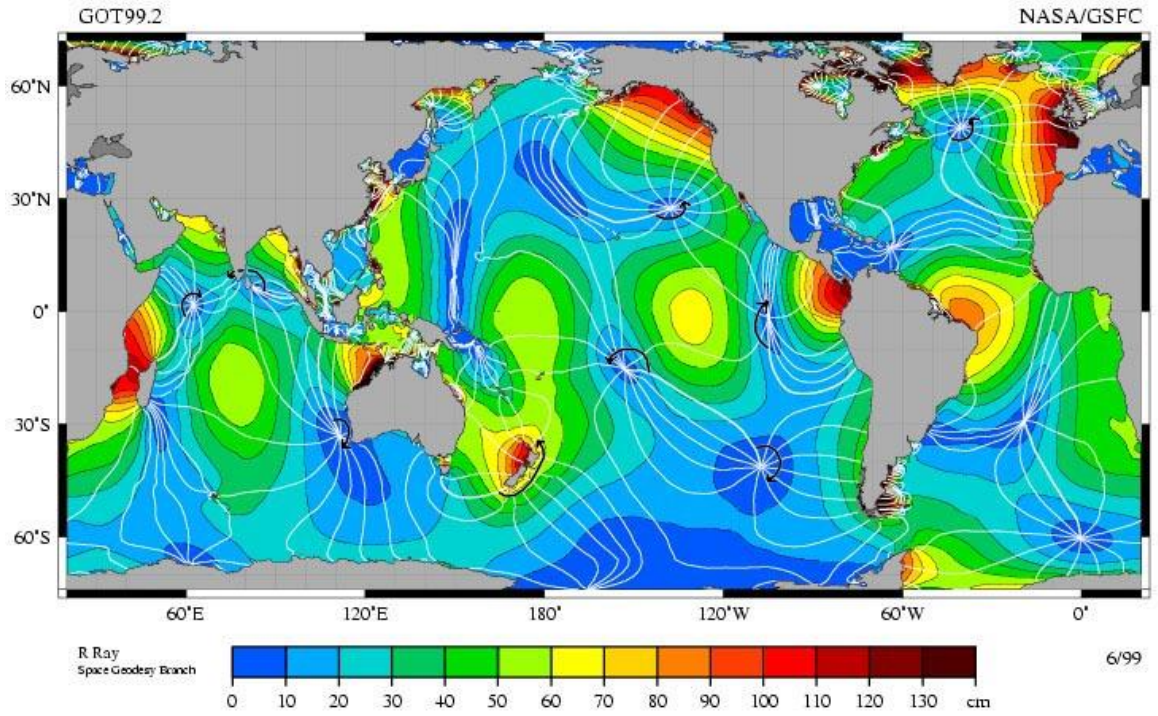
Tidal resource

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



Amplitude of M2 tidal constituent (cm)

Wave

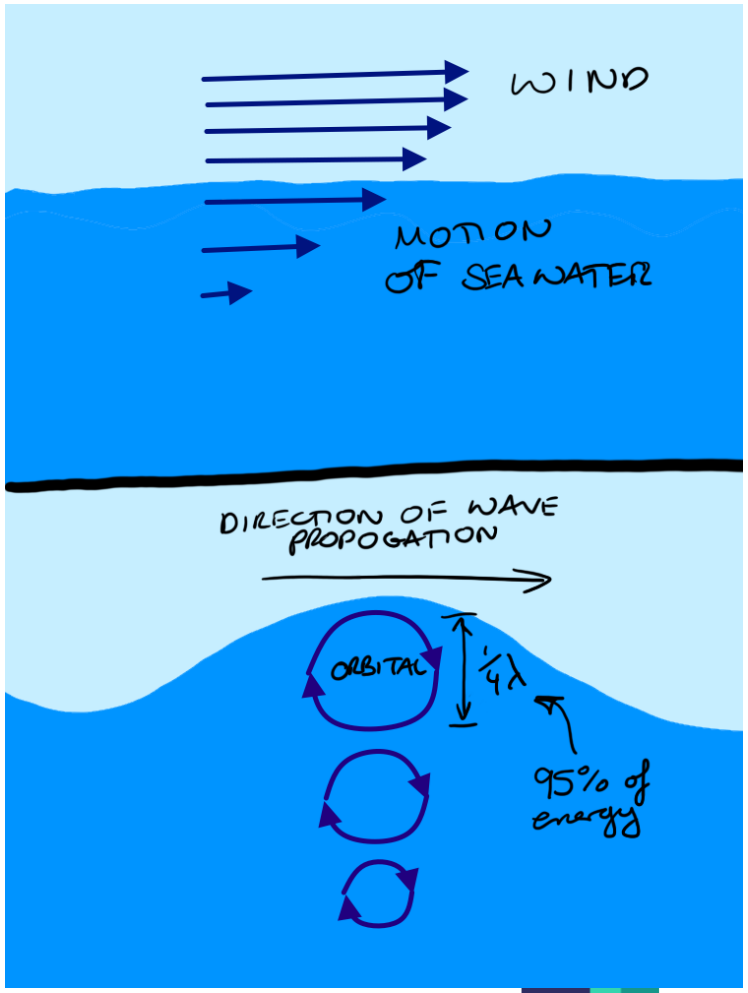
Pelamis Wave Energy Converter

Energy extracted from water motion

- Heave, sway, surge
- Converted to yaw, pitch, roll

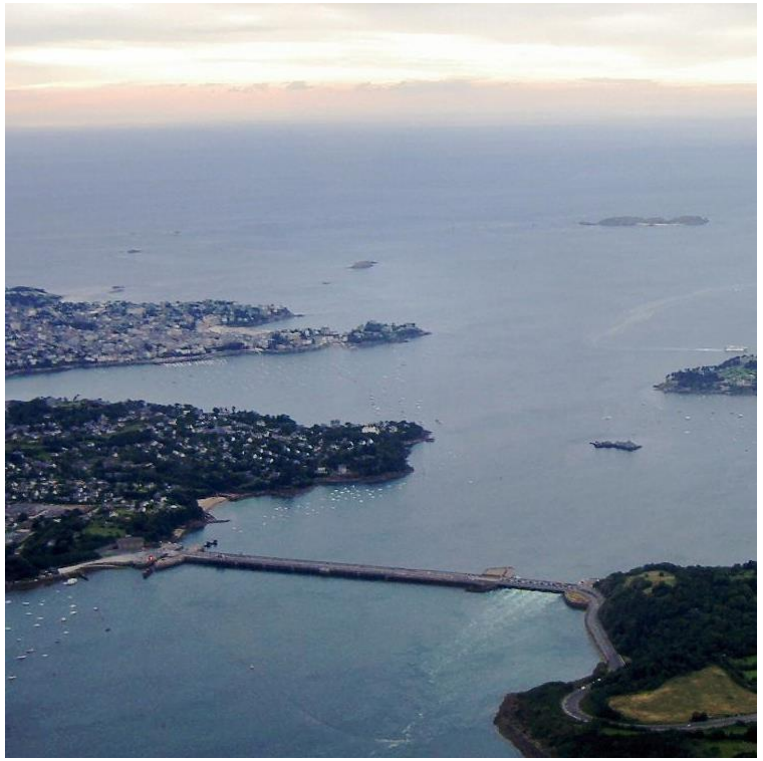
No technological convergence:

- Oscillating water column
- Terminator
- Attenuator
- Oscillating wave surge
- Point absorber
- Rotating mass
- Bulge wave
- Overtopping device



Wave creation and water motion

Tidal range



Barrage at La Rance, France

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

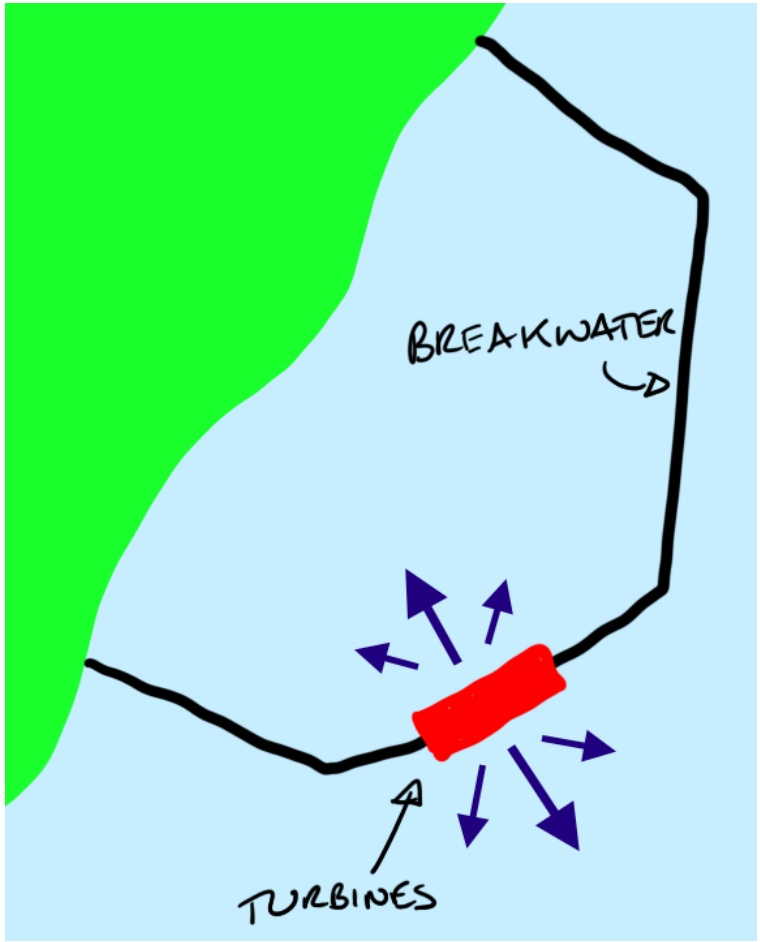
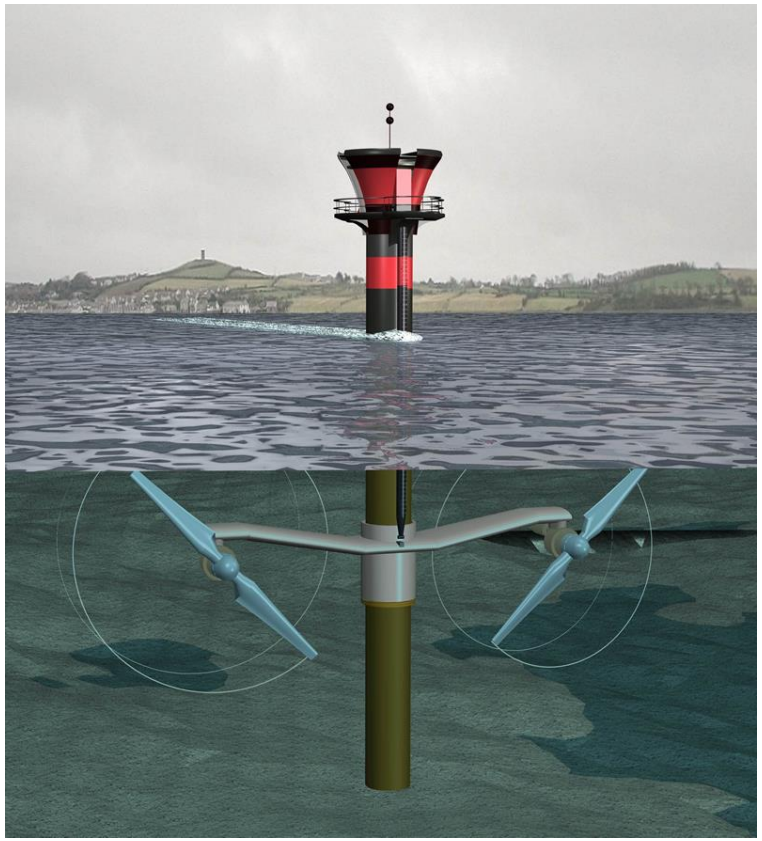


Illustration of tidal lagoon

Tidal stream



SeaGen Tidal Turbine

Energy extracted from tidal **current**

- Funnelled by seabed/coastline

Several approaches:

- Horizontal axis turbine
- Vertical axis turbine
- Venturi-based device
- Linear lift-based device

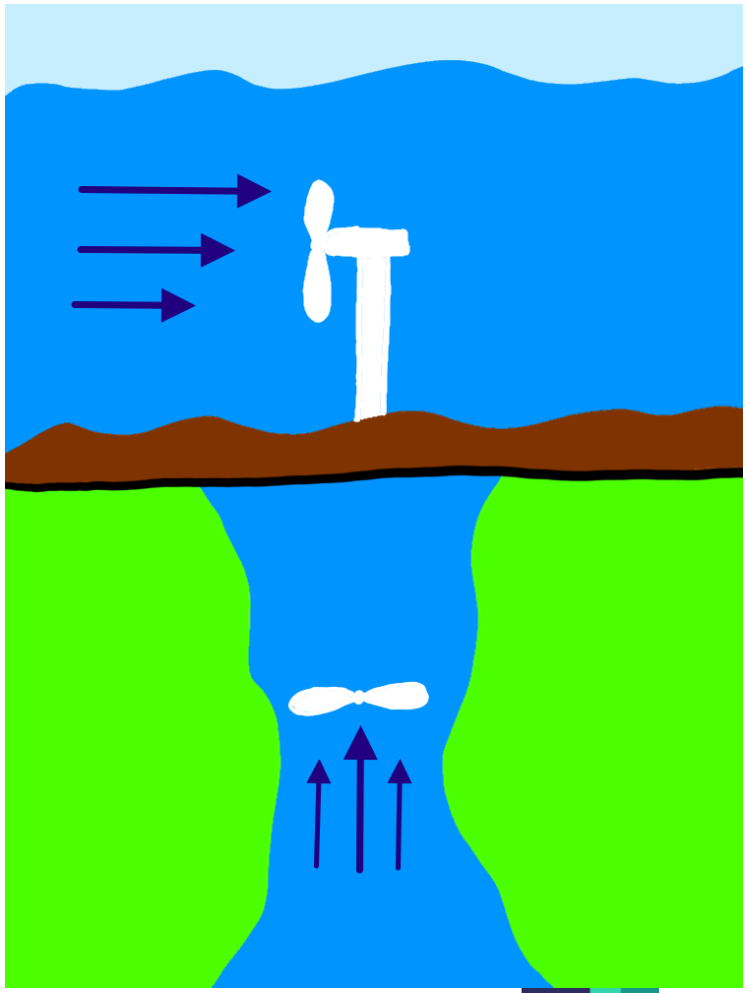


Illustration of tidal stream

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

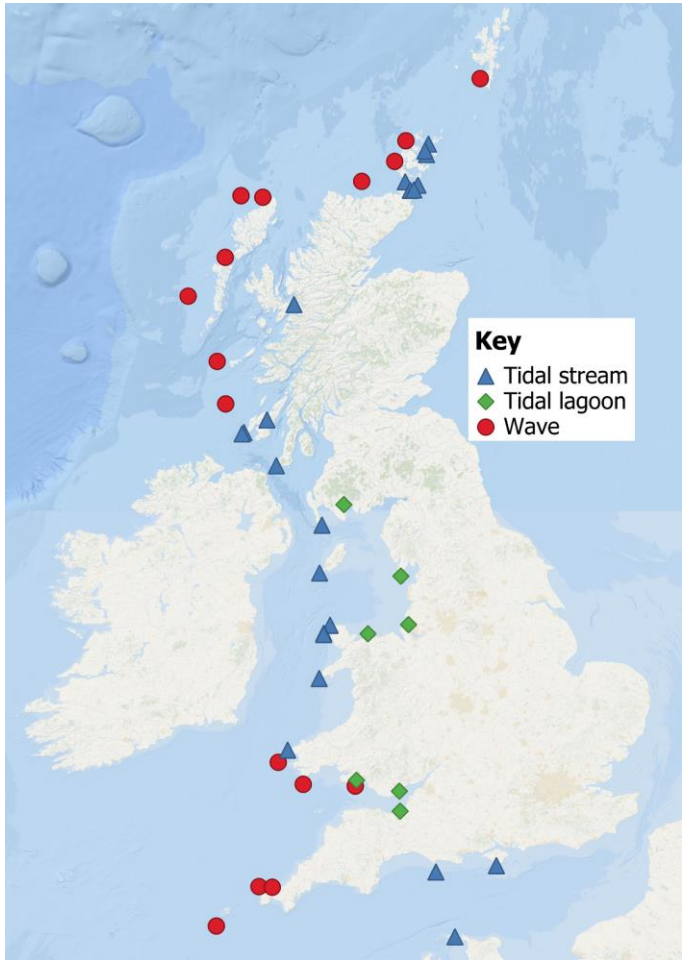
Key parameters

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]



Potential installation locations

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

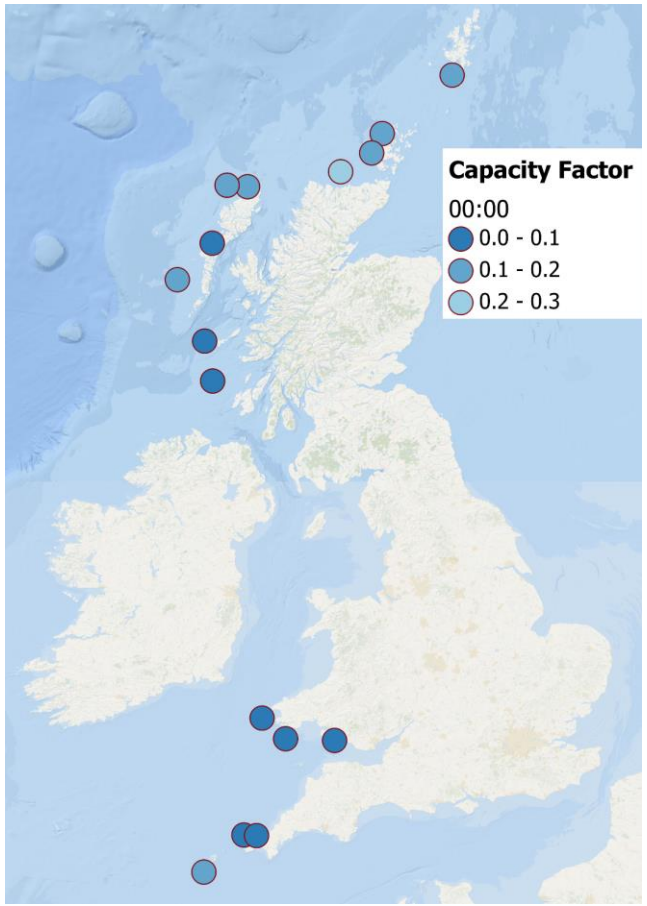
- Predictable over long time horizons
- Based on Thetis[6] coastal ocean flow model of **velocities** as per Jordan et al[7]
  - 2025, 2030, 2035, 2040, 2045, 2050
  - Hourly resolution
- Representative floating turbine power curve

TIDAL LAGOON

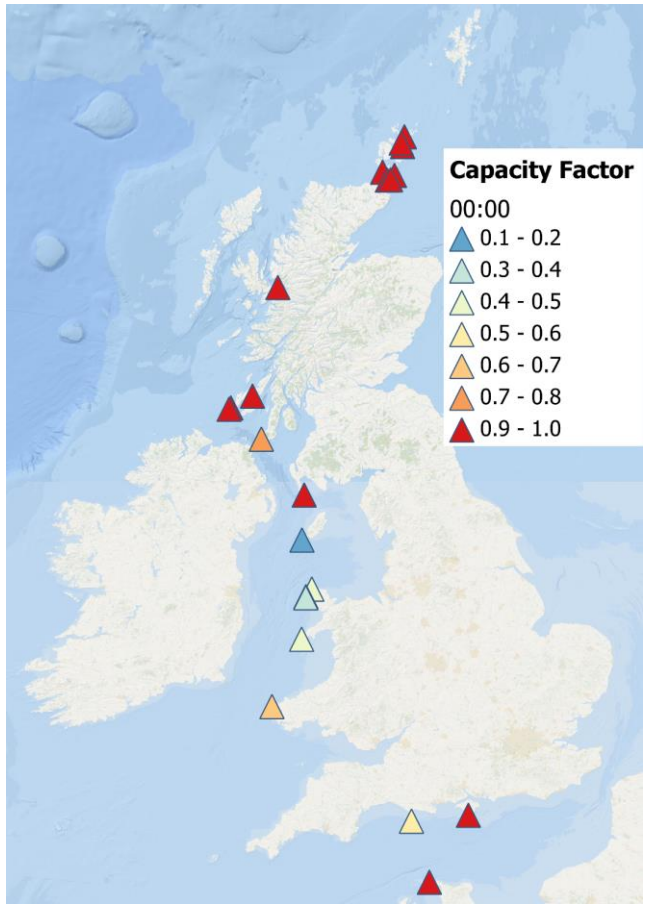
- Predictable over long time horizons
- Based on Thetis[6] coastal ocean model of **elevation** as per Mackie et al[4]
  - 2025, 2030, 2035, 2040, 2045, 2050
  - Hourly resolution
- Turbine hill chart and 0D operation model[4]

Resource fluctuation – 21st March

WAVE (2018)



TIDAL STREAM (2050)



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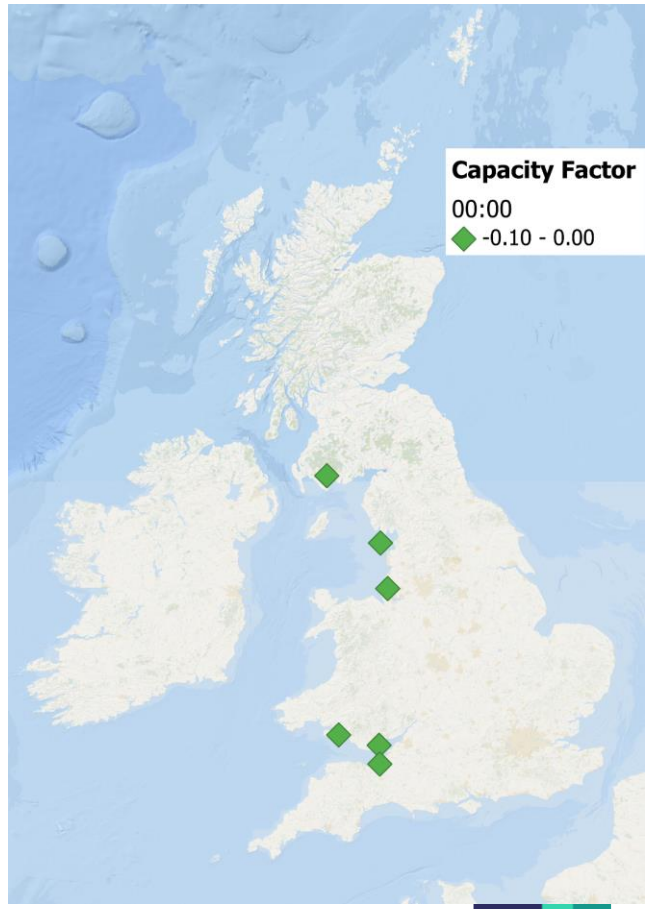

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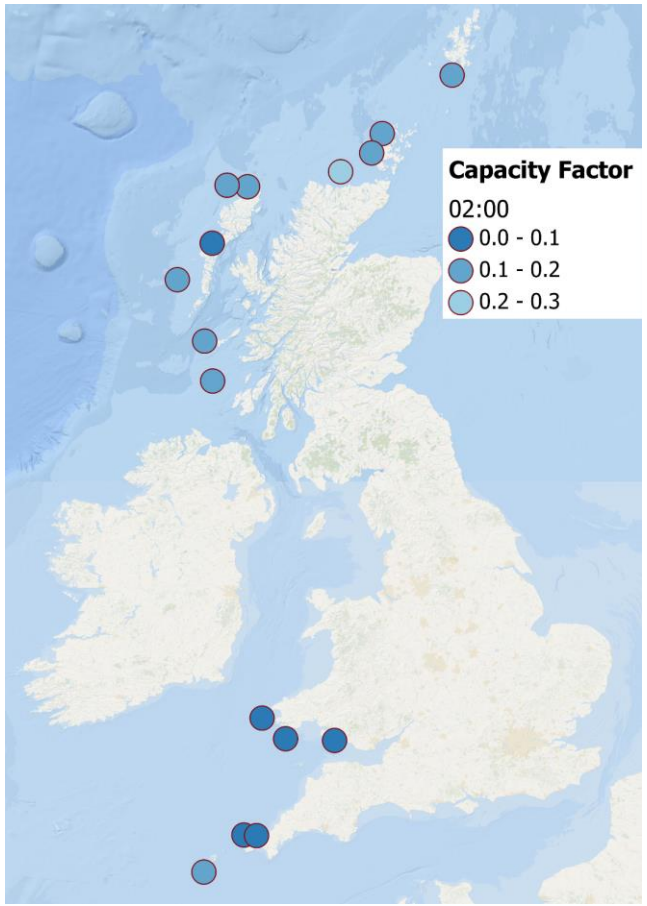

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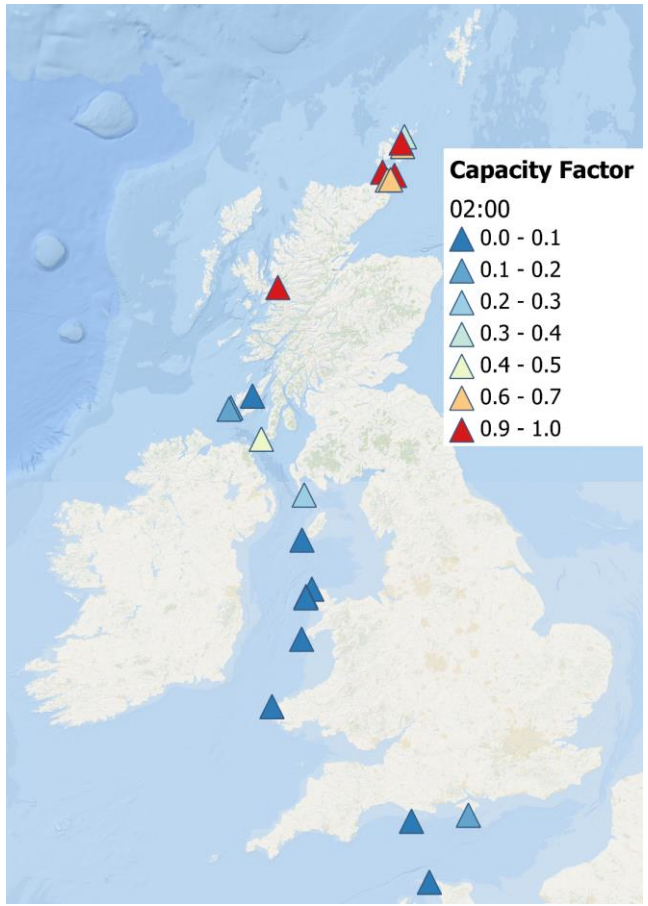

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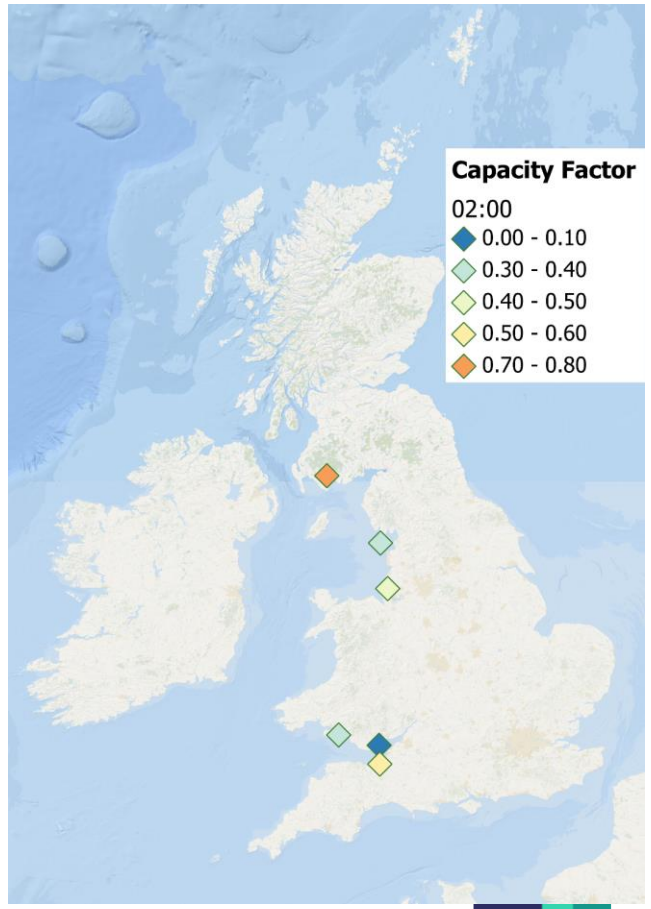

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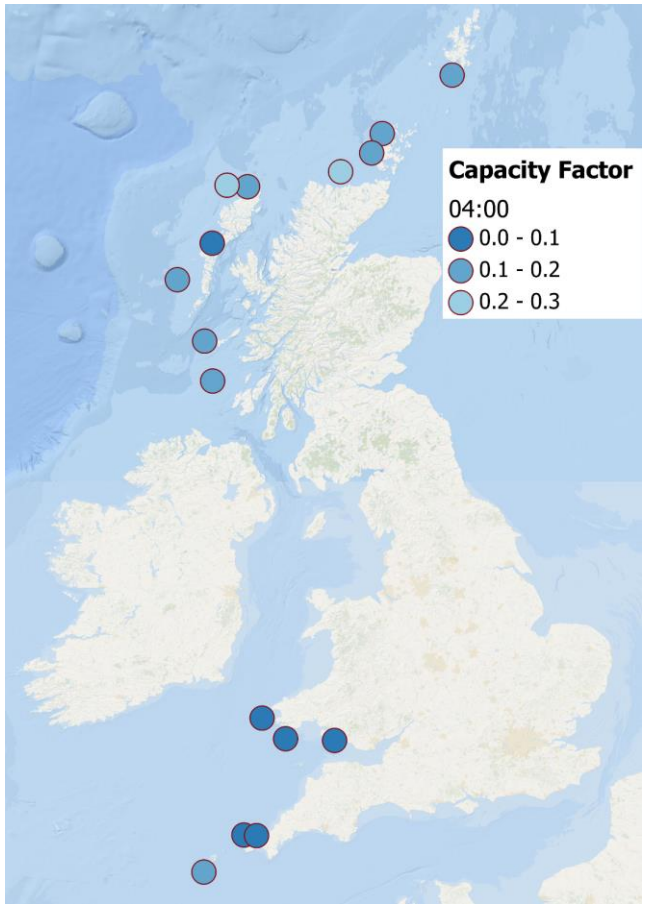

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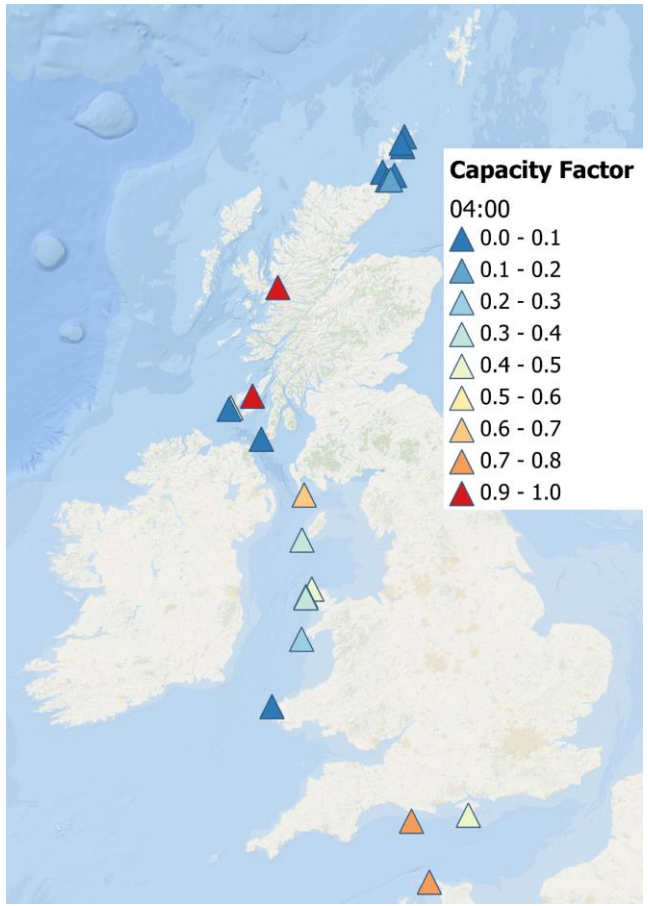

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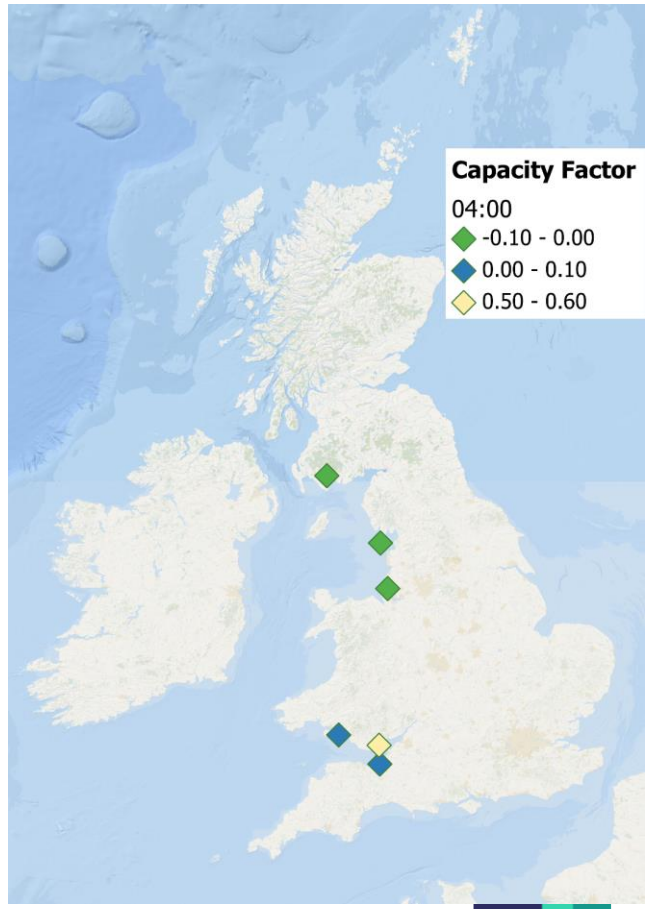

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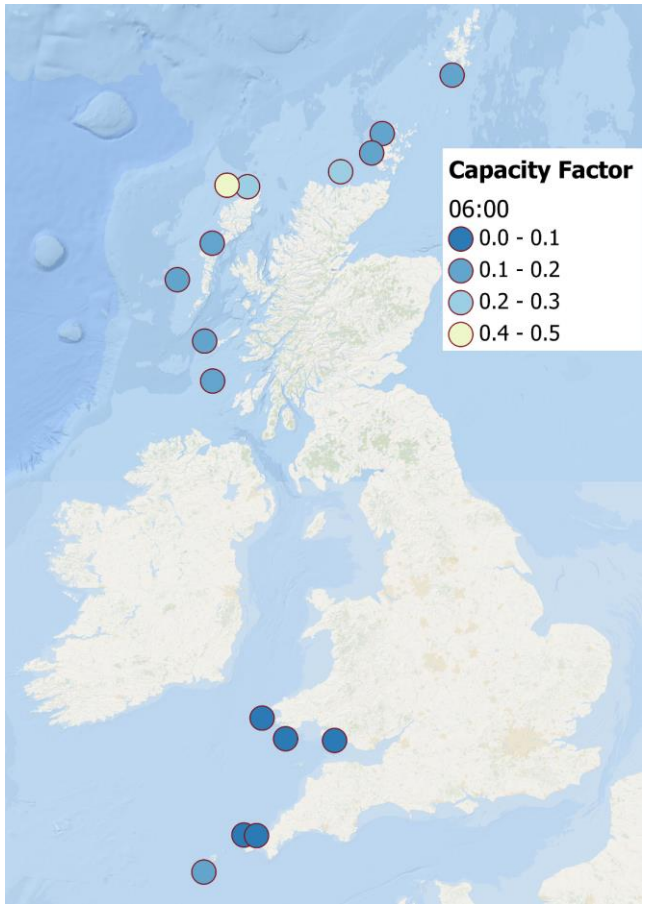

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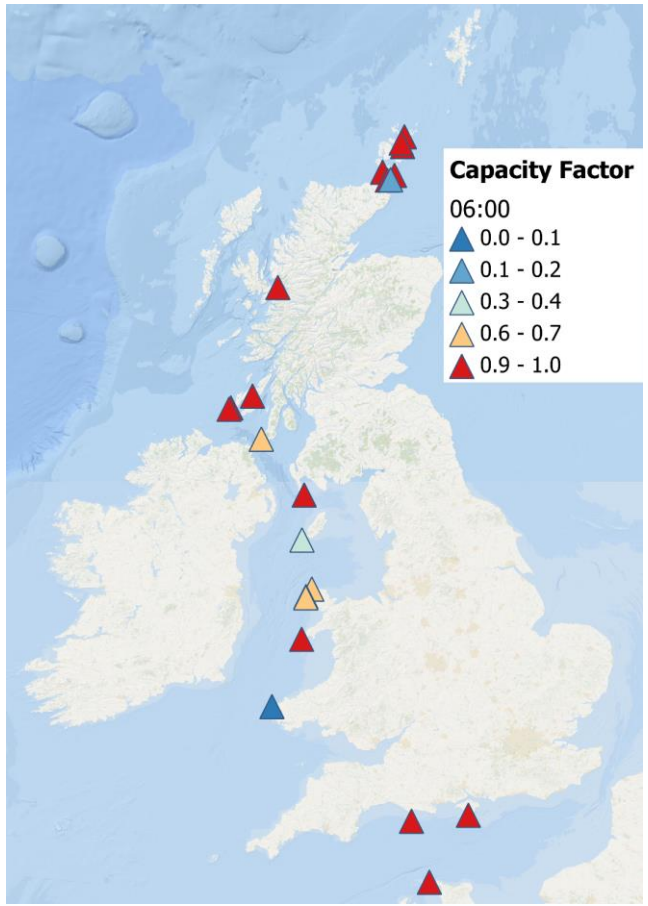

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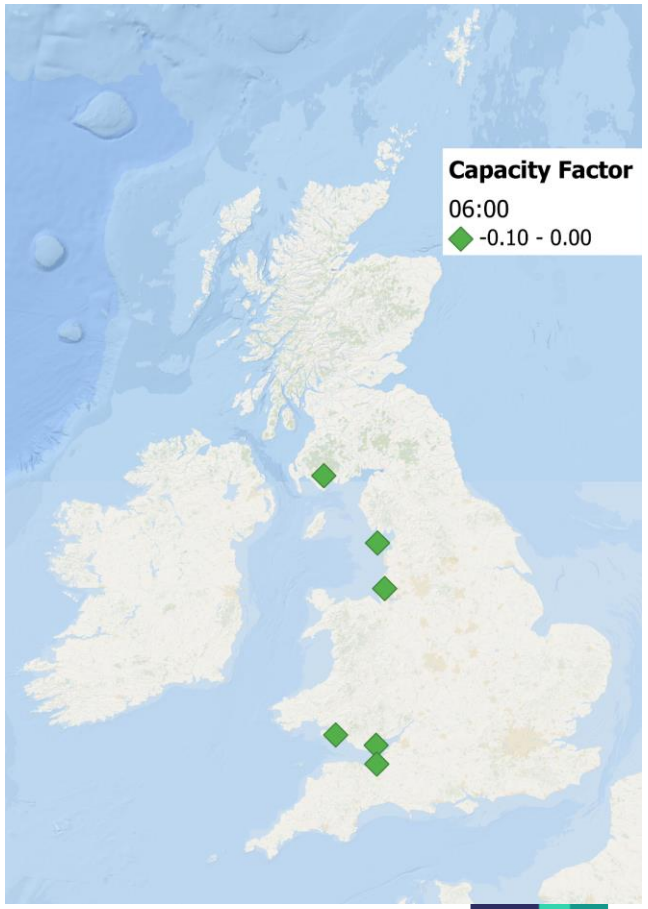

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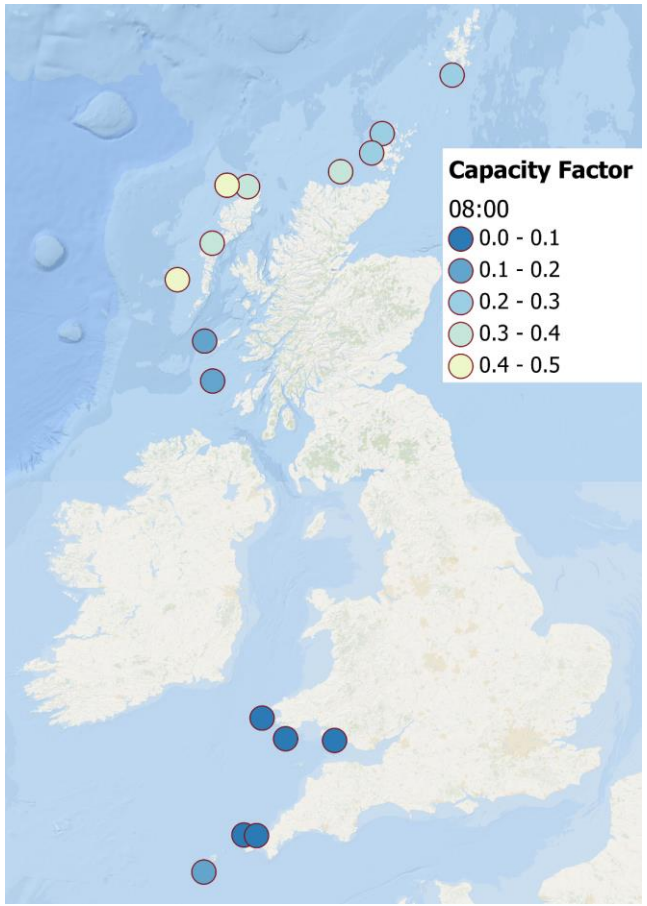

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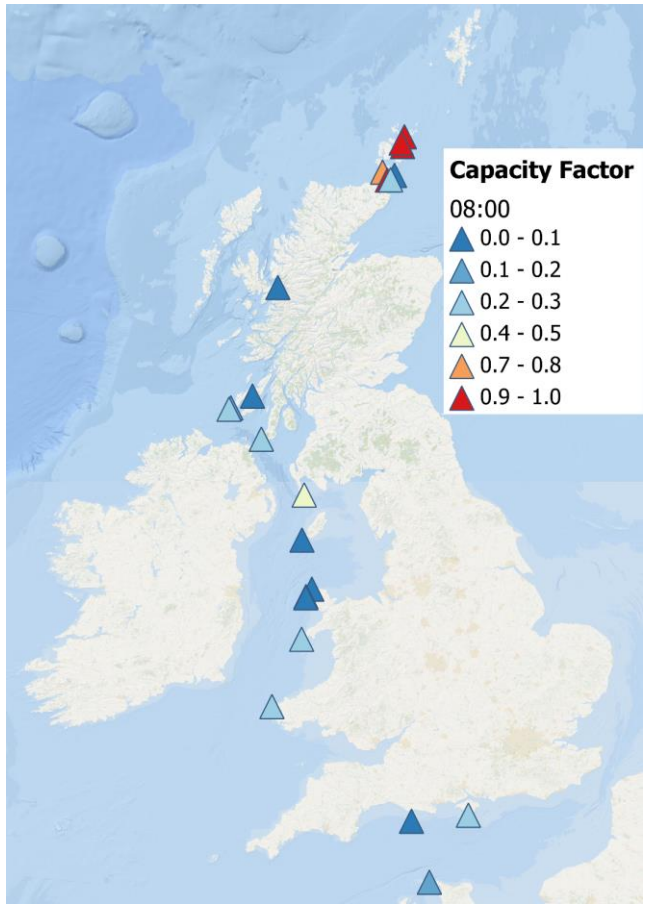

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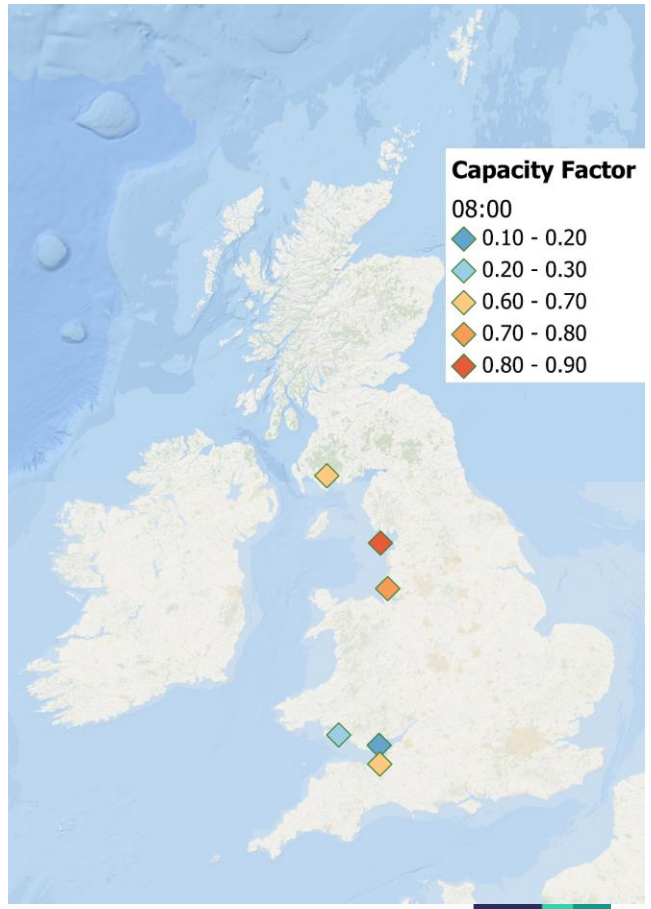

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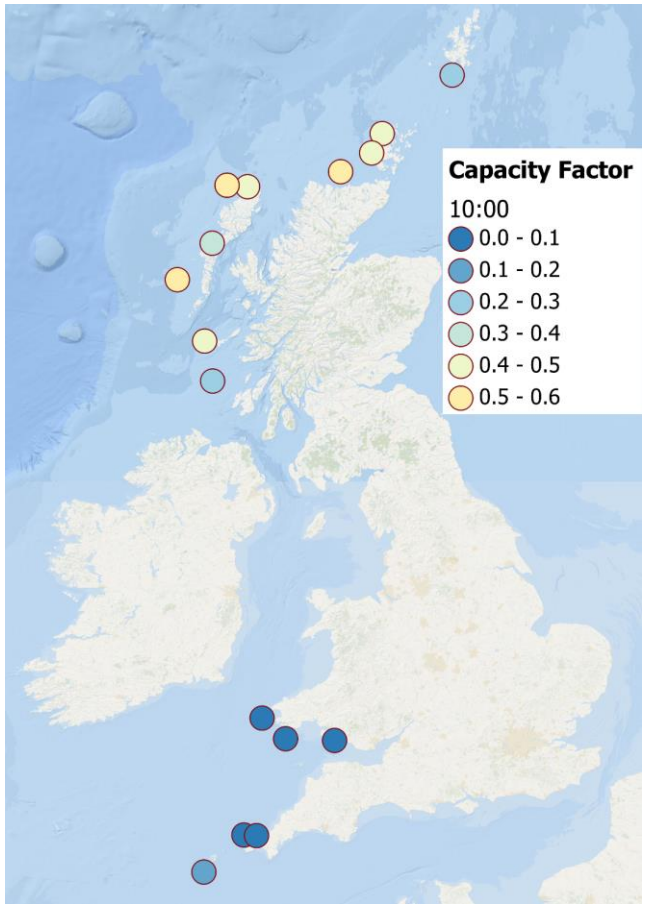

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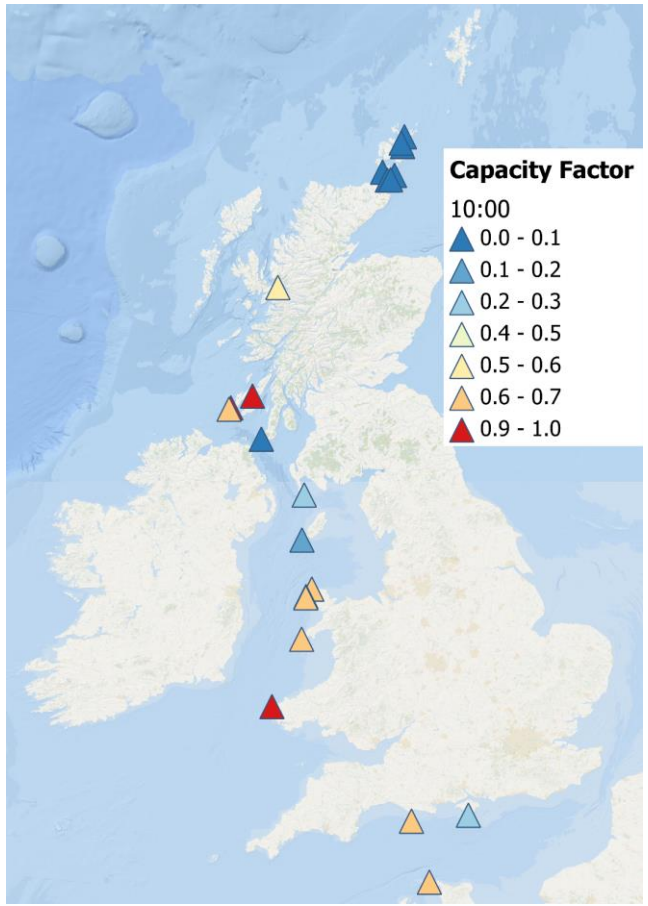

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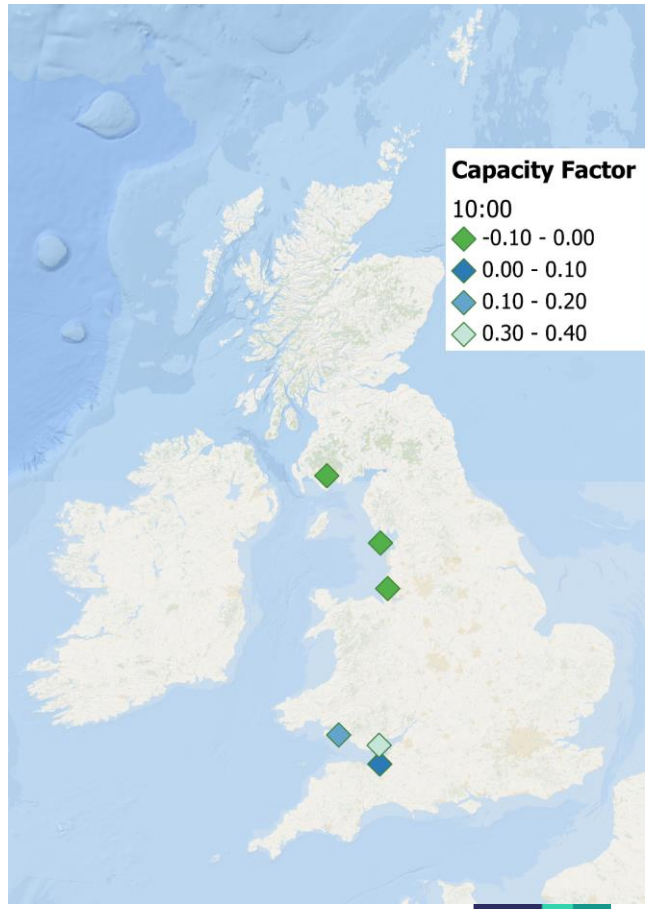

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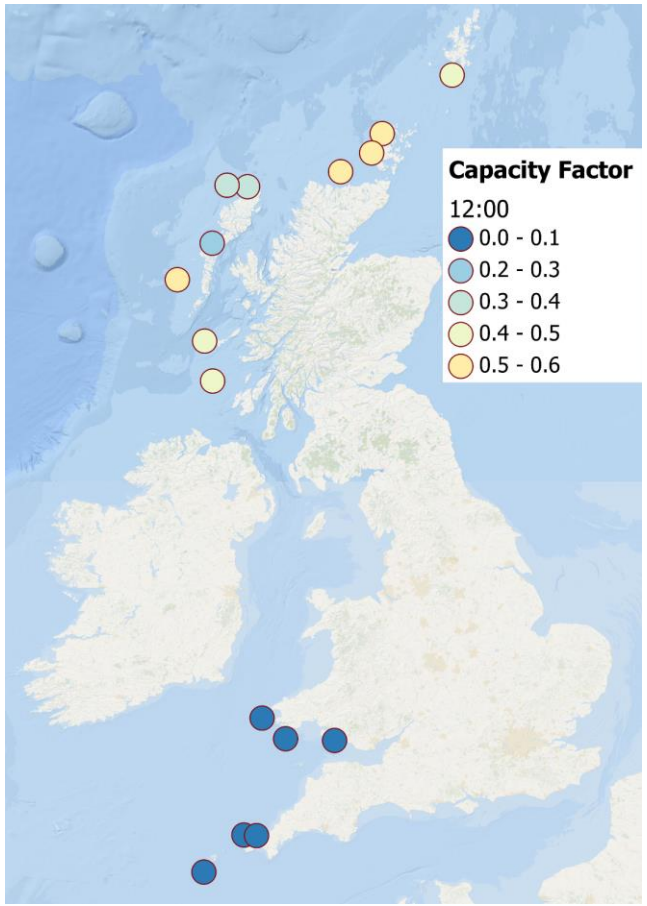

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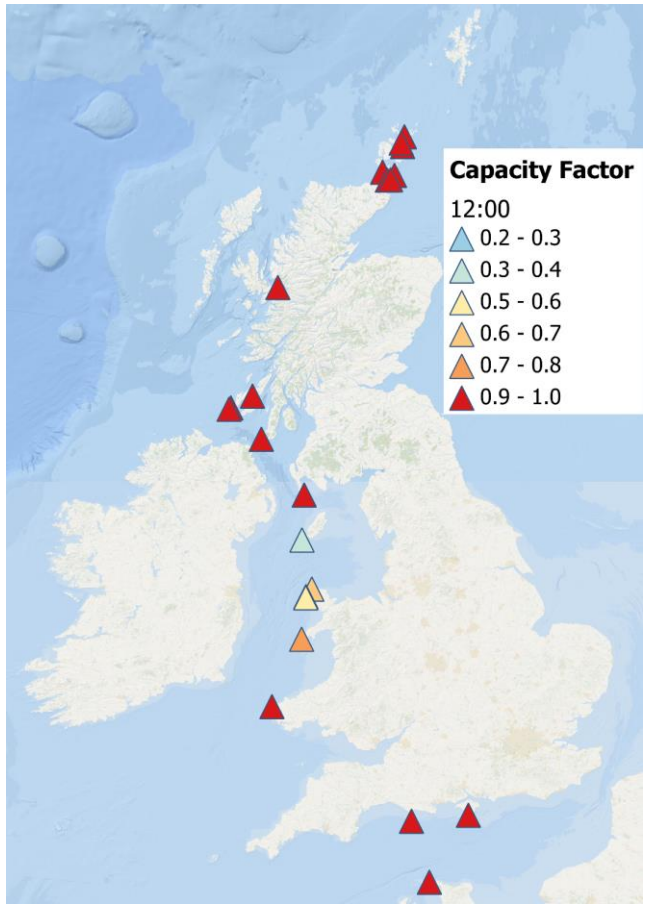

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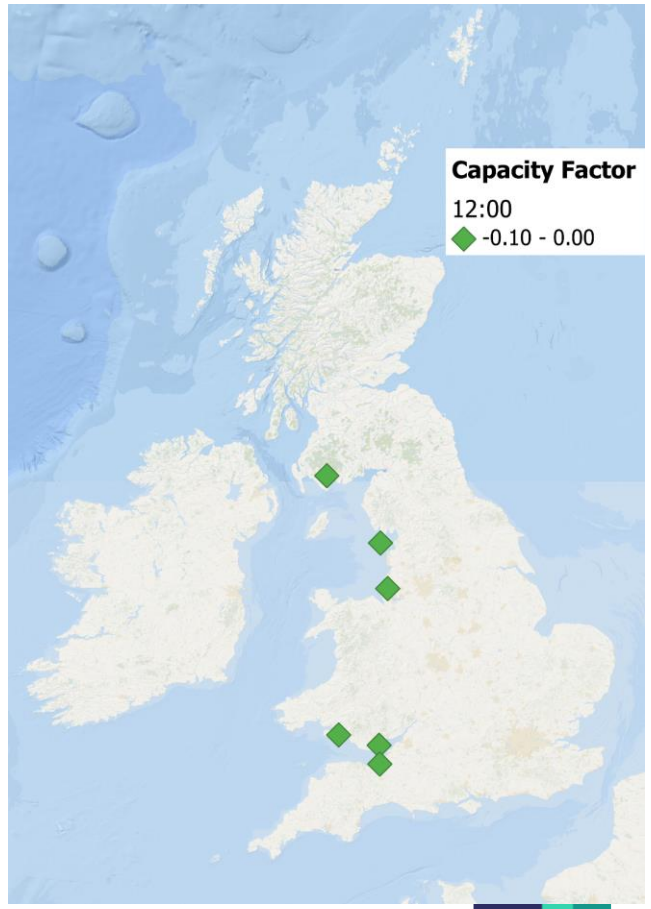

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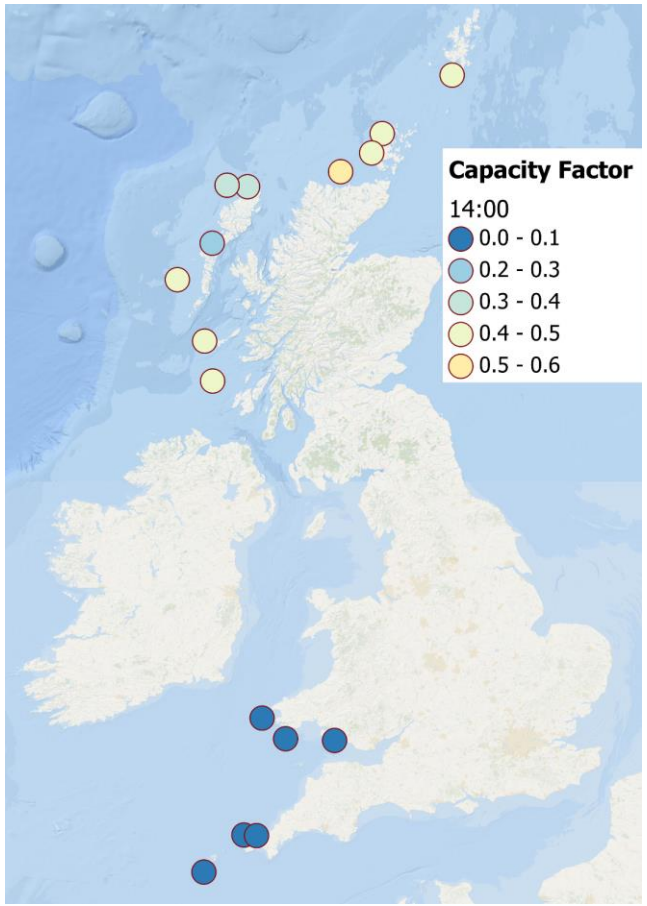

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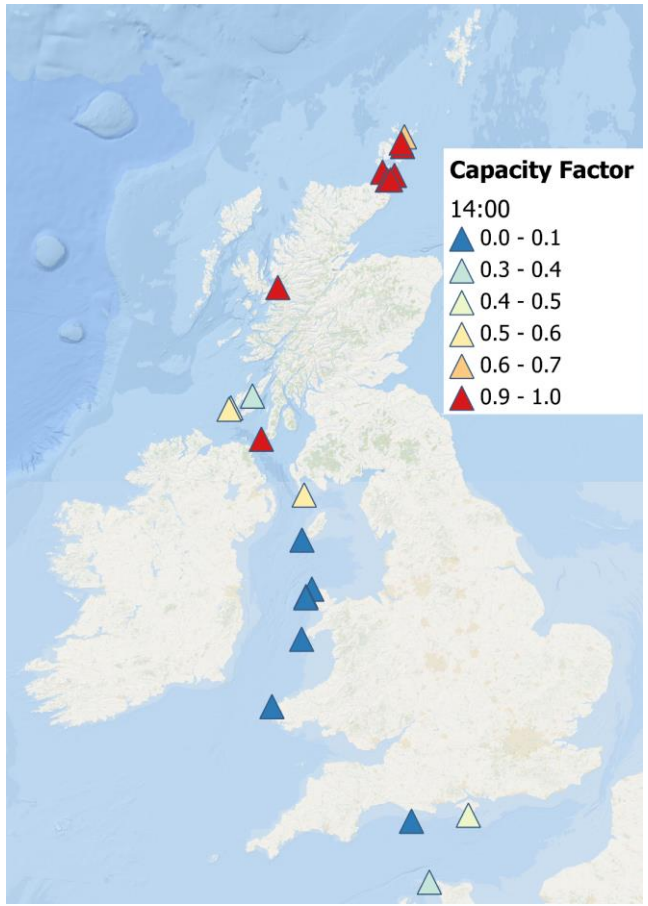

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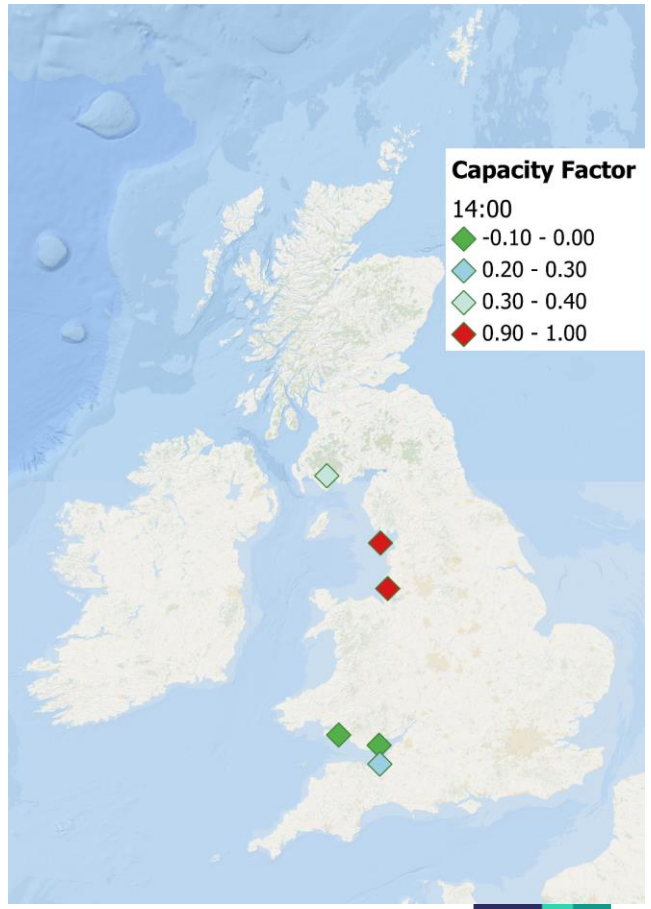

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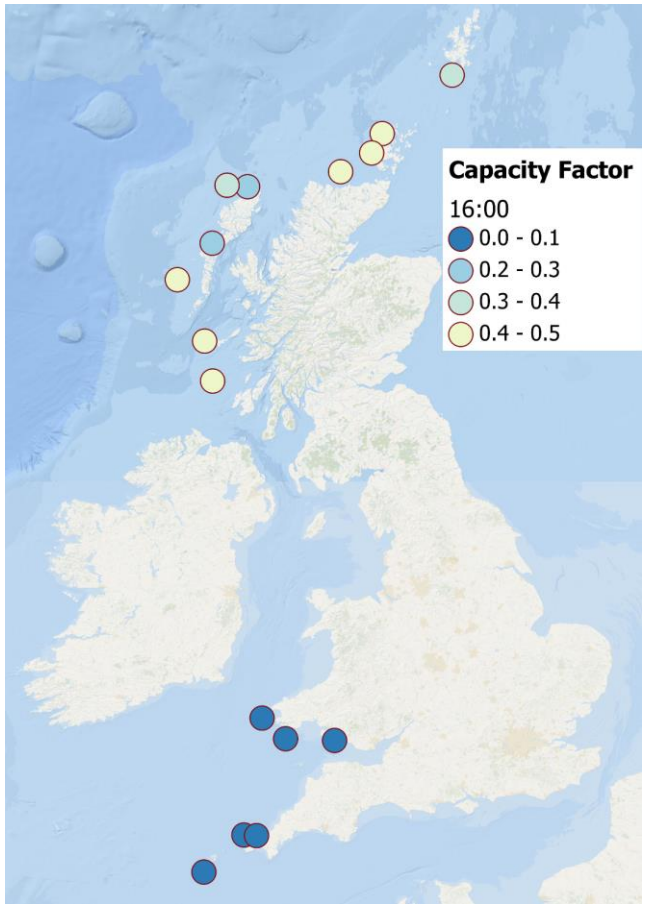

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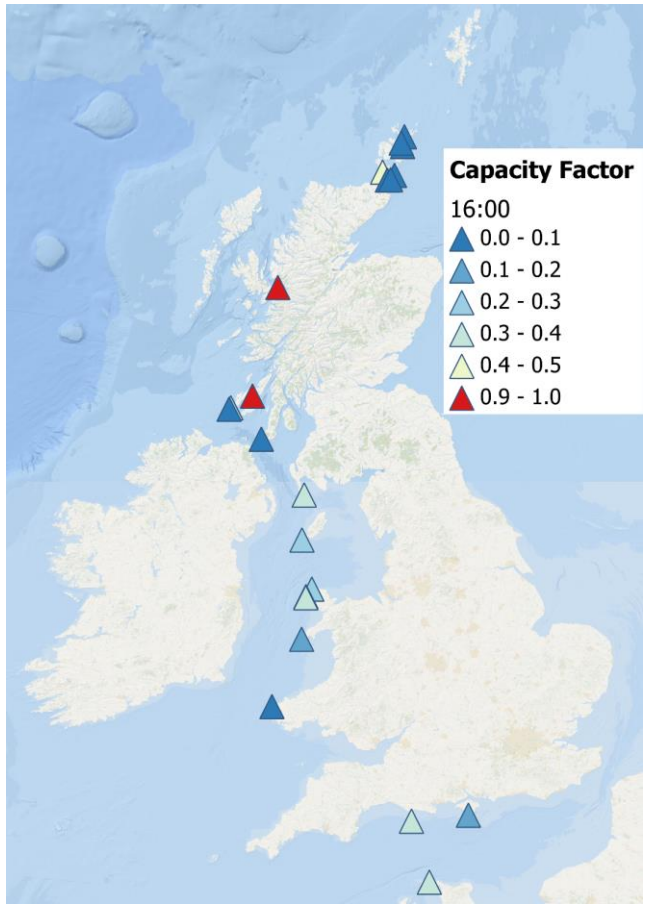

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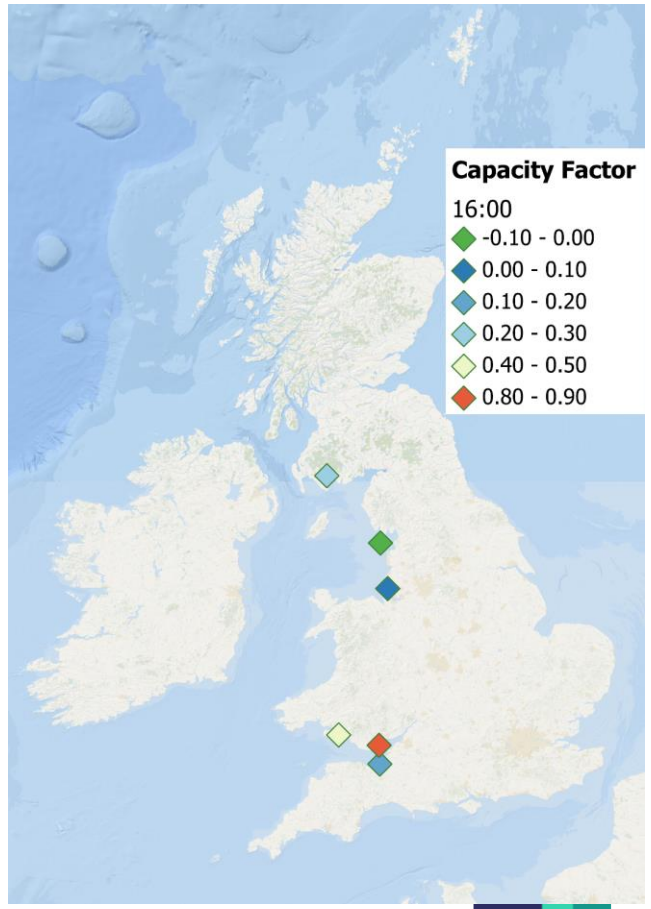

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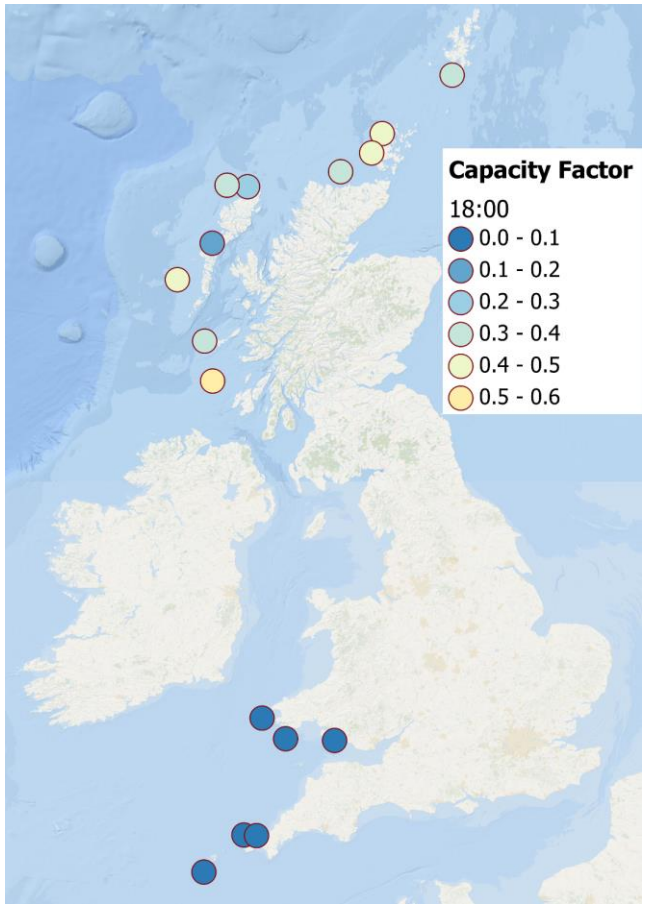

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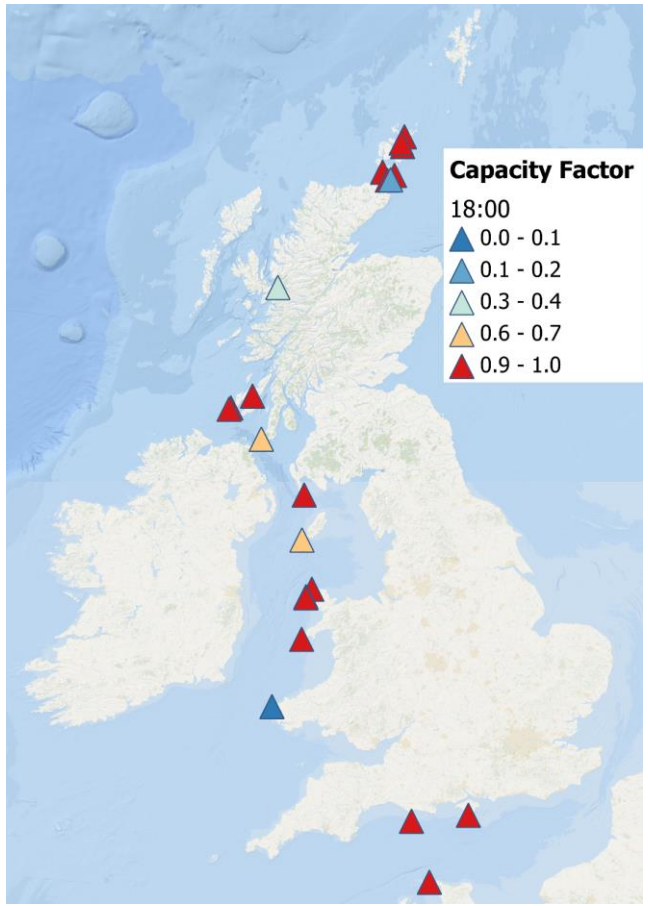

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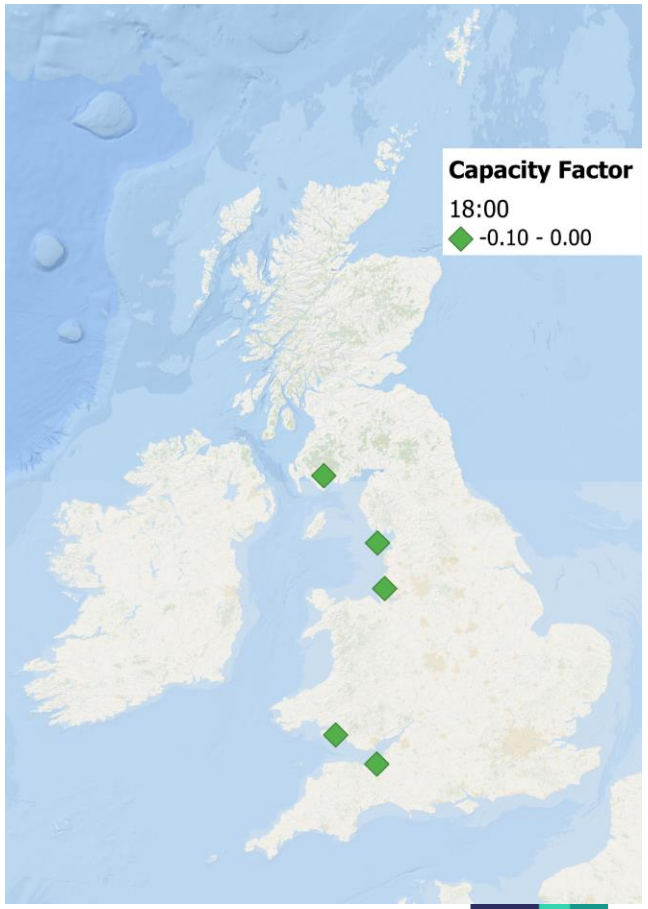

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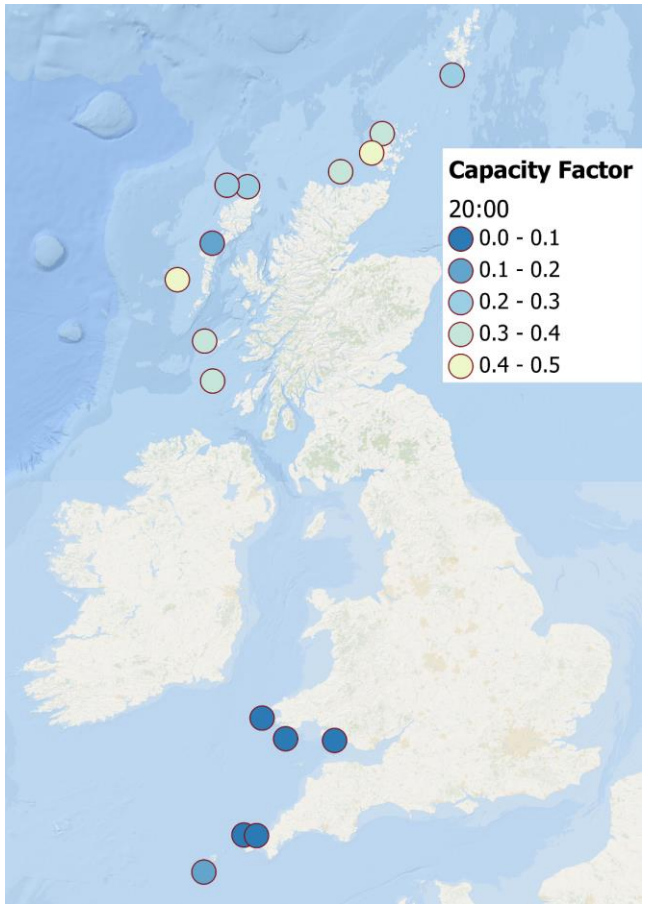

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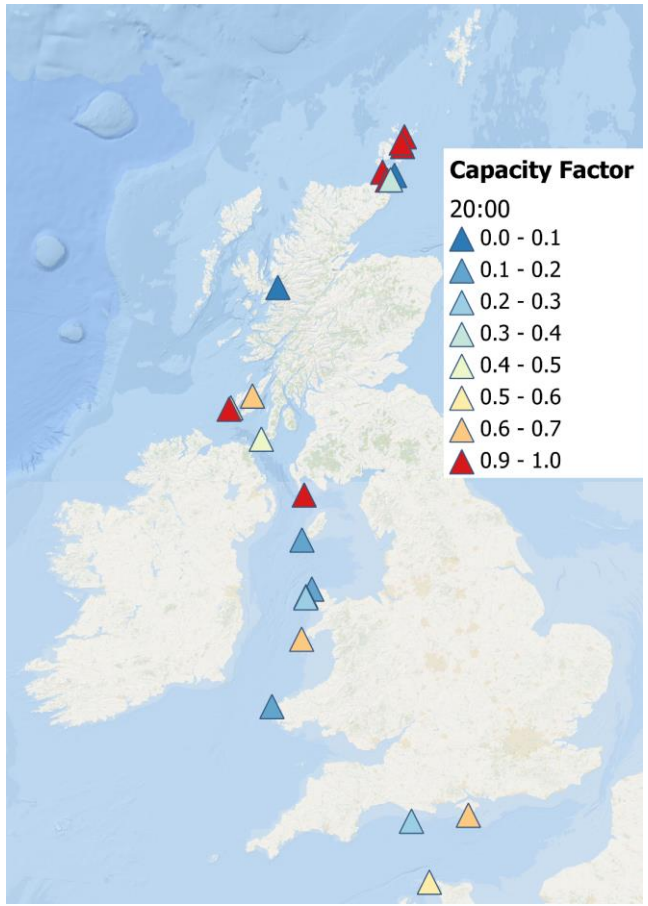

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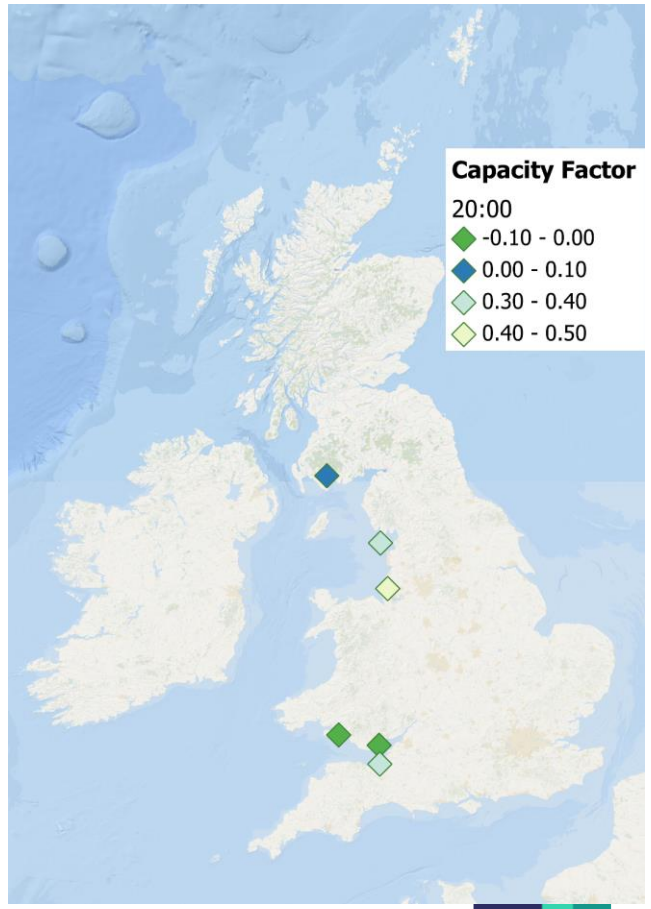

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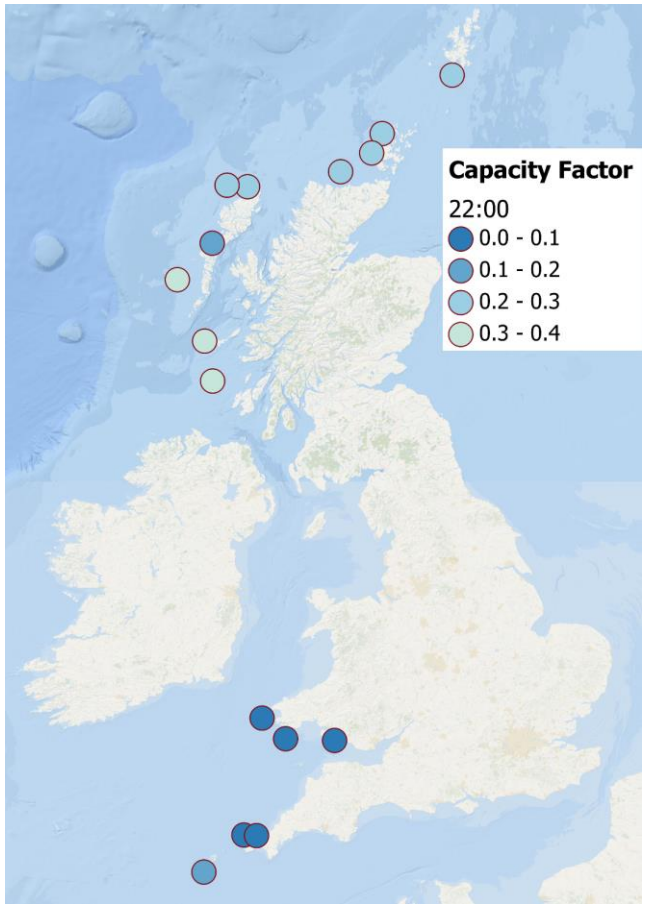

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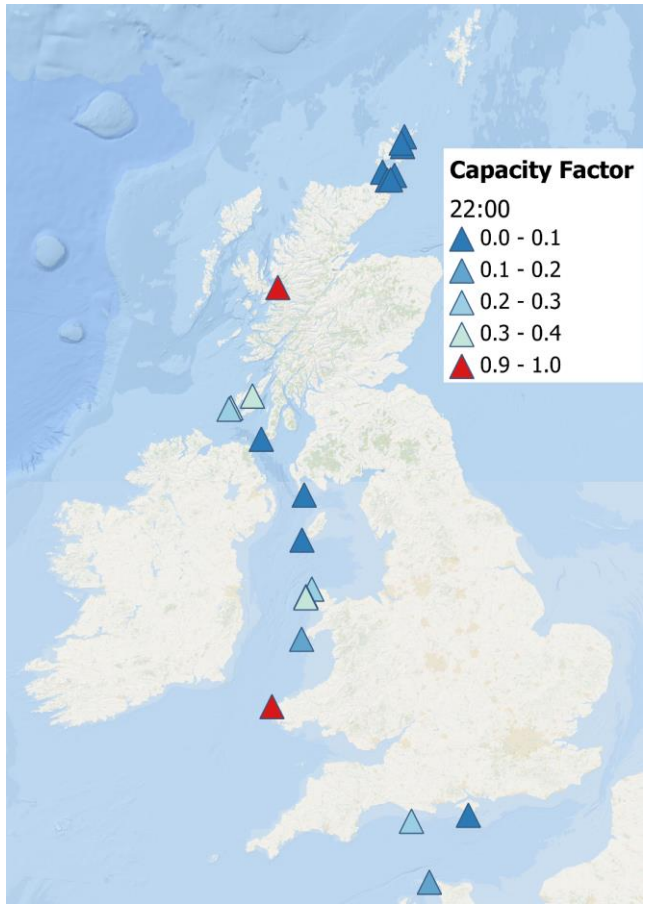

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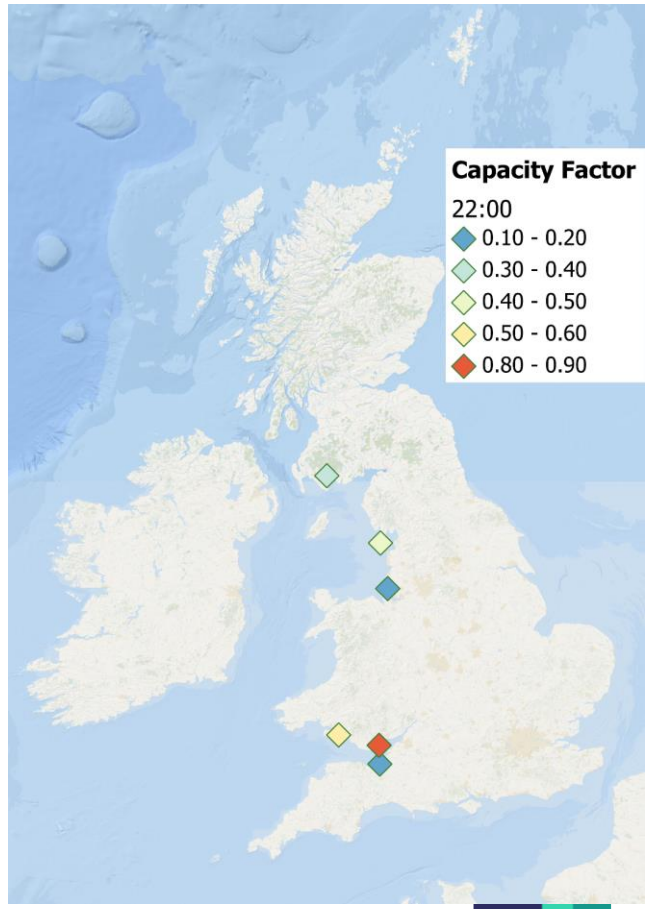


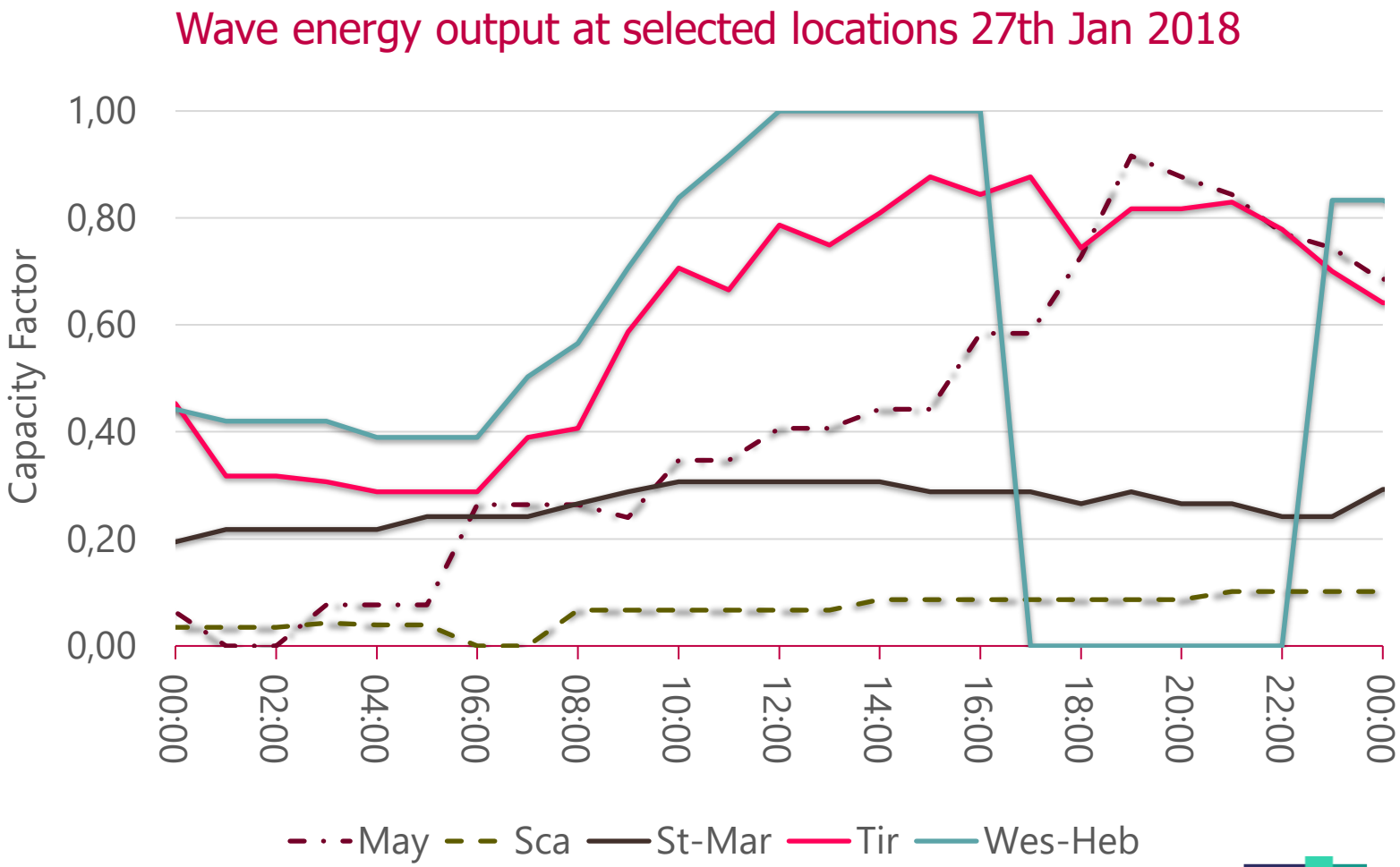
Resulting power output profiles

Power output dependent on installed capacity

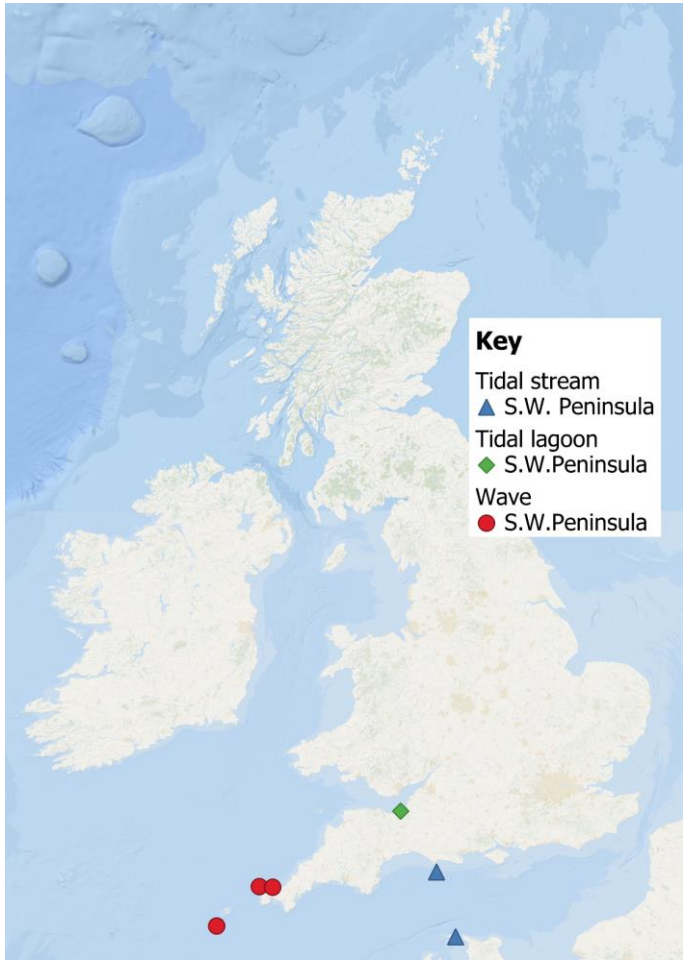
Capacity factor:

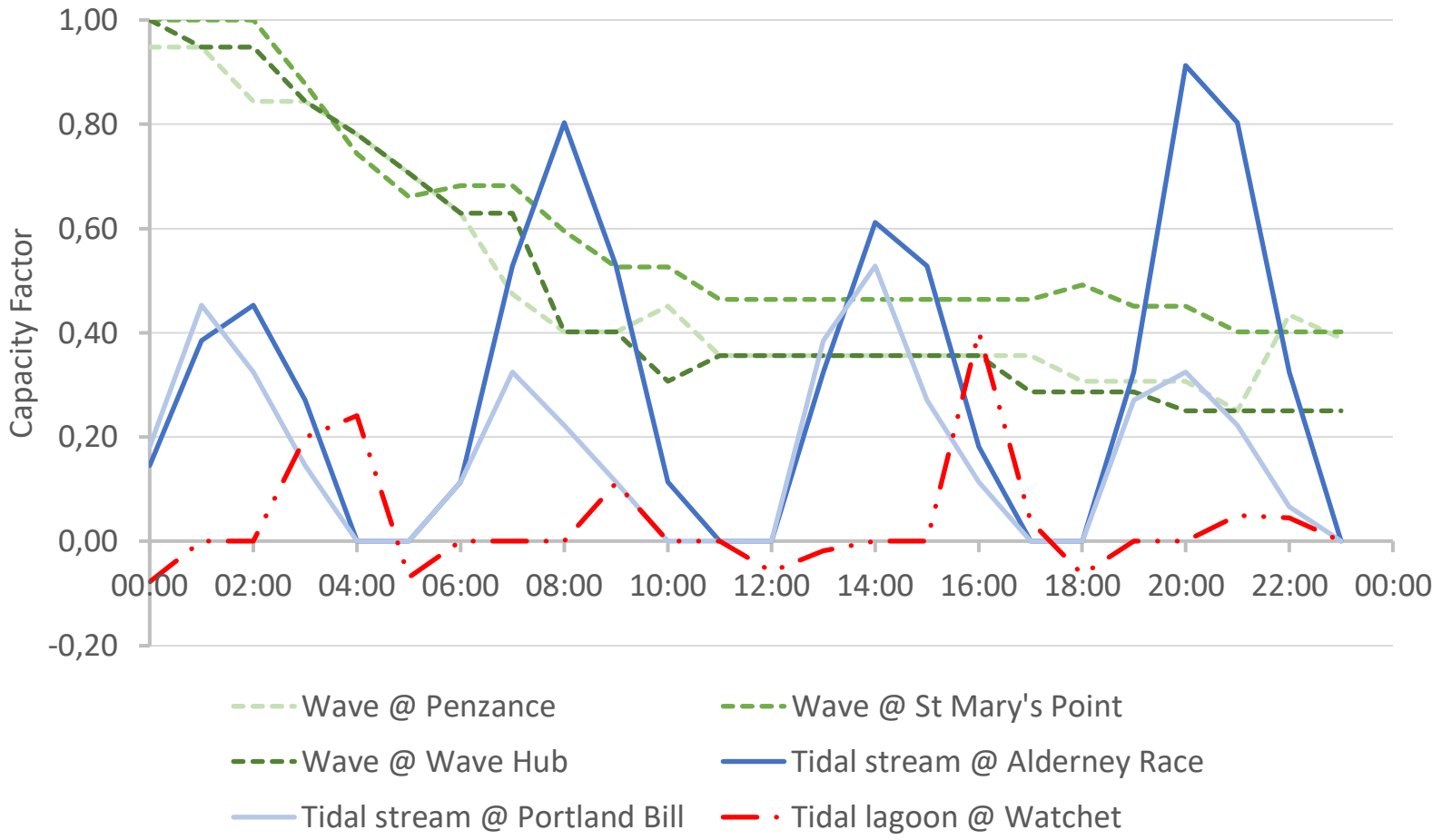
- Power output as a ratio of rated power

Tidal stream and tidal range usually complementary

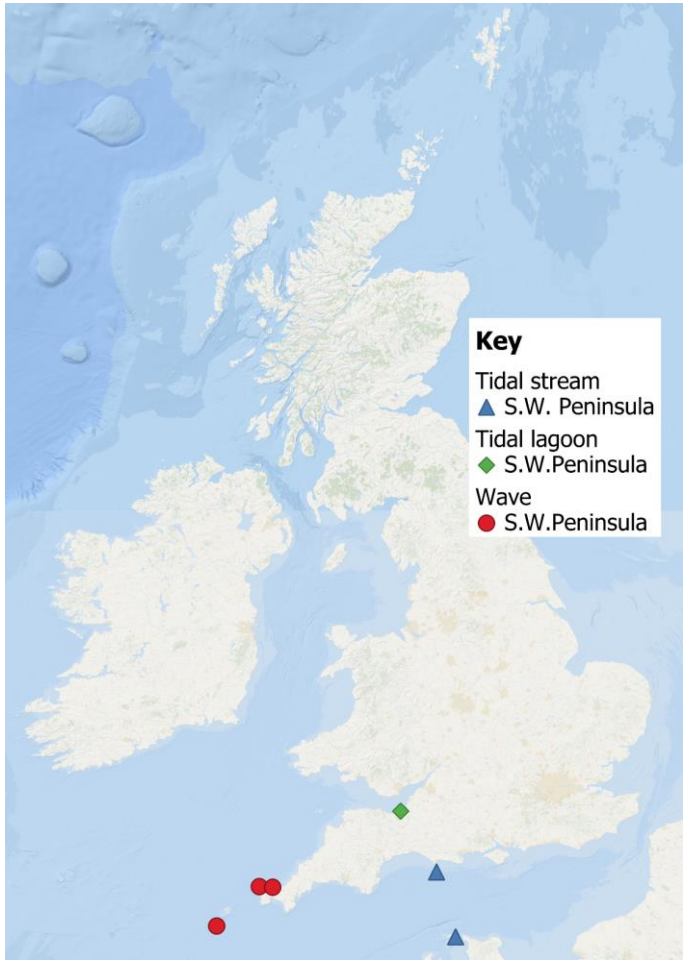


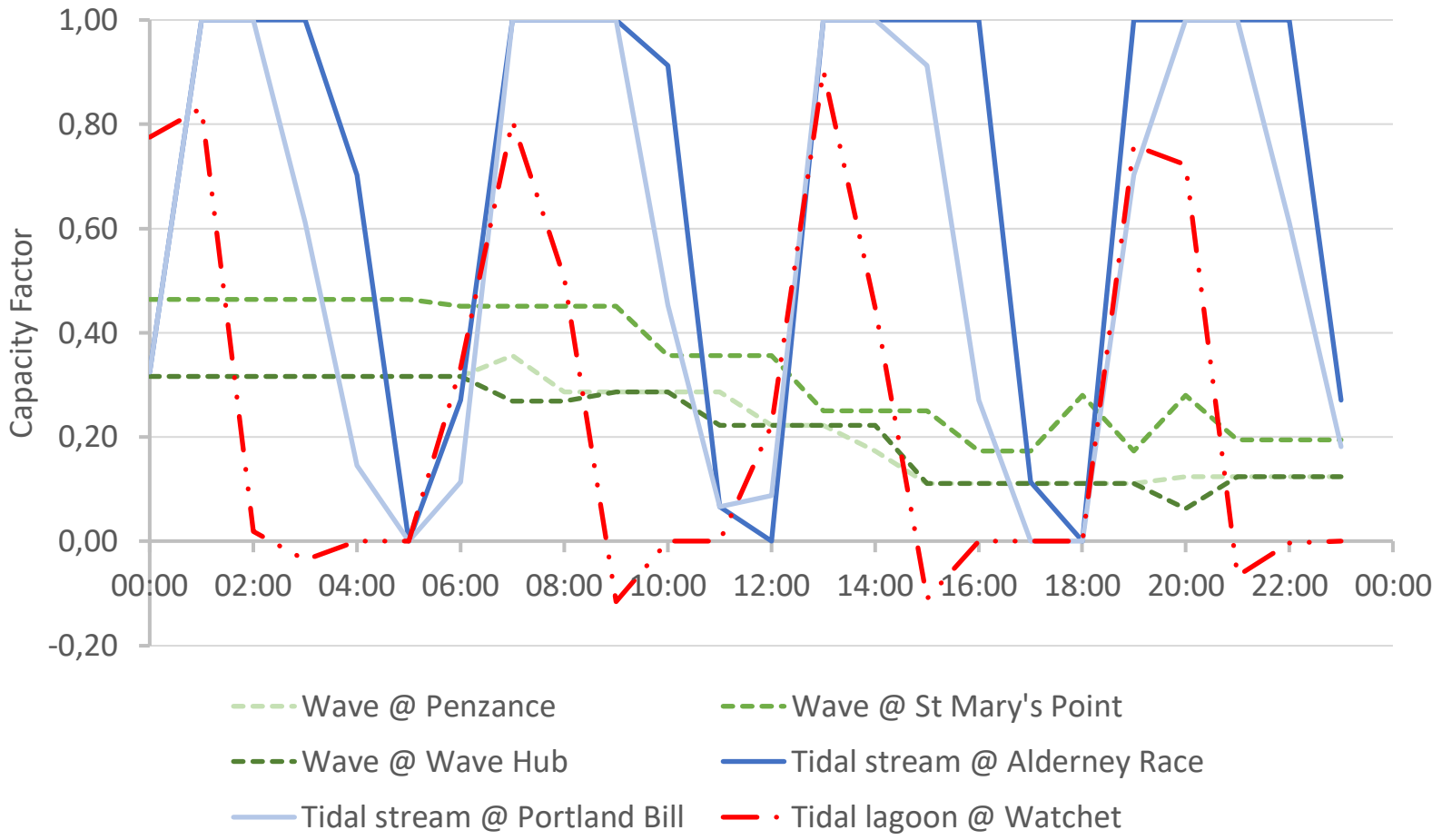
SW Peninsula – 18th Jan





SW Peninsula – 26th Jan





Example application (1)

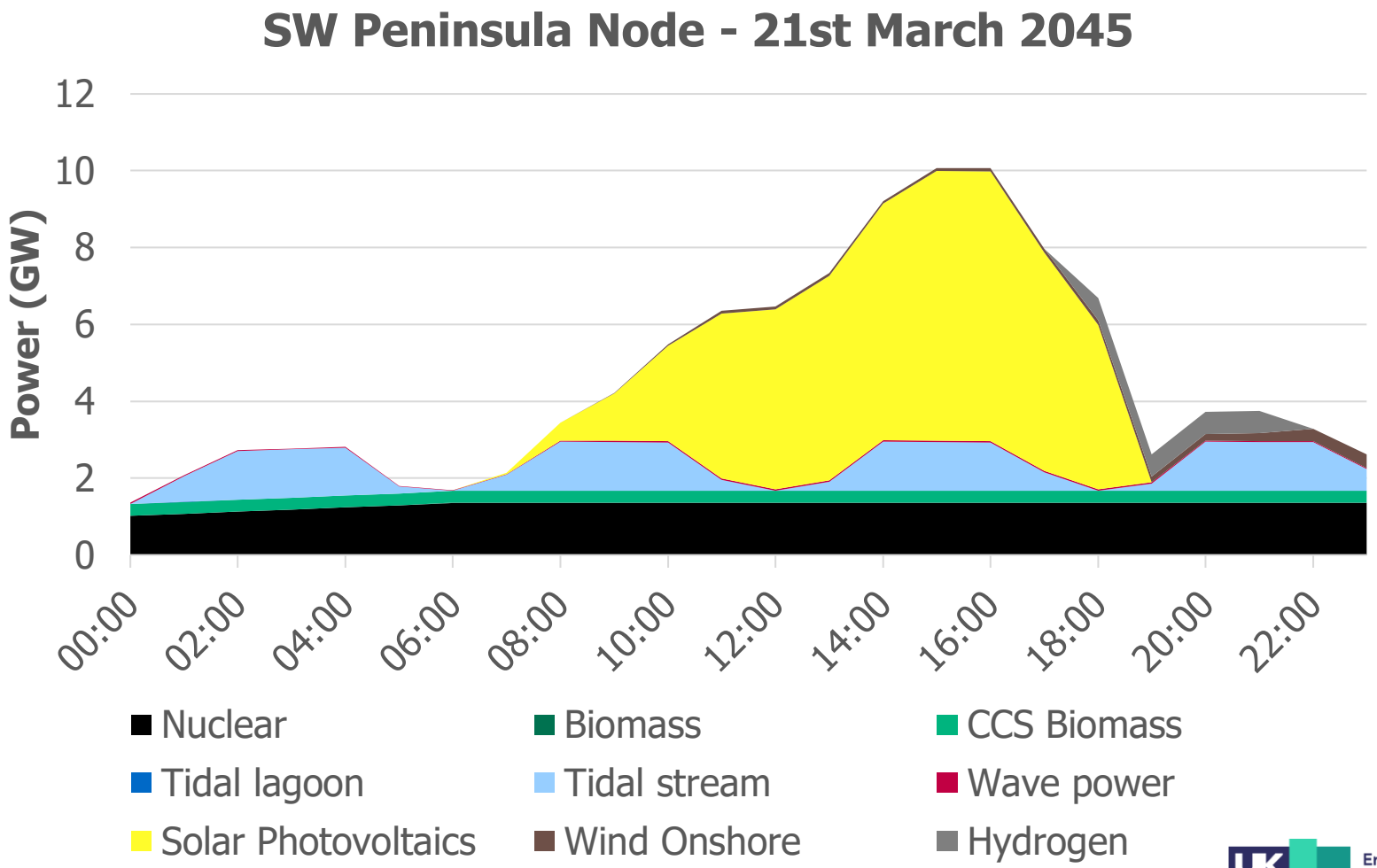
Datasets applied in PyPSA GB

Dispatch of National Grid Future Energy Scenarios 2022

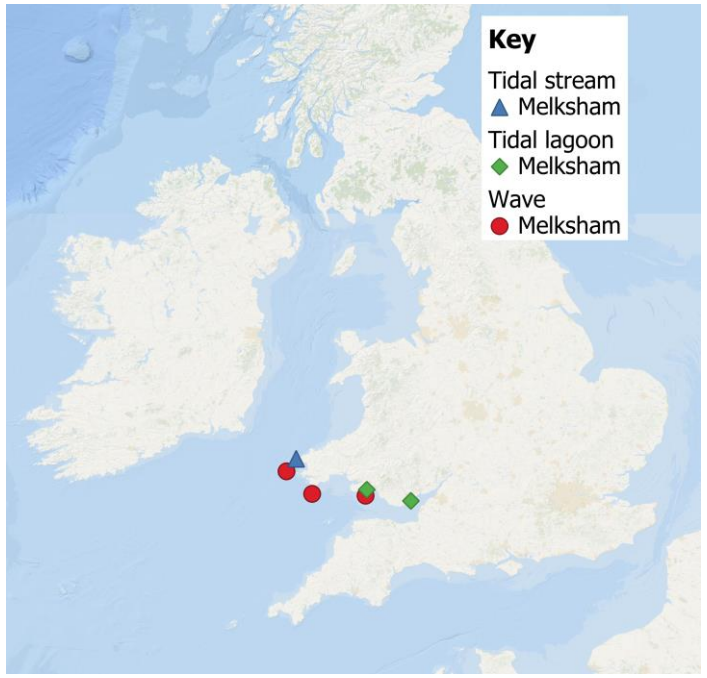
- System Transformation scenario
- Limited marine energy capacity

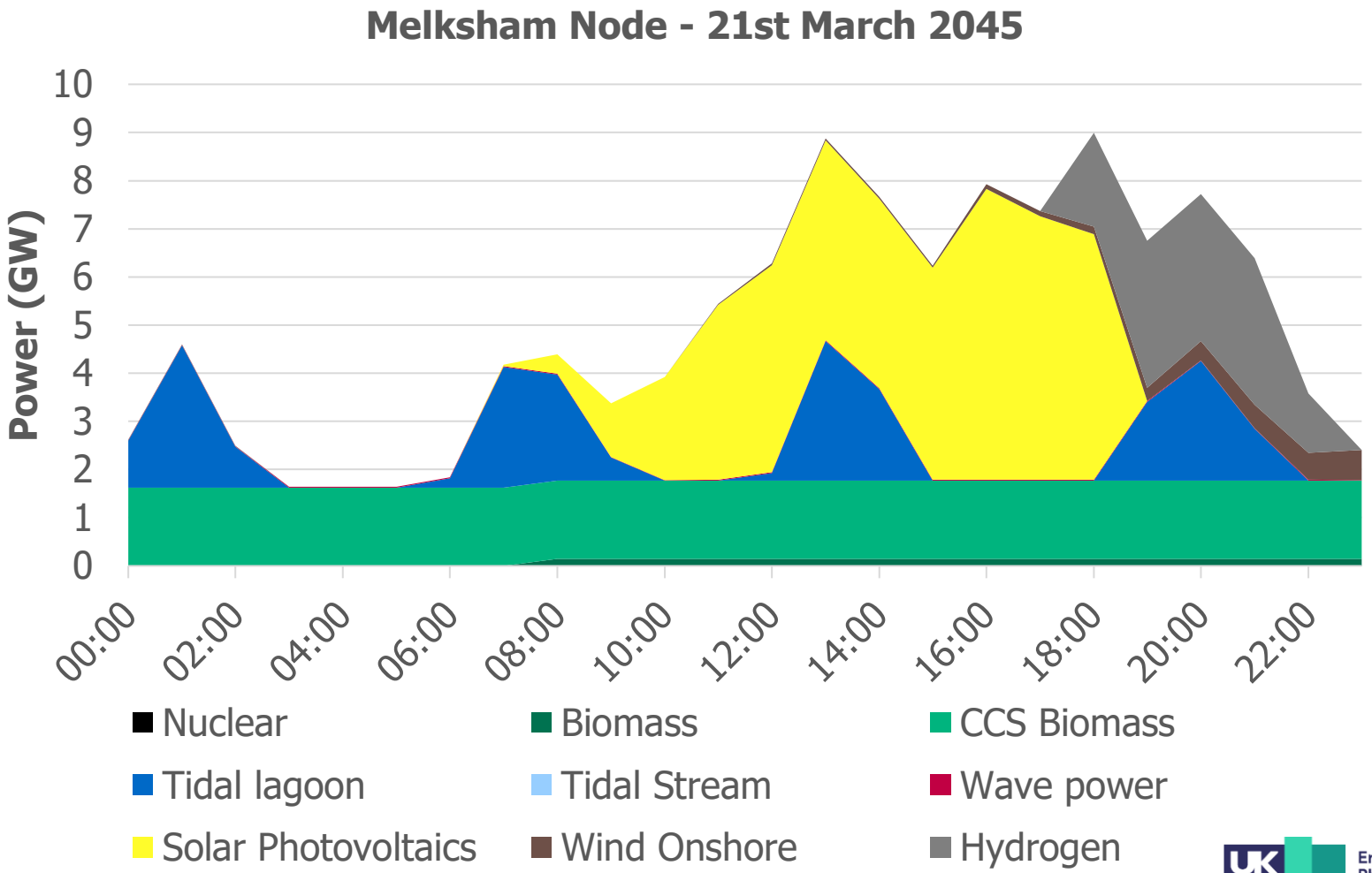
SW PENINSULA NODE:

- Measurable **tidal stream** output



Example application (2)





MELKSHAM NODE:

- Measurable **tidal lagoon** output

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

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Acknowledgements

C.Thomson@ed.ac.uk

Iain.Struthers@ed.ac.uk

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