Tidal Range Energy: Opportunities and Challenges

11 JUNE 2024

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AGENDA

- **Introduction**
  Muttucumaru Sivakumar, University of Wollongong, Australia
- **Housekeeping Rules**
  Fang Yenn Teo, University of Nottingham, Malaysia
- **Tidal Range Energy Opportunities: West Somerset Lagoon Case Study**
  Roger Falconer, Cardiff University, United Kingdom
- **Bringing forward the Tidal Range potential in the UK**
  Kate Gilmartin, British Hydropower Association, United Kingdom
- **Q&A Panel Discussion**
  Speakers & Moderators
- **Close**
  Fang Yenn Teo, University of Nottingham, Malaysia

SUSTAINABLE COASTAL AND ESTUARINE DEVELOPMENT SPECIALIST GROUP

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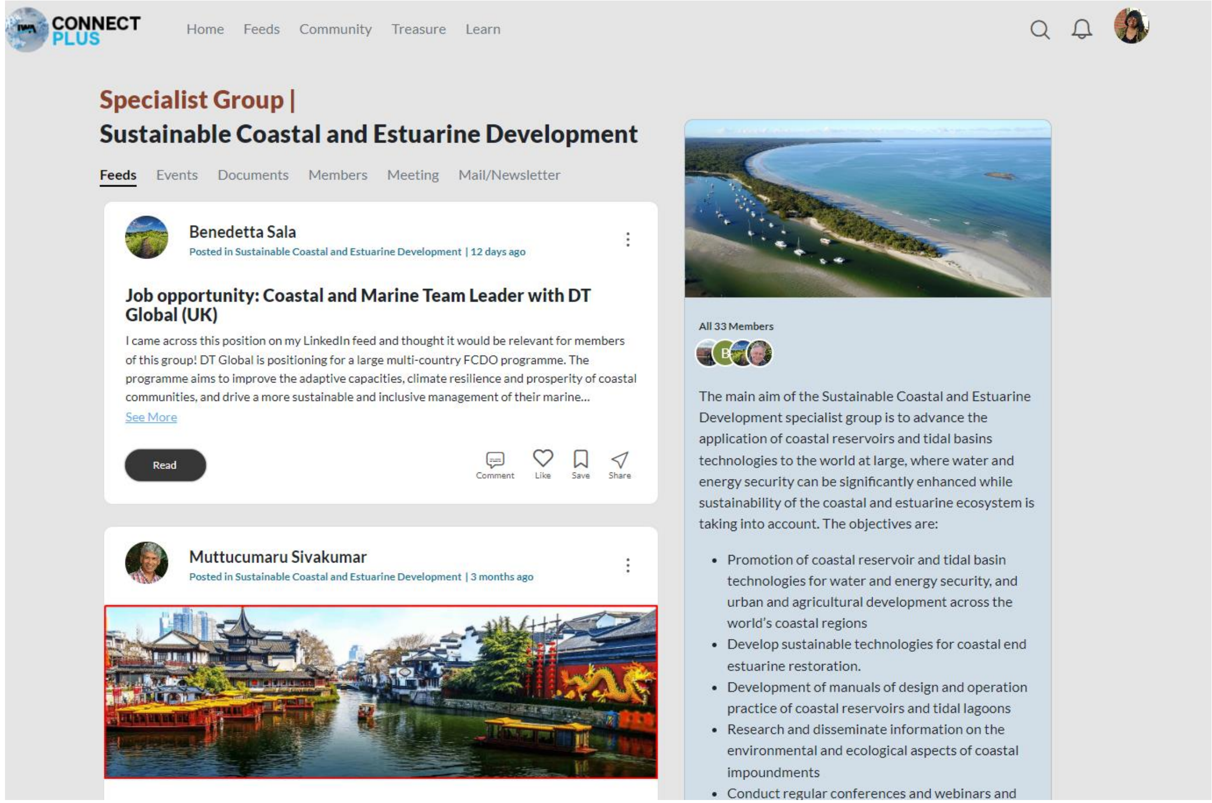
The main aim of the Sustainable Coastal and Estuarine Development specialist group is to advance the application of coastal reservoirs and tidal basins technologies to the world at large, where water and energy security can be significantly enhanced while sustainability of the coastal and estuarine ecosystem is taking into account.



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- **‘Chat’ box**: please use this for general requests and for interactive activities.
- **‘Q&A’ box**: please use this to send questions to the panelists.
  (We will answer these during the discussions)

Please Note: *Attendees’ microphones are muted. We cannot respond to ‘Raise Hand’.*

SPEAKERS & MODERATORS

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United Kingdom

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Australia

Fang Yenn Teo
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Tidal Range Energy Opportunities: West Somerset Lagoon Case Study

EMERITUS PROF. OF WATER ENGINEERING,CARDIFF UNIVERSITY (CU), UK

DIRECTOR, TIDAL ENGINEERING AND ENVIRONMENTAL SERVICES LTD, UK

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NEED FOR TIDAL ENERGY ➪ KEY ISSUES

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- Climate change and population growth ➪ increasing energy demand ➪ UK planning for net-zero emissions by 2050
- Tidal energy is predictable ➪ advantage over wind and solar energy
- Severn Estuary has 2nd highest tidal range world-wide (peak > 14 m) ➪ 4h out of phase with tides along northwest coast of UK
- Two key types of tidal energy generation:
  - **Tidal stream turbines** ➪ Kinetic Energy: $\boldsymbol{Power} \propto \boldsymbol{V^3}$

    where $\boldsymbol{V}$ = mean free-stream tidal current at turbine site
  - **Tidal range schemes** ➪ Potential Energy: $\boldsymbol{Power} \propto \boldsymbol{A\ H^2}$

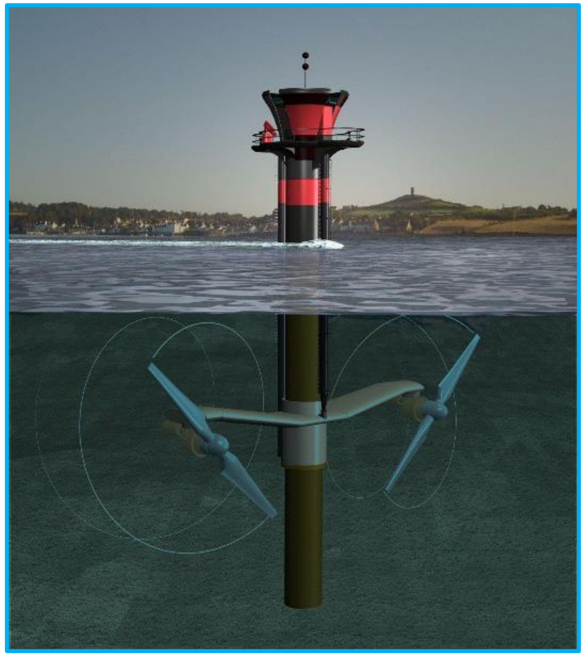
    where $\boldsymbol{H}$ = water level difference across barrage/lagoon wall

    $\boldsymbol{A}$ = plan surface area impounded by barrage/lagoon

TIDAL STREAM V. TIDAL RANGE

- Tidal Range
  - An embankment impounds tides ➪ potential energy drives turbines to generate energy ➪ need large tidal range and minimum depth
  - Barrage - an embankment across an estuary including a major river
  - Lagoon - an embankment not enclosing a major river ➪ either attached to coast or offshore

- Tidal Stream
  - Devices similar to wind turbine in water column
  - Need large tidal currents and deeper water ➪ drives turbines to generate energy
  - Generally complementary to tidal range schemes
  - Image shows installation in Northern Ireland

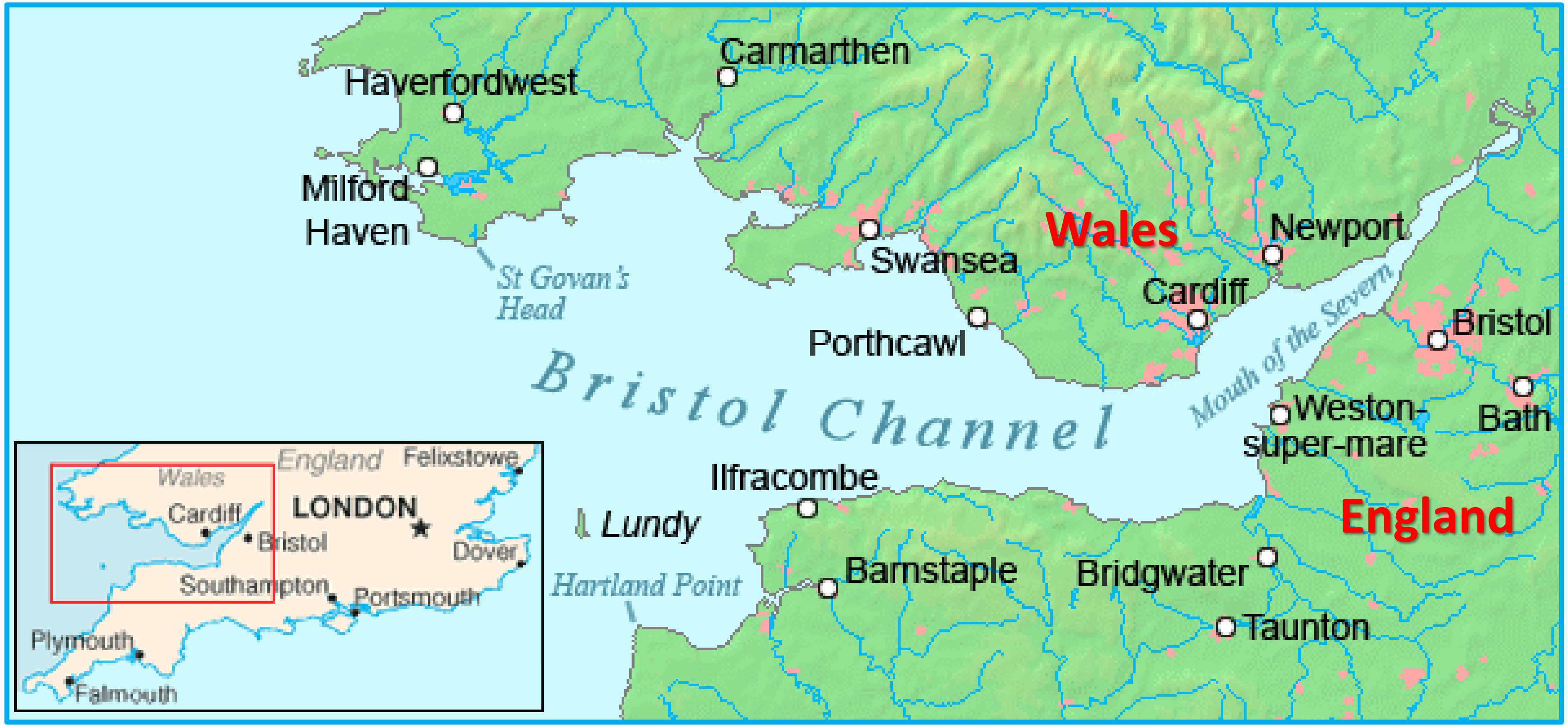


LA RANCE BARRAGE ⇨ PROVEN TECHNOLOGY

Key Details:

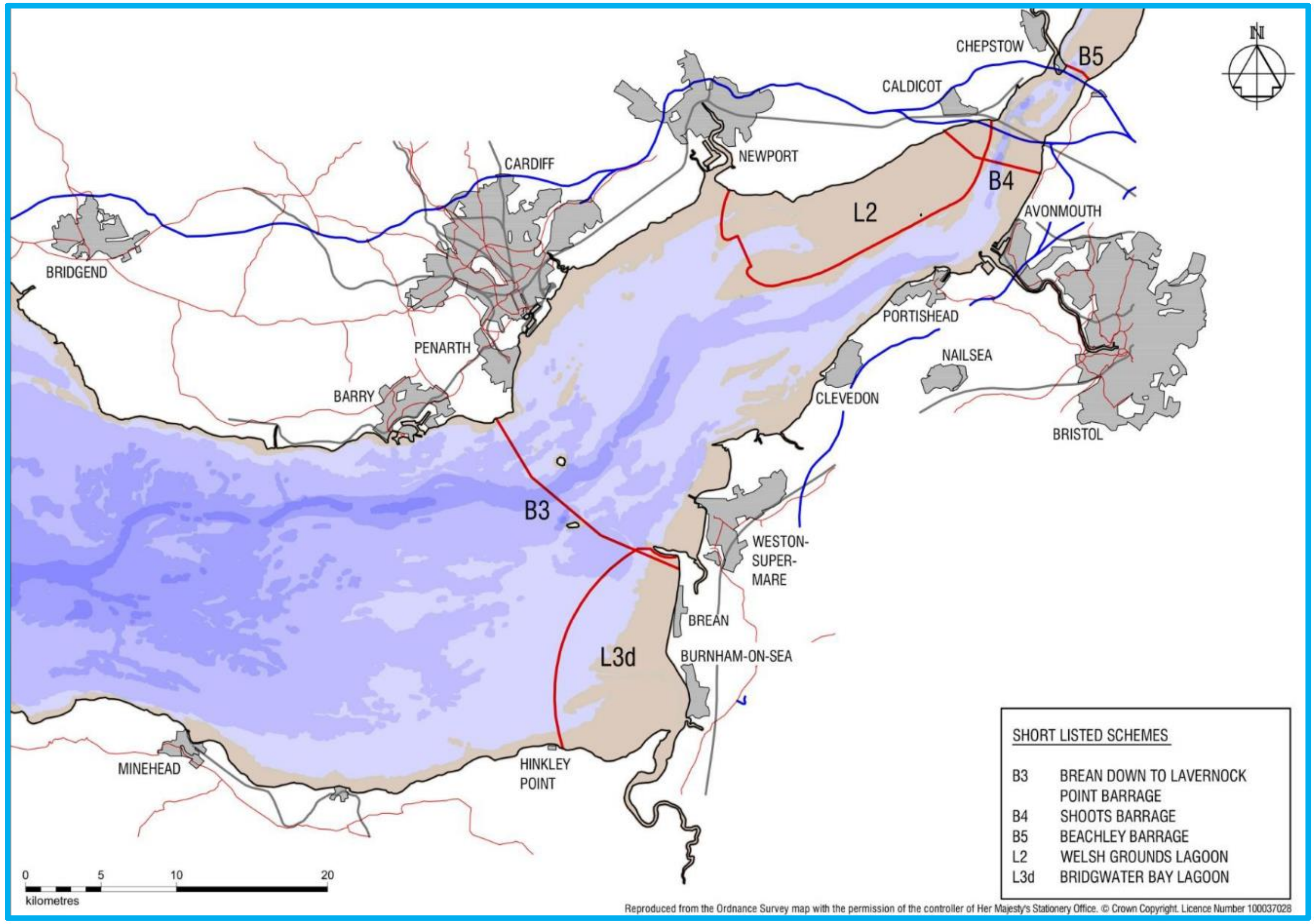
- Completed in 1966
- 24 turbines & 6 sluices
- 240 MW total capacity ⇨ 0.54 TWh/yr
- Turbine operation ⇨ ebb-only (+ pumping)
- *‘Passage of fish---- without major problems’*
- Operational for over 50 years with minimal turbine maintenance

FOCUS ⇨ SEVERN ESTUARY - BRISTOL CHANNEL



- Tides generated at Continental Shelf ⇨ amplified through funnel shaped basin from Bristol Channel boundary to tidal limit at Gloucester
- Strong spring tidal currents ⇨ high SPM and turbidity levels + Severn Bore

DECC[1] ➪ SEVERN ESTUARY STUDIES 2008-10

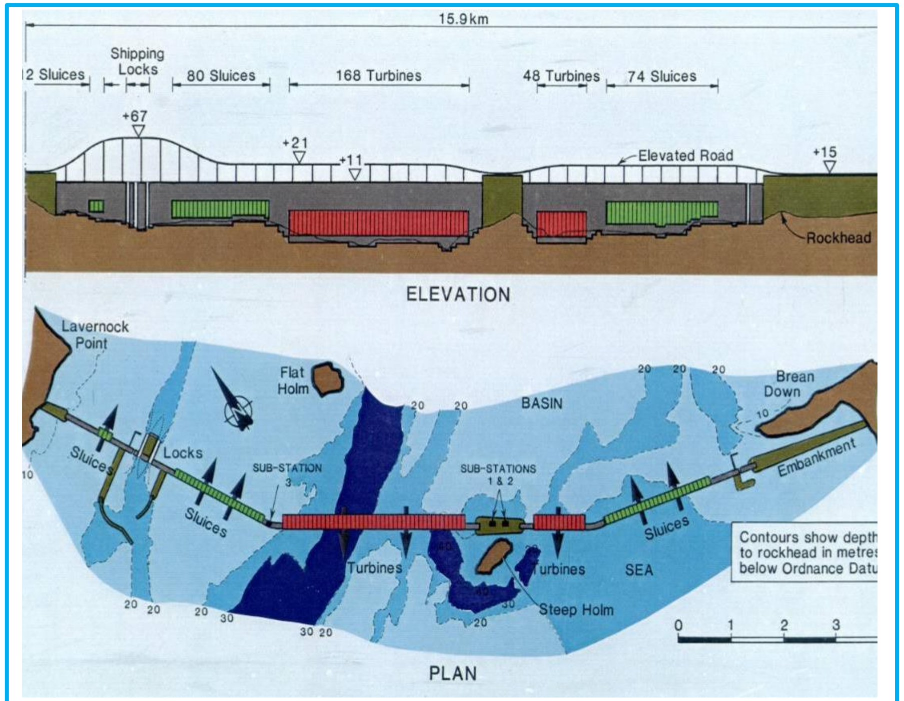


[1] DECC: UK Government Department of Energy and Climate Change (2008-16)

General Issues:

- Cost ➪ barrages impound larger plan surface area for a shorter embankment
- Flooding ➪ barrages reduce risk and SLR impacts upstream
- Fish ➪ barrages provide an obstruction to migration upstream
- Navigation ➪ need large locks to access ports with barrages

TIDAL BARRAGE ➩ SEVERN BARRAGE (1989)



Severn Tidal Power Group Barrage Layout

Barrage Location
Cardiff - Weston

Key facts STPG layout:

- 216 bulb turbines ➩ 40 MW ≈ 16.4 TWh/yr
- 166 sluice gates
- Length ≈ 16 km
- Cost ≈ $32 Billion
- Ship locks
- Generate 5% of UK electricity
- Save 7 M tonnes of Carbon
- Designed to operate ebb-only generation with bulb turbines

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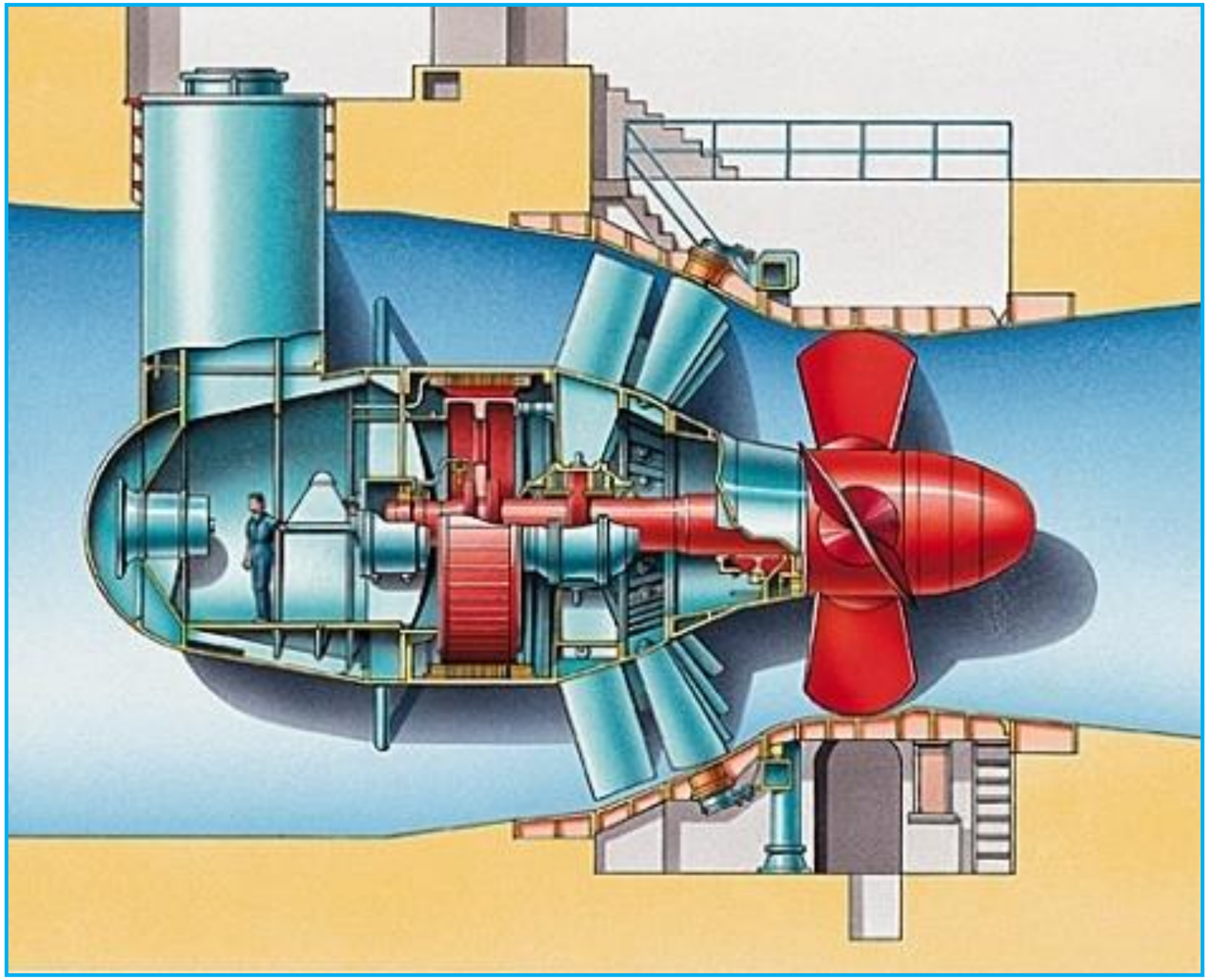
BULB TURBINES ➪ DOUBLE / TRIPLE REGULATED

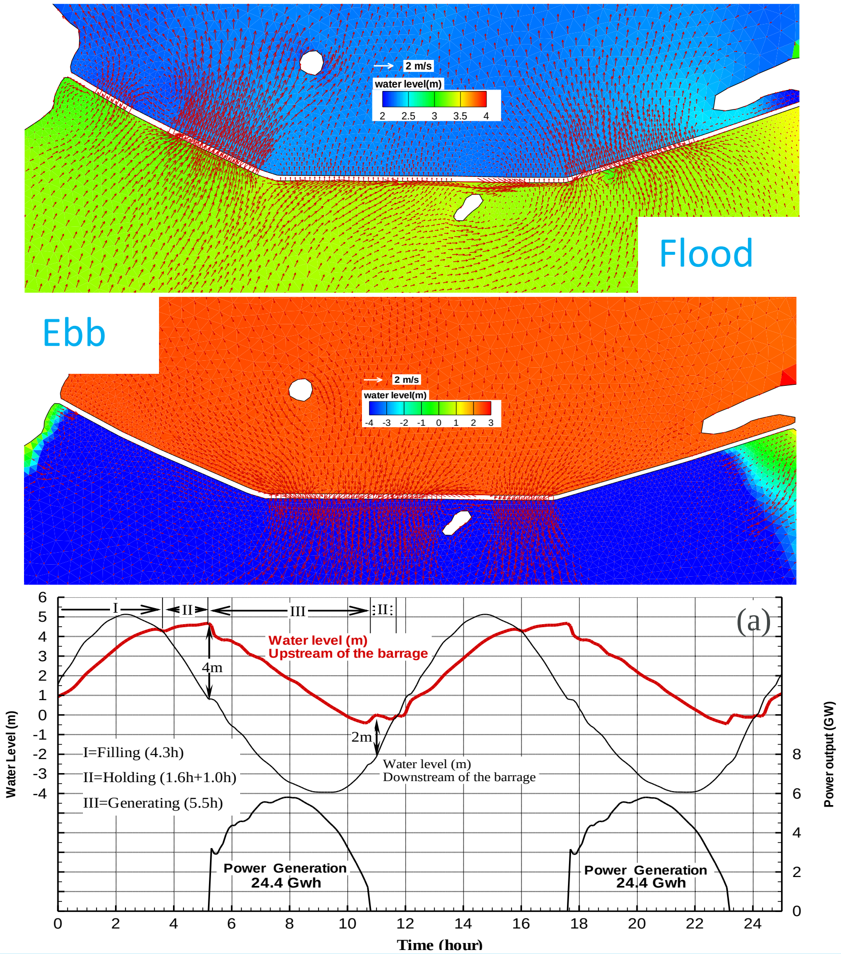


Key turbine facts:

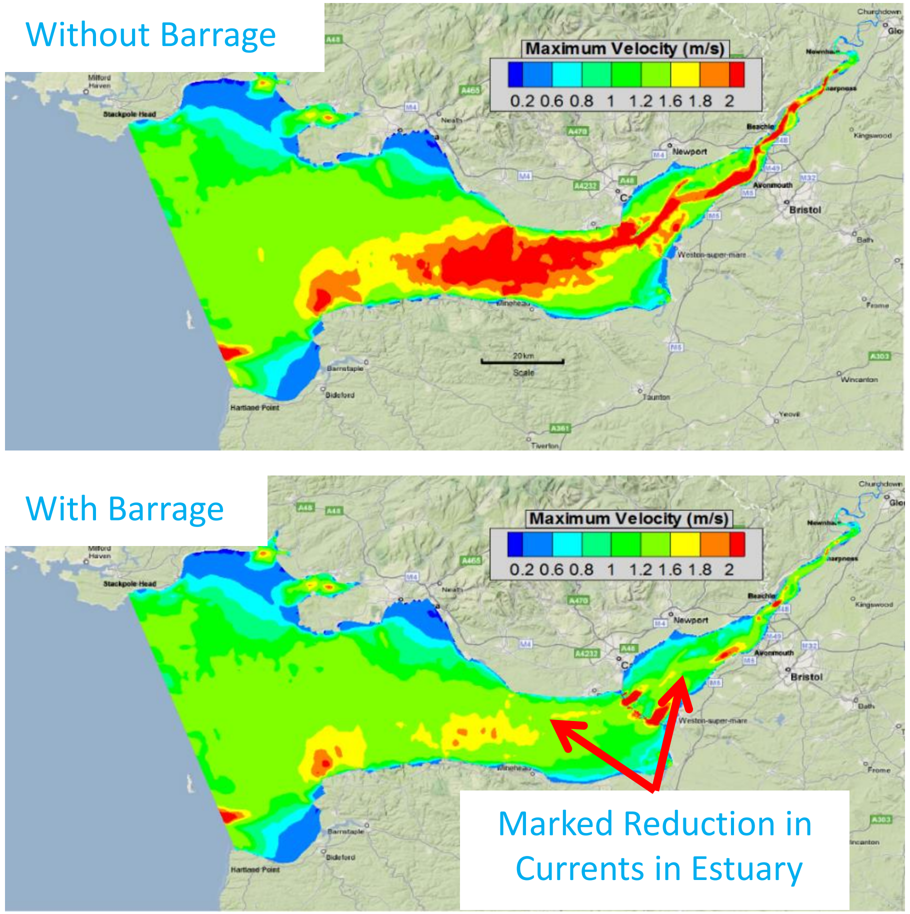
- Turbines allow bi-directional flow ➪ but not symmetric
- Turbines operated as pumps ➪ can reduce inter-tidal habitat losses upstream
- Turbines with 3 blades and non-synchronous operation lead to reduced fish mortality
- Typical Installed capacity of 9 m diam. turbine ➪ 30 MW

STPG BARRAGE ⇨ EBB-ONLY GENERATION

Water levels upstream/downstream



Velocity magnitude without/with barrage



- Marked reduction in currents ⇨ significant reduction in turbidity

STPG BARRAGE ➩ ENVIRONMENTAL IMPACT

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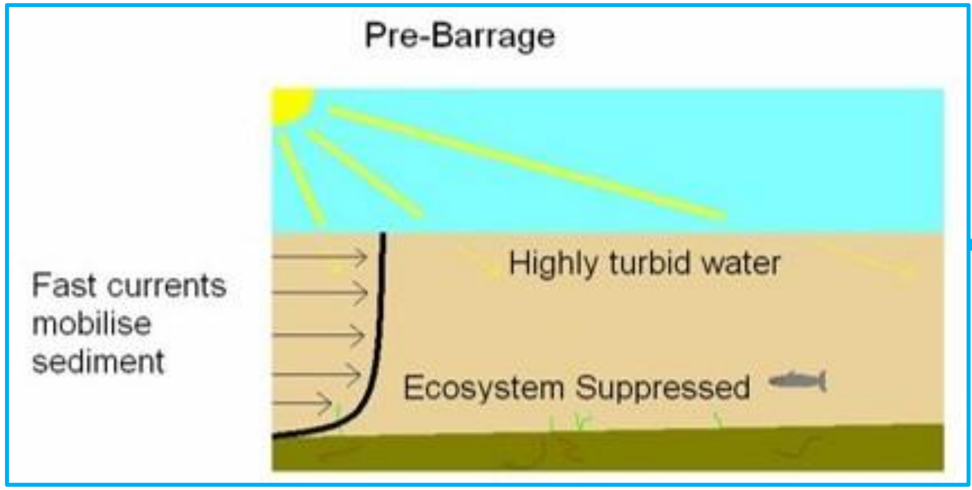
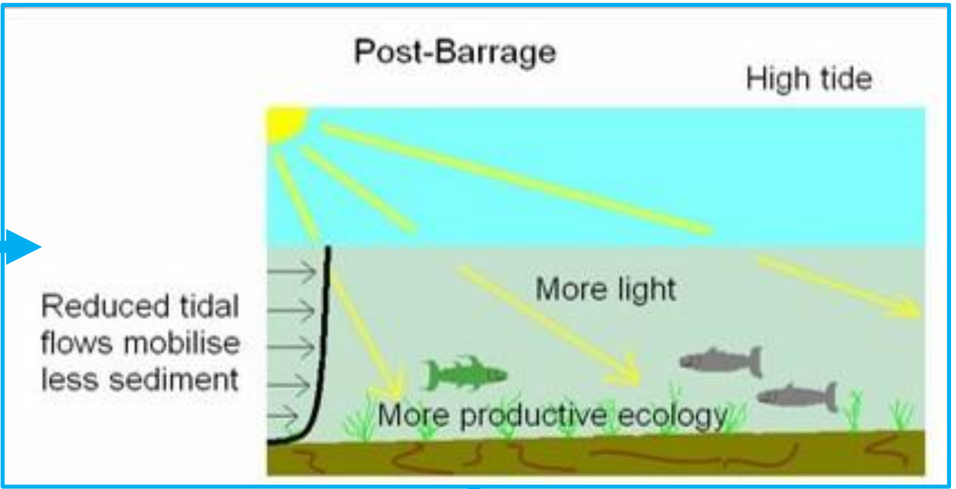
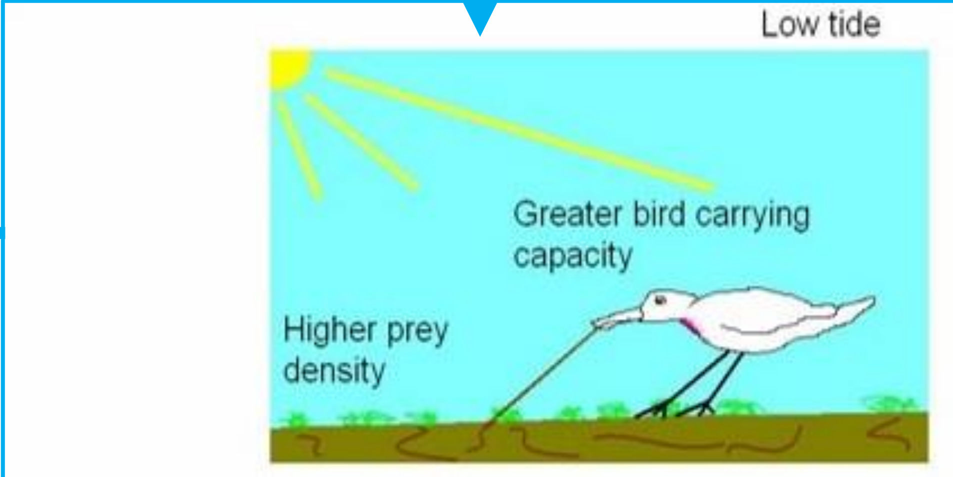
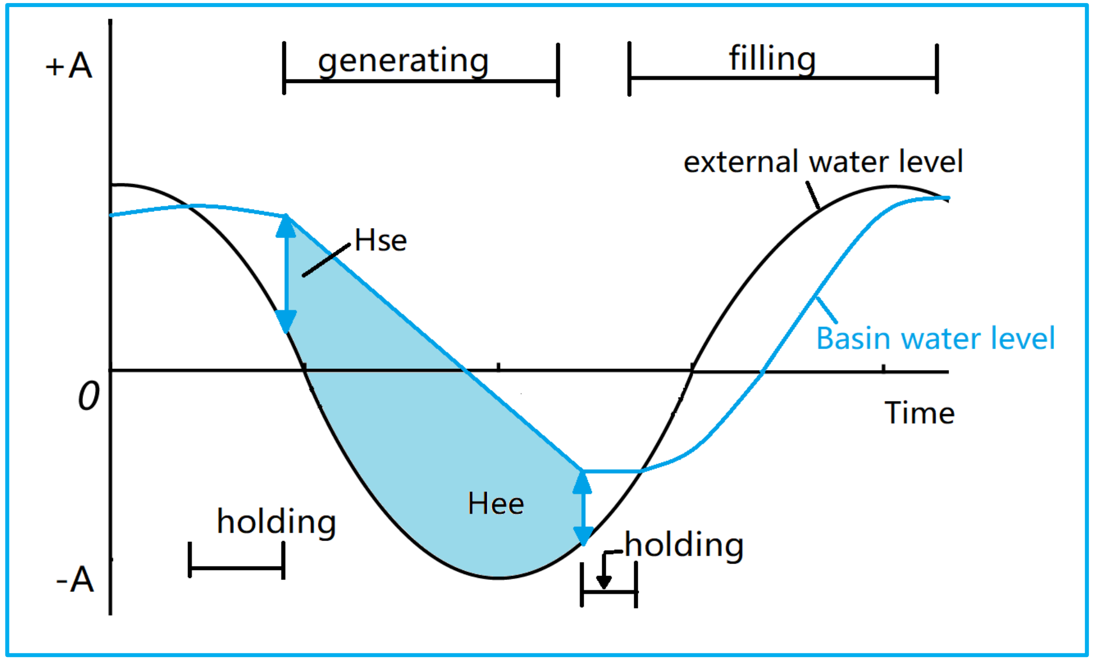


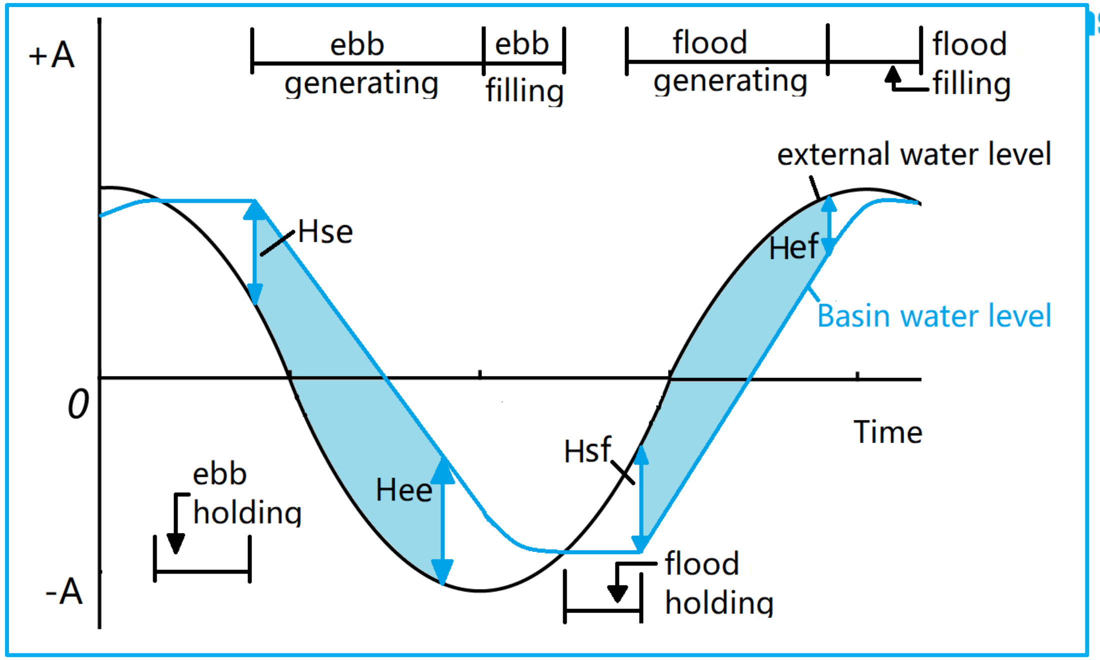




But what type of birds?
Dunlin or Seagulls?

TIDAL RANGE GENERATION OPTIONS





- Ebb-Only Generation
  - Most tidal schemes used this method in the past
  - 1 large pulse of power per tide with gap ≈ 8 hrs
- Two-Way Generation
  - Now preferred scheme for environmental reasons
  - 2 smaller pulses of power per tide with gaps ≈ 2-3 hrs

VERY LOW HEAD TURBINE ➪ TWO-WAY SYMMETRIC

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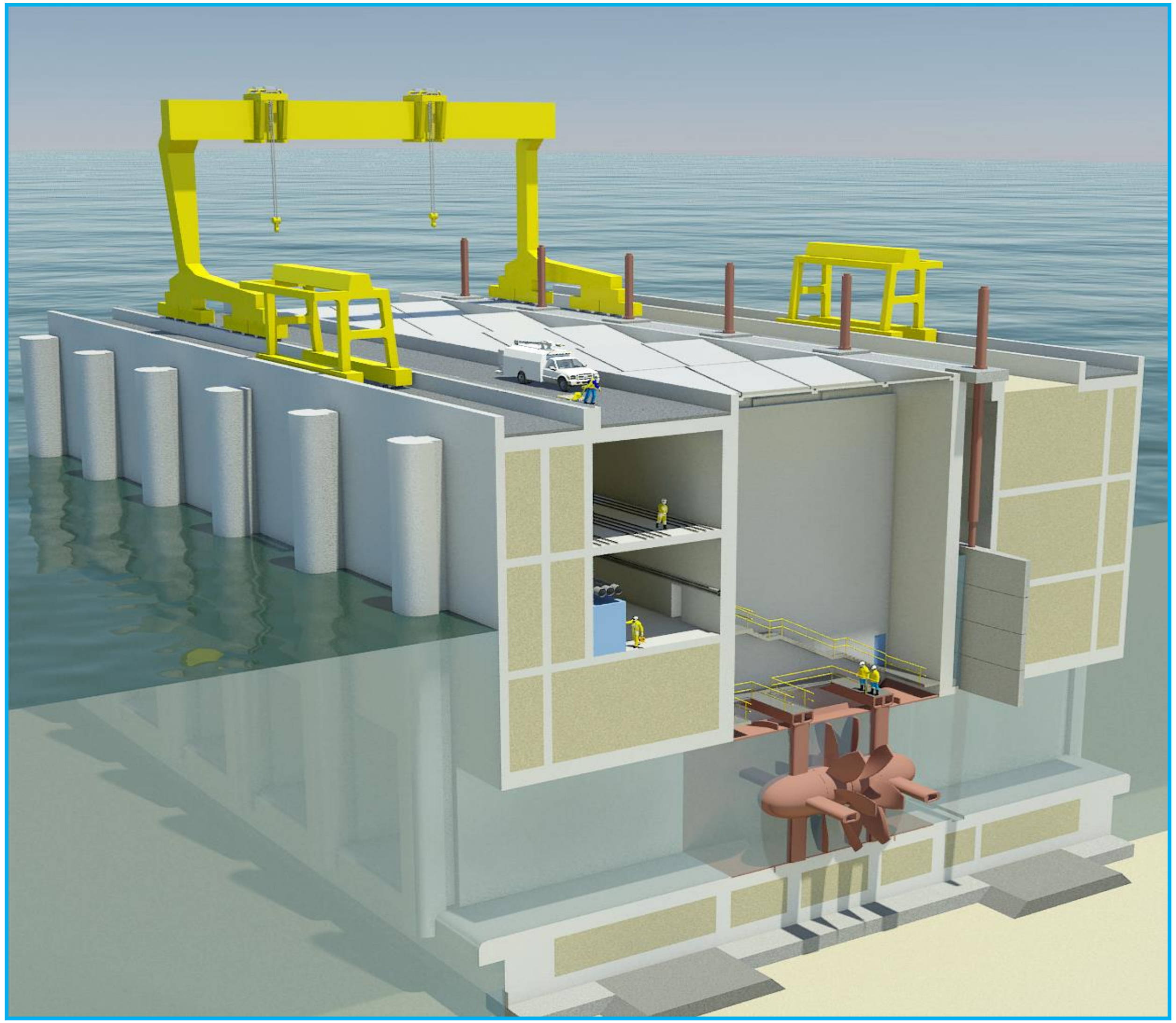

Key benefits of VLH turbines

- Longer time-span generating at peak efficiency
- Slower rotating blades ➪ less stressful to marine life
- Less impact on surrounding hydro-environment
- Reduced cost ➪ caissons do not need burying in sea floor

Jacobs and Sever Estuary Tidal Bar Ltd. awarded £0.87M UKRI Smart grant to design, build and test new VLH turbine

SEVERN BARRAGE ⇨ TWO-WAY GENERATION

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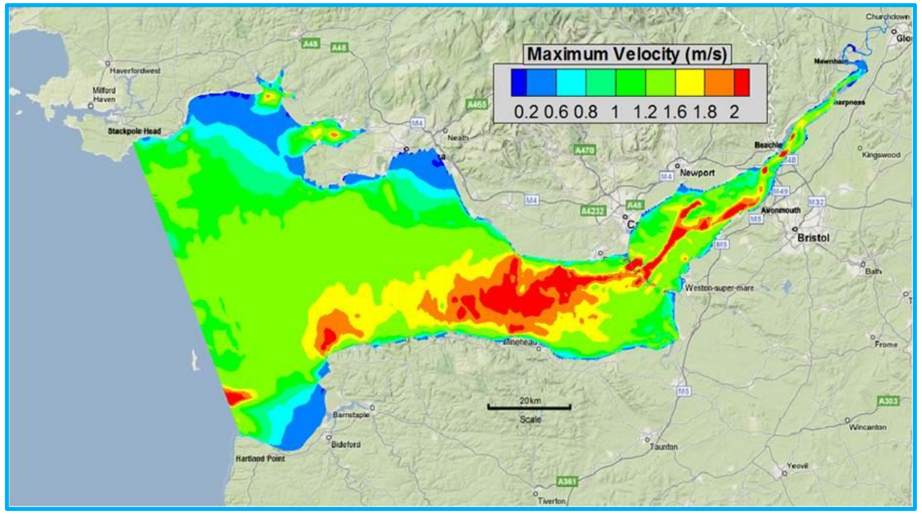
CU Severn Barrage ⇨ studies

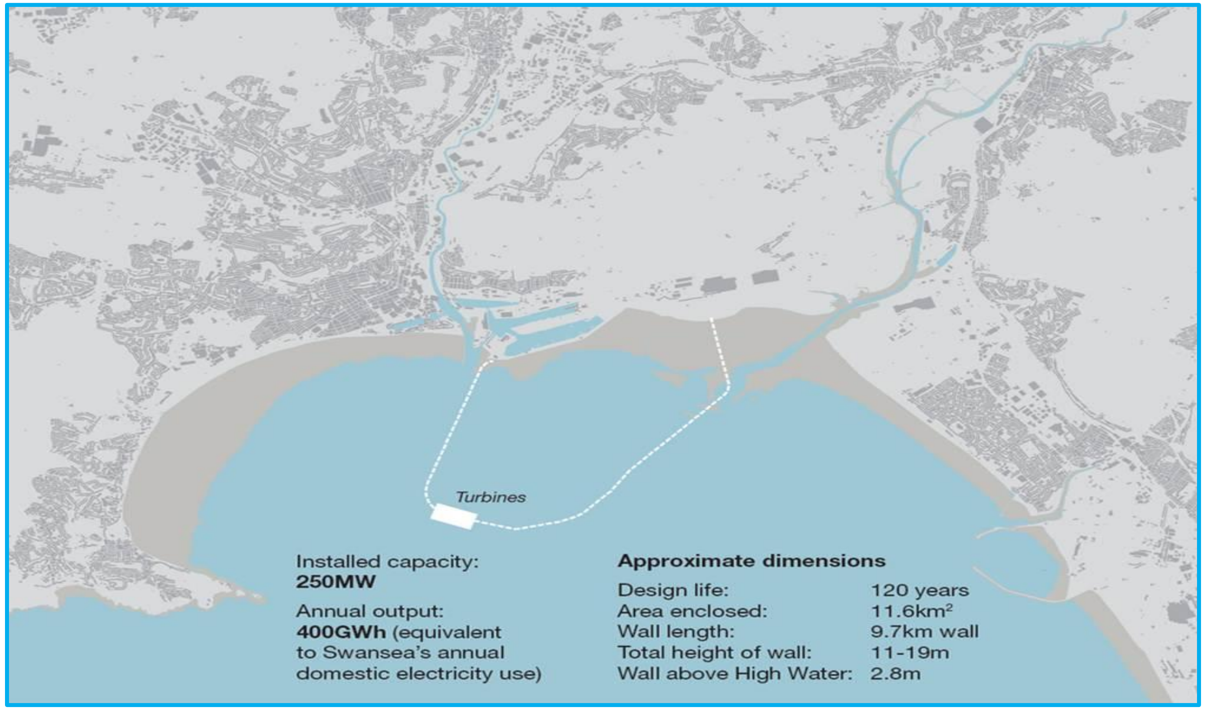
- 360 x 30 MW turbines + pumping, and 10,000 m^2 sluice gate area
- Tidal currents close to no barrage
- Much reduced inter-tidal habitat losses relative to ebb-only generation

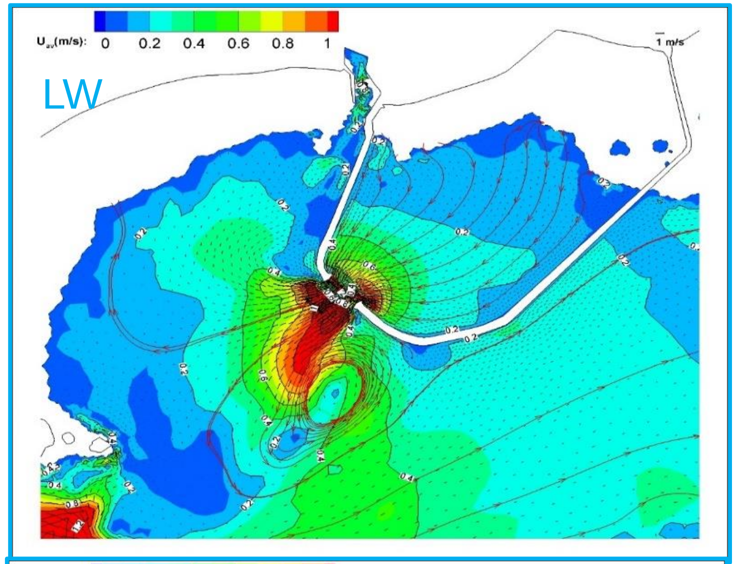


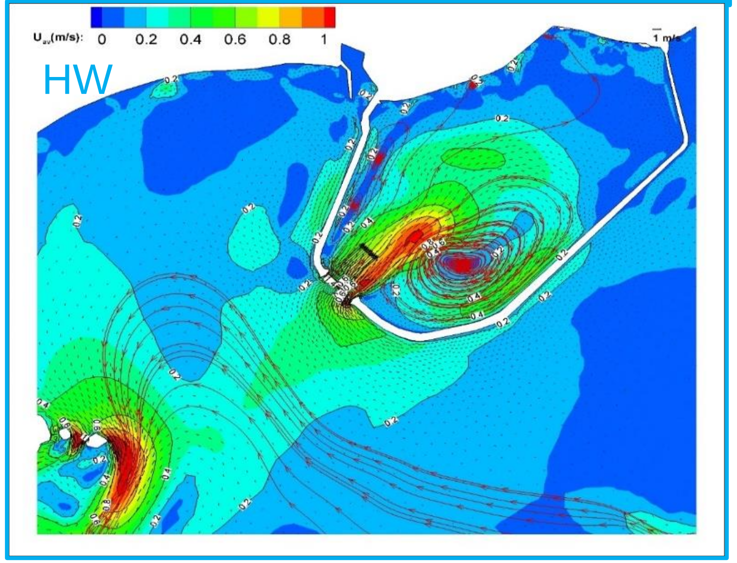
Hafren Power Barrage Scheme

- 1026 VLH turbines - each 6.3 MW ≈ 16.4 TWh/yr in 238 caissons
- Designed for two-way generation
- Substantially less environmental impact than for ebb-only generation

TIDAL LAGOONS ⇨ SWANSEA BAY LAGOON (FOAK)



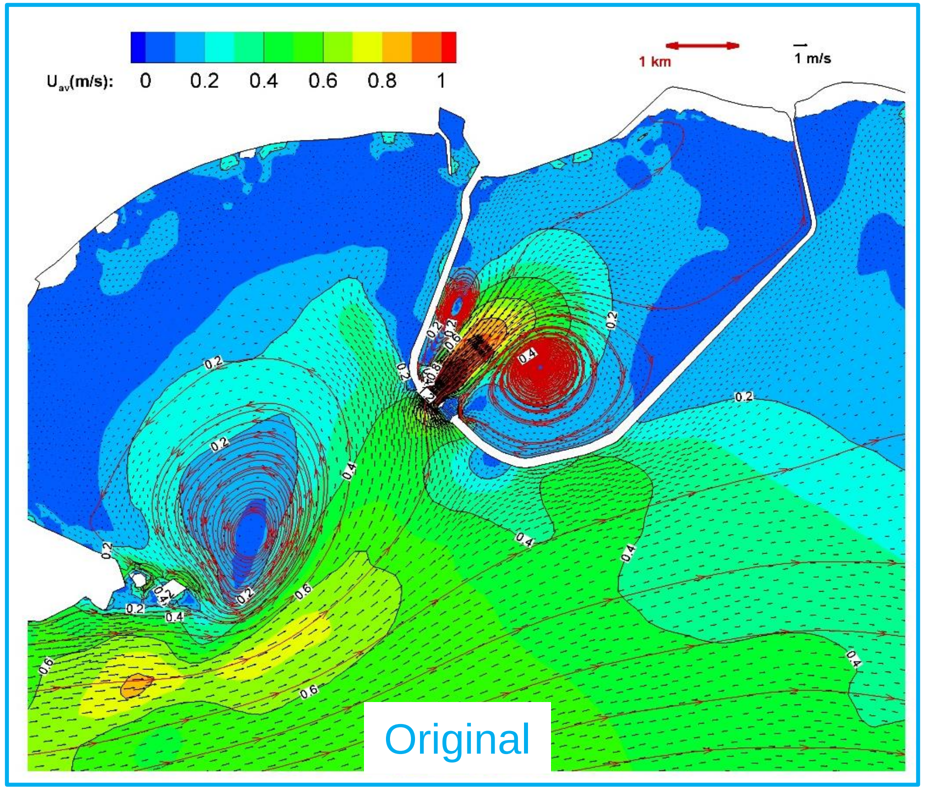


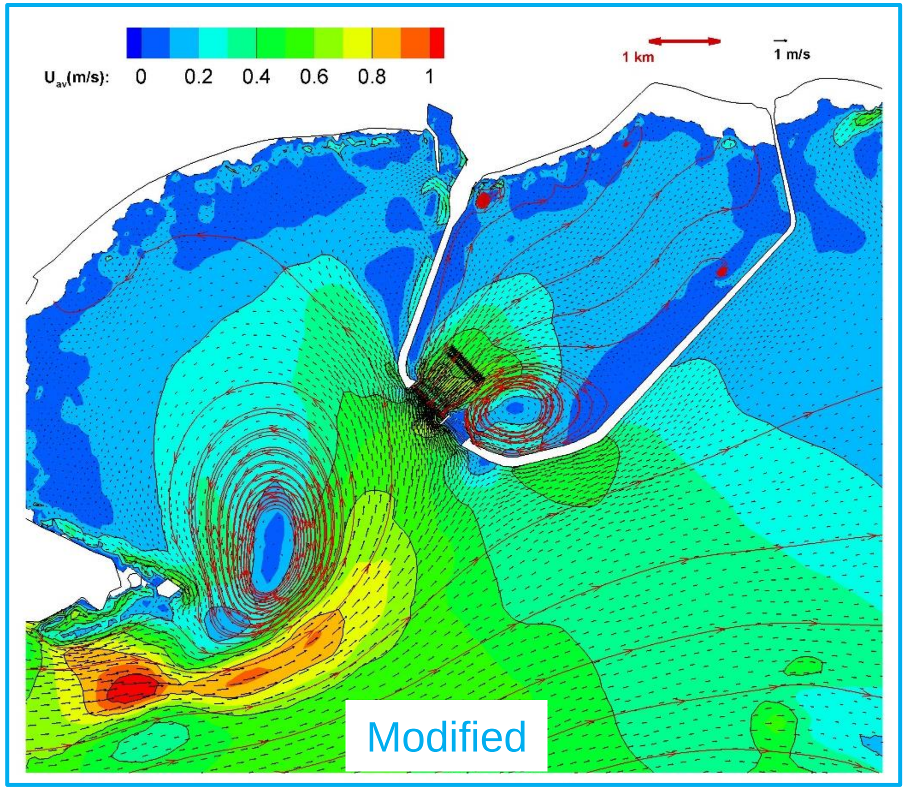


Swansea Bay Lagoon:

- Wall ≈ 9.7 km long embankment
- Area ≈11.6 km^2 ≈ 5.8 x Cardiff Bay
- 16 turbines and 8 sluice gates
- Energy output ≈ 0.58 TWh/yr

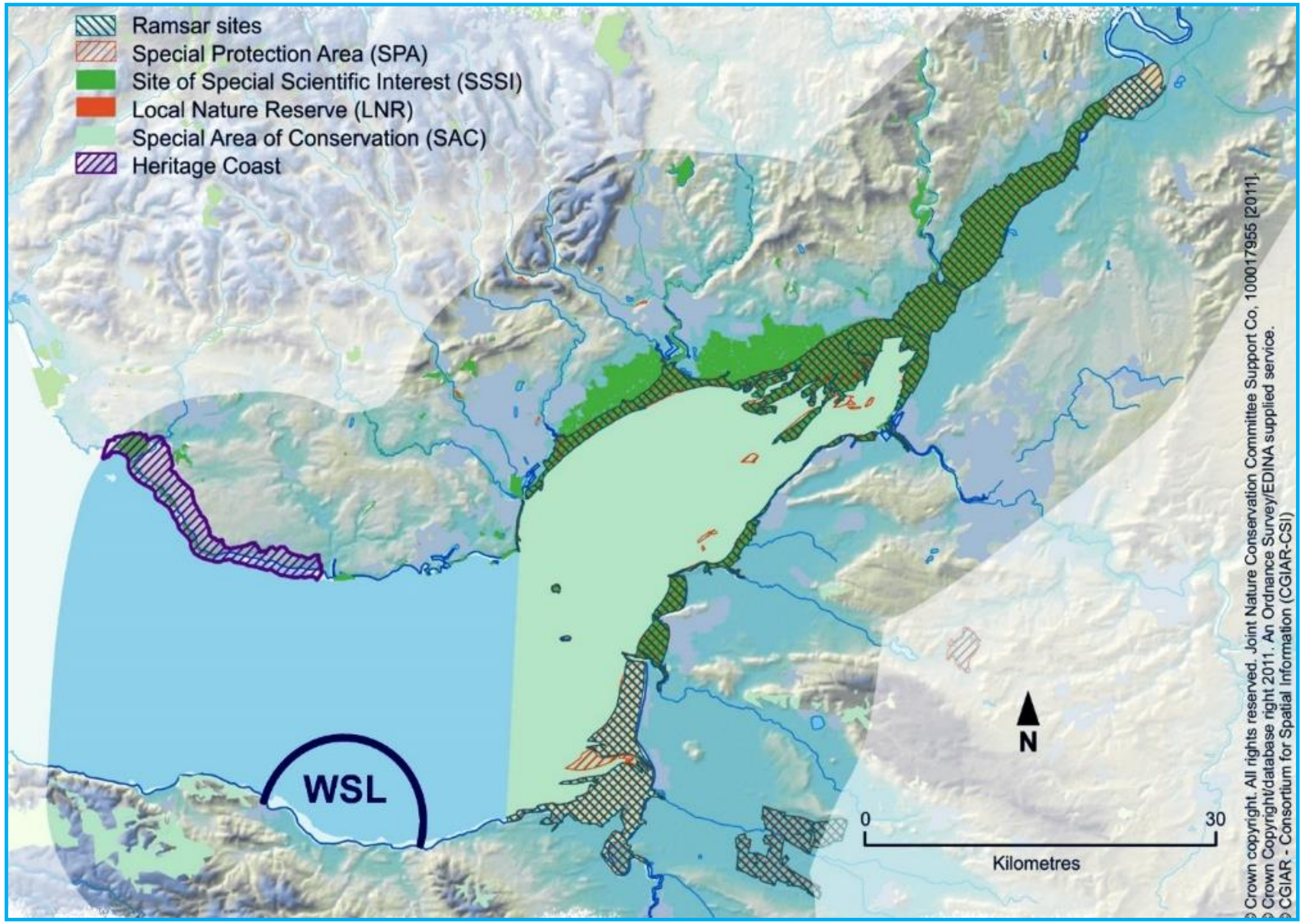
TIDAL EDDIES ⇨ TURBINE ⇔ SLUICE LOCATIONS





- Distributing momentum of flow through turbines and sluices over greater wall length ⇨ markedly reduces wake effects etc.

WEST SOMERSET LAGOON (WSL) LOCATION



Key Details:

- Located in Bristol Channel ➪ outside of SAC and SPA
- Located outside main navigation channel to Bristol and Cardiff ports
- Semi-circular shape ➪ max lagoon area ➪ min wall perimeter

WSL ⇨ GENERAL AND ENGINEERING LAYOUT

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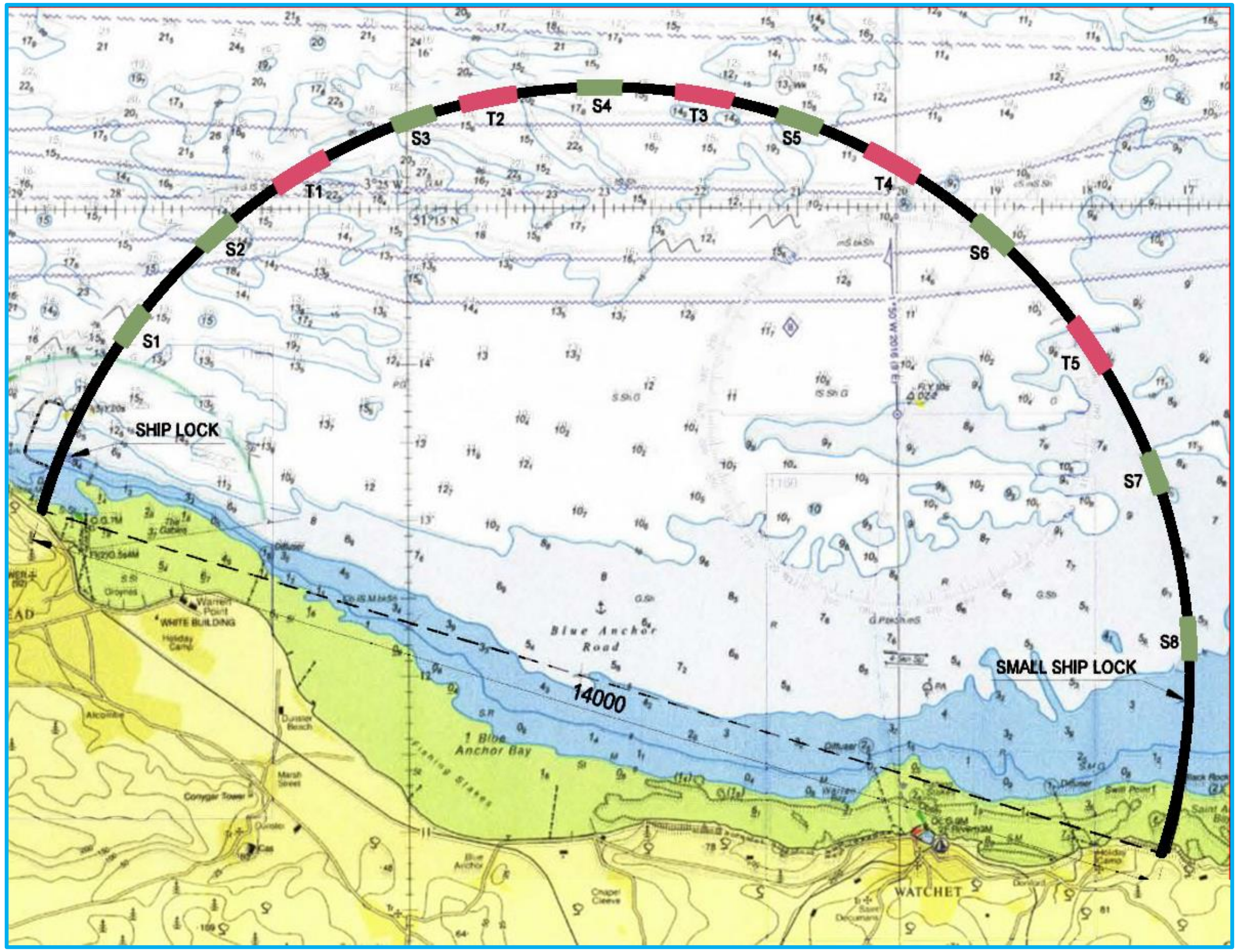
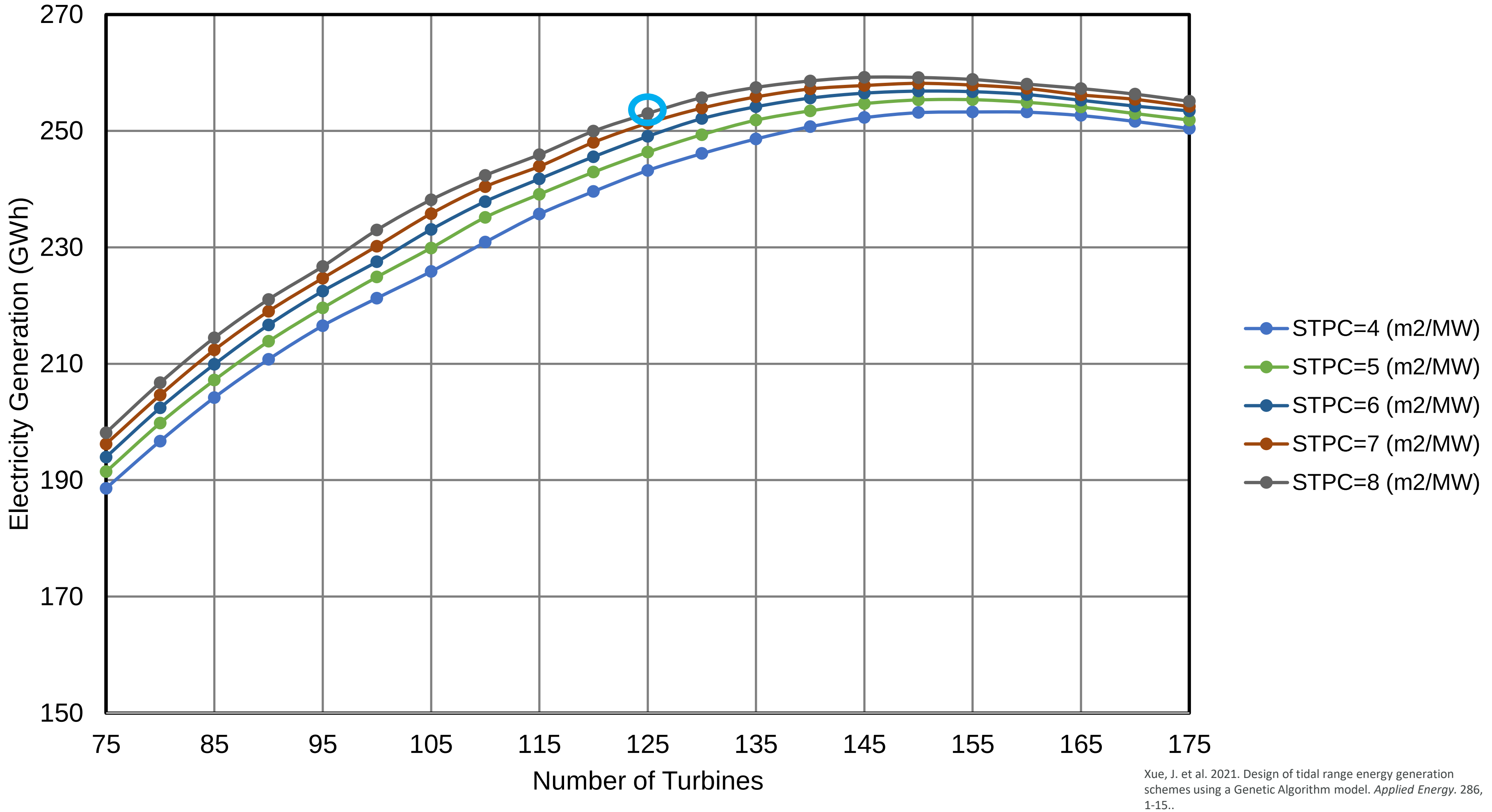


Turbines Sluices

Key Details:

- Tidal range = 10 m peak
- Plan area = 80 km^2 and perimeter = 22 km
- 125 turbines ⇨ 5 groups
- Concrete caissons ⇨ built in dry dock
- 2.5 GW ⇨ 6.5 TWh/yr, Cost ≈ £8.5Bn
- Cost ⇨ similar to that of nuclear and offshore wind

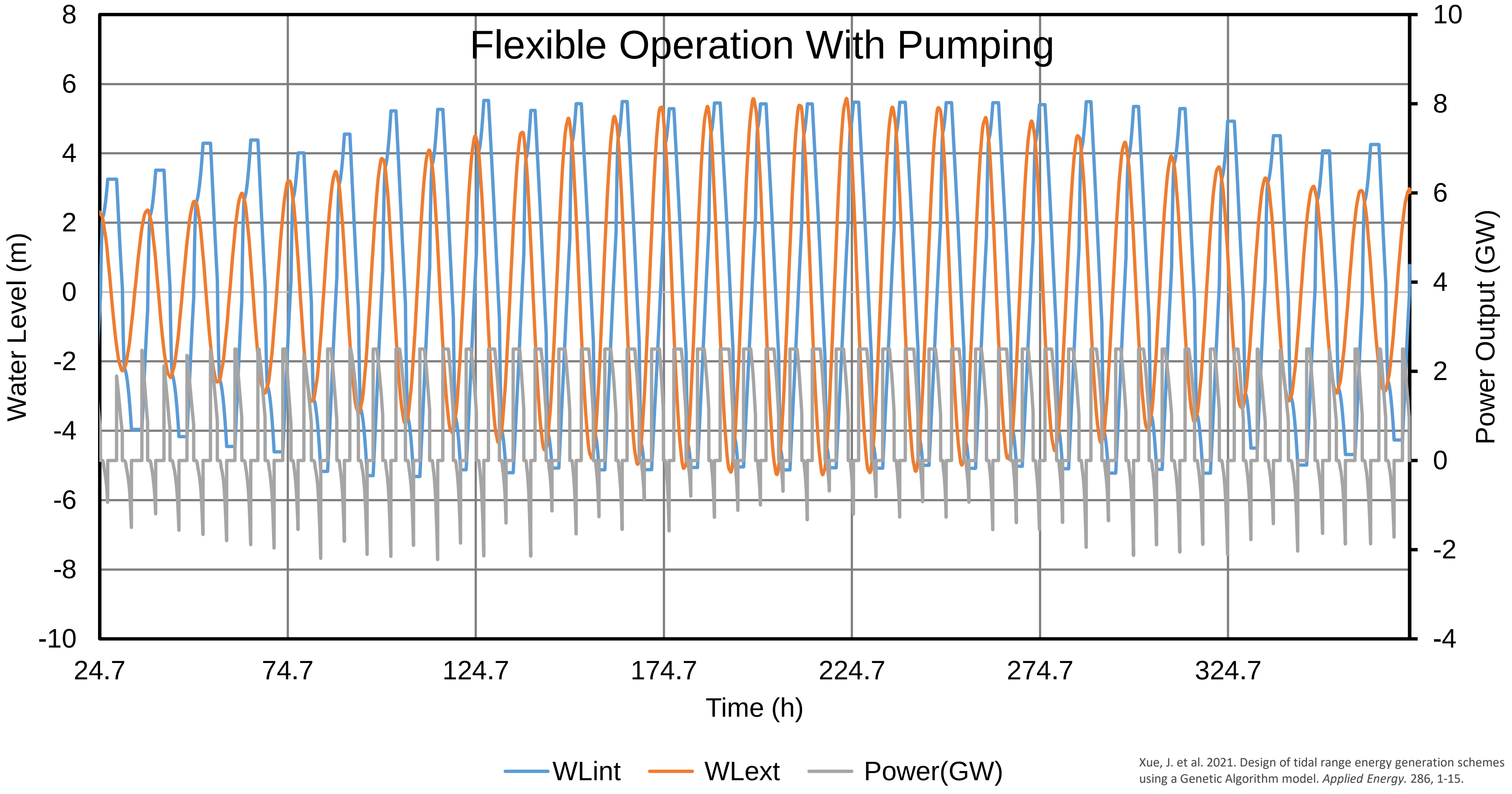
WSL ⇨ GA PREDICTED ENERGY OUTPUT



Xue, J. et al. 2021. Design of tidal range energy generation schemes using a Genetic Algorithm model. *Applied Energy*. 286, 1-15..

- Optimum design for WSL ⇨ 125 turbines and 20,000 m^2 sluice area
- Cost-benefit analysis ⇨ negative energy cost for > 125 turbines

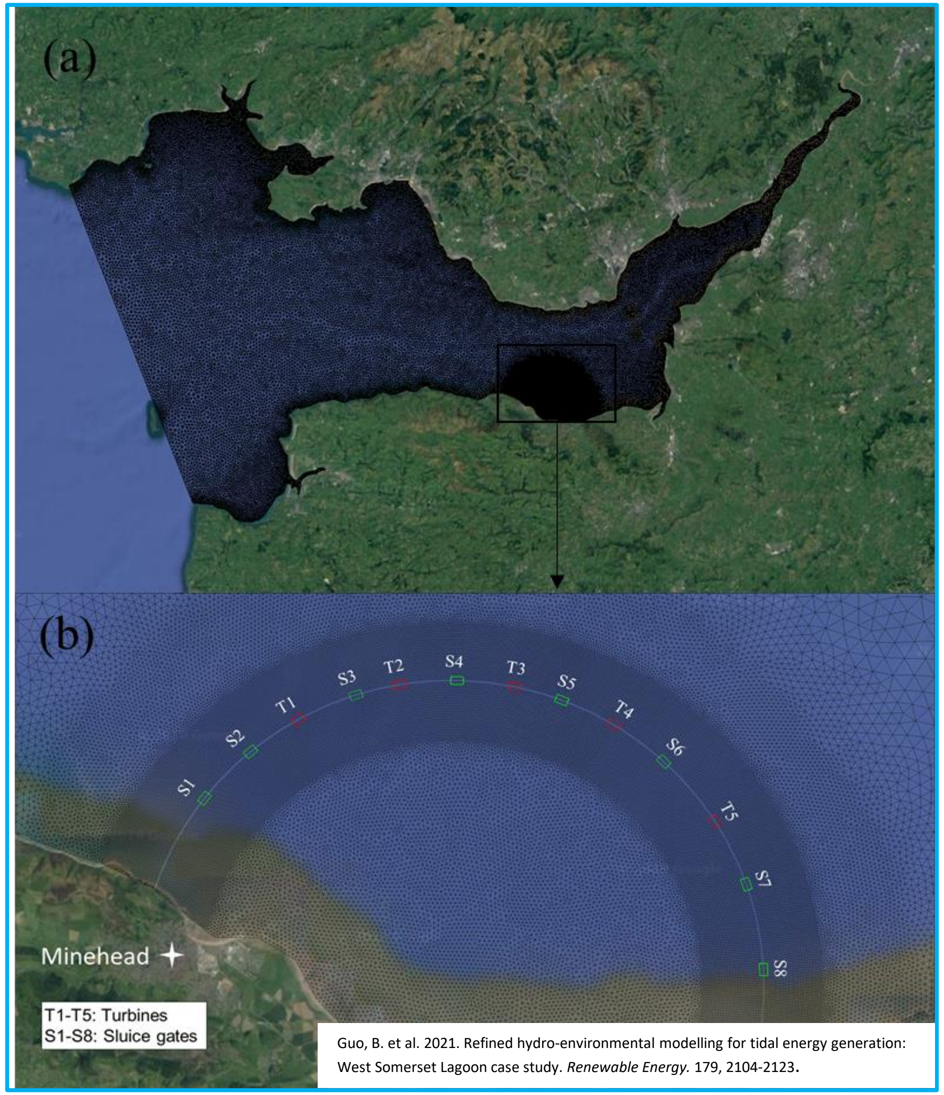
WSL ⇨ OPTIMISED POWER WITH PUMPING



Xue, J. et al. 2021. Design of tidal range energy generation schemes using a Genetic Algorithm model. *Applied Energy.* 286, 1-15.

- Predicted annual energy yield ≈ 6.5 TWh/yr ⇨ 18% energy increase
- Analysis for double regulated turbines ⇨ triple regulated to be higher

WSL ➪ HYDRO-ENVIRONMENTAL MODEL DETAILS

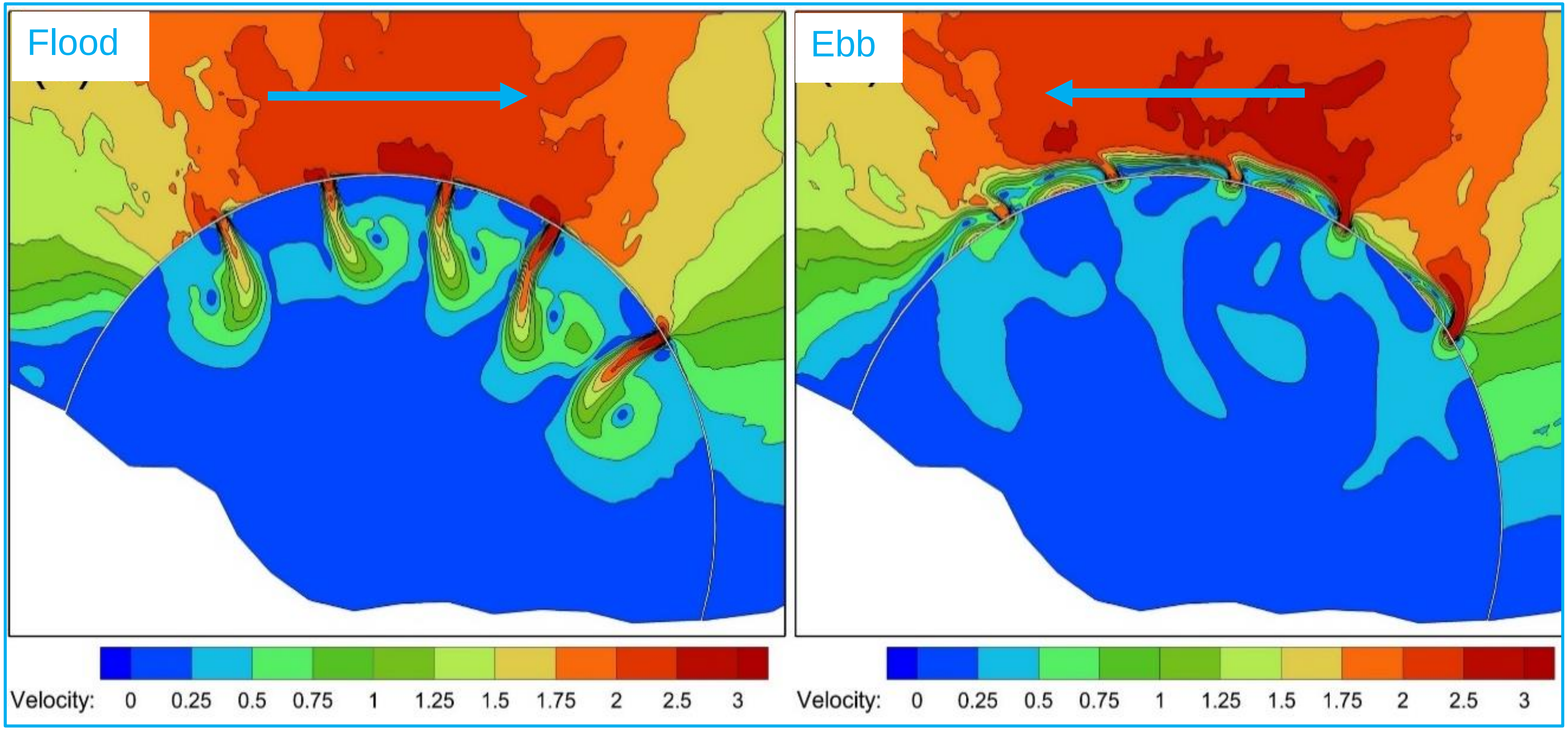


Guo, B. et al. 2021. Refined hydro-environmental modelling for tidal energy generation: West Somerset Lagoon case study. *Renewable Energy.* 179, 2104-2123.

Key Details

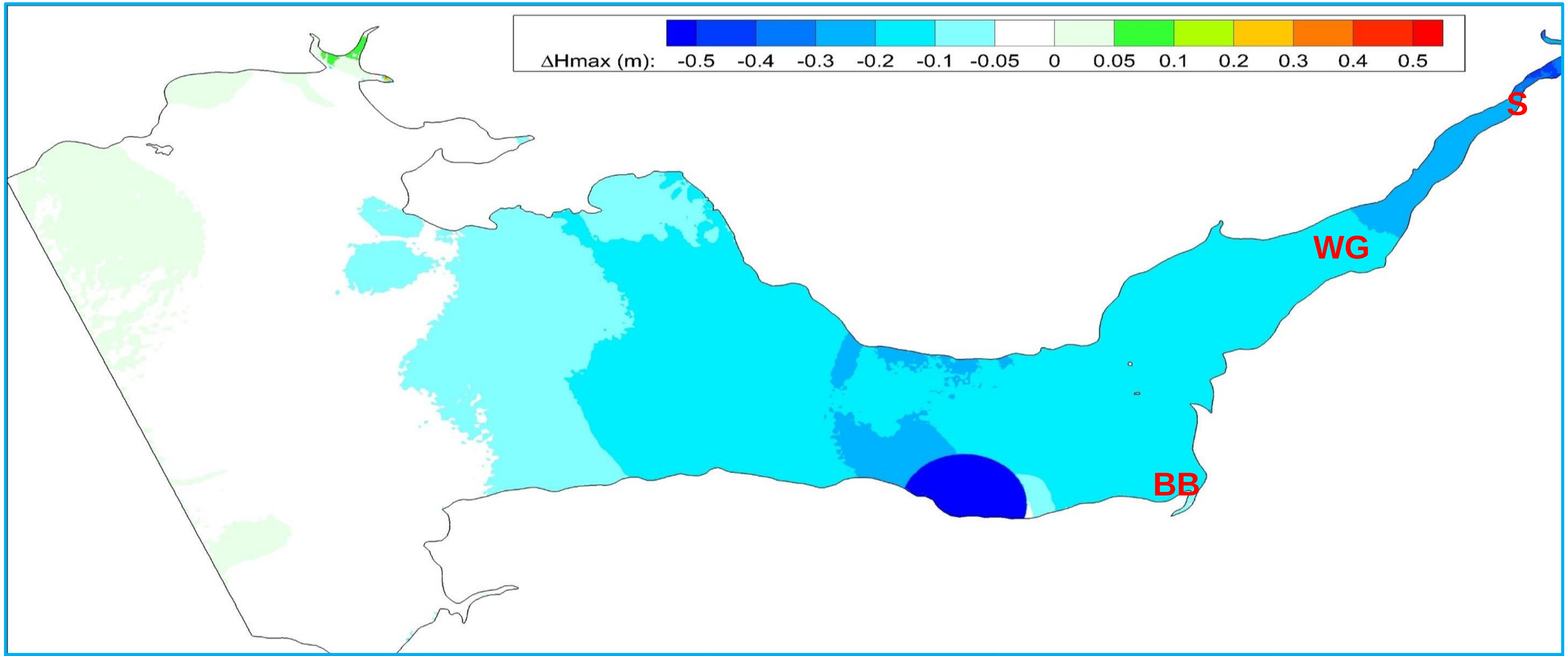
- TELEMAC finite element model
- Driven by boundary conditions from Continental Shelf
- Modules include 2-D and 3-D hydro-environmental coupling
- Domain size of 134,674 elements ➪ mesh size from 800 m to 50 m
- Momentum conservation applied
- Turbines modelled using double regulated hill chart with pumping
- Sluices modelled using standard orifice hydraulics formulae

WSL ➪ MODEL PREDICTED WAKE FEATURES



- Predicted spring tide currents in WSL with full momentum conservation through turbines and sluices around embankment for mean: flood and ebb tides

WSL ⇨ PREDICTED TIDE LEVELS UPSTREAM



Site	HWS (m)	LWS (m)	HWN (m)	LWN (m)
Bridgwater Bay (BB)	-0.09	0.26	-0.04	0.14
Welsh Grounds (WG)	-0.15	0.11	-0.10	0.16
Slimbridge (S)	-0.36	0.01	-0.28	0.01

Key: HW = High Water, LW = Low Water, S = Spring, N = Neap

ENERGY COST ⇨ NUCLEAR V. TIDAL RANGE

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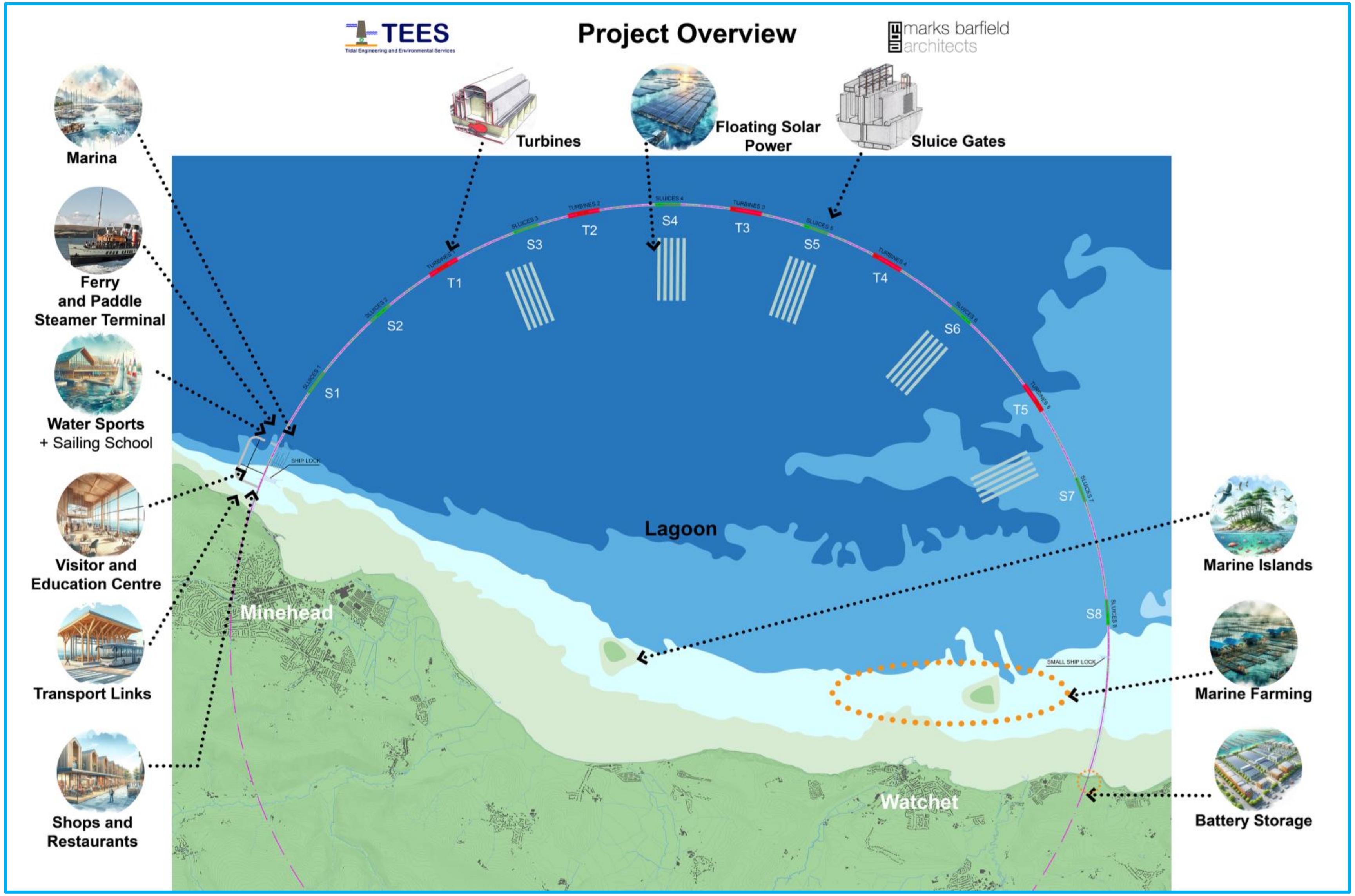
Projects Parameters	Hinkley Point C	West Somerset Lagoon
Capacity	3.2 GW	2.5 GW
Annual Output	25 TWh/yr	6.5 TWh/yr
Total Output Over Project Life	1,500 TWh	780 TWh
Estimated Project Cost	£33Bn - £46Bn	£10.9Bn[1]
Capital Cost Per MWh	**£22.0 - £30.7**	**£13.9**
Capital Cost per MWh ratio: Hinkley to WSL	**>1.6**	**1.0**

[1] "Oxera, independent financial economists, have assessed that with Regulated Asset Base financing, as approved for Sizewell C, then the cost of WSL's energy at 2020 prices would be £74/MWh"

WSL ⇨ PROJECT OVERVIEW AND WIDER BENEFITS



KEY BENEFITS ➪ TIDAL RANGE SCHEMES

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- Proven technology ➪ to generate predictable renewable energy
- Project working life ➪ 120+ years
- AI optimised flexible starting head ➪ energy increase ≈ 8%
- Pumping at low head ➪ reduces inter-tidal habitat losses and increase energy on subsequent tides ≈ 10%
- Larger schemes ➪ energy cost similar to offshore wind and nuclear
- Schemes offer protection against coastal erosion, flood risk and SLR
- Many other benefits ➪ tourism, recreation, etc. ➪ sites generally close to high energy demand centres

Thank You

Prof. Roger A. Falconer

Email: FalconerRA@cardiff.ac.uk

Acknowledgements

Modelling: HRC at CU – Prof. Reza Ahmadian, Dr Jingjing Xue, Dr Bin Guo

Design: Tidal Engineering & Environmental Services - Chris Binnie, David Kerr

Tidal Range Energy: Opportunities and Challenges

Bringing forward the Tidal Range potential in the UK

BHA ©

BRITISH HYDROPOWER ASSOCIATION

Kate Gilmartin
CEO British Hydropower Association

BRITISH HYDROPOWER ASSOCIATION

BHA is the leading trade membership association solely representing the interests of the UK hydropower industry

Our Mission is to drive growth in the sector by engaging, influencing and promoting Hydropower, Tidal Range and Pumped Storage Hydro, making these technologies relevant within the Government's ambition to enable a decarbonised, secure grid by 2035.

The BHA: working to bring forward policy support

BRITISH HYDROPOWER ASSOCIATION

What are we calling for?

Hydropower:	Tweak existing Contracts for Difference to enable deployment of another **1 GW**
Pumped Storage Hydro:	A cap and floor, to enable delivery of the **15GW** amongst wider 50GW LDES
Tidal Range:	Regulated Asset Base, (used for Nuclear), to enable delivery of **20GW**

What's been the main barriers to support?

Hydropower:	Hard to raise relevance (too small, can't scale, too expensive)
Pumped Storage Hydro:	Geographically constrained, market can deliver batteries
Tidal Range:	Too expensive (LCOE Of Swansea Bay) used as reference case

What can Tidal Range deliver?

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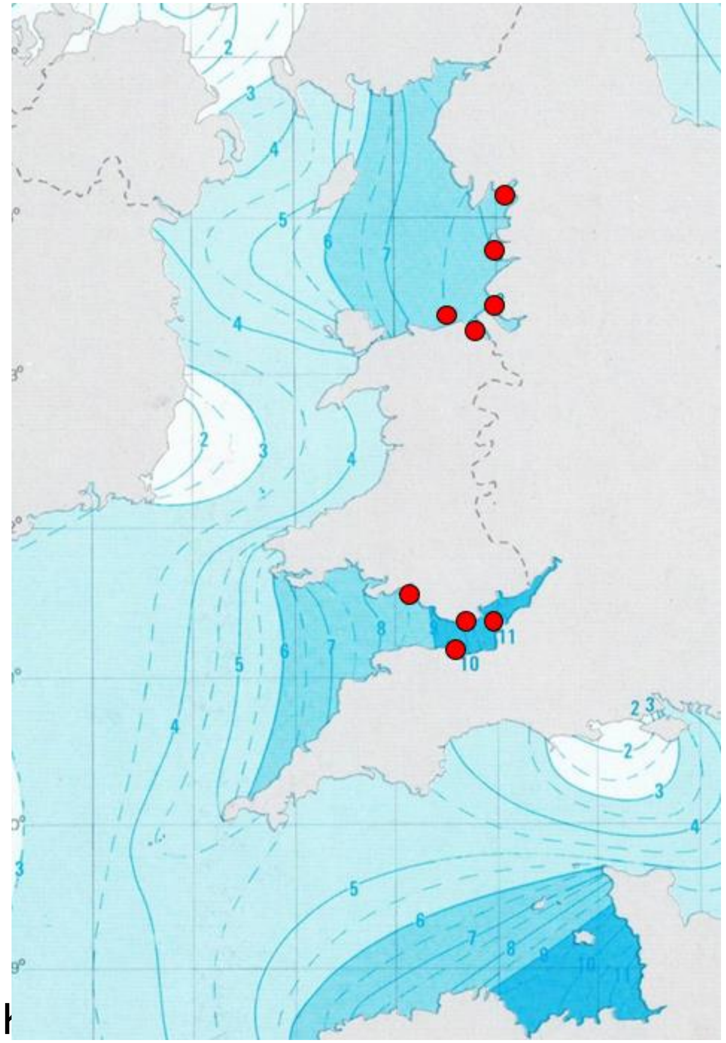
TIDAL RANGE ALLIANCE

UK Statistics

- UK holds 10% of the world's accessible tidal resource.
- Potential for 20 GW Installed capacity.
- Generating 30 TWh/yr ~12% of UK demand

Advantages

- Mature & proven technology
- Non weather dependent
- Long term asset (ca. 120 years)
- Predictable & reliable
- Generates near population densities.
- Potential to circumvent grid barriers.
- Semi dispatchable power and ancillary services to GB grid.
- Mitigation for flooding, erosion and sea level rise.
- Direct and indirect employment opportunities across the UK



Sites of Tidal Range Schemes across the UK

The Hendry Review

TIDAL RANGE ALLIANCE

- Independent Review into the feasibility and practicality of tidal lagoon energy in the UK
- Led by Charles Hendry, published January 2017, with the conclusion that Tidal Range could:
  - Play a cost effective role in the UK's energy mix;
  - Help deliver security of supply; they would assist in delivering our decarbonisation commitments; and they would bring substantial opportunities for the UK supply chain;
  - At scale, could deliver low carbon power in a way that is very competitive with other low carbon sources.

This means that a clear **long-term Government strategy in favour of tidal** lagoons will be required if the full supply chain and cost reduction opportunities are to be realised.

"Tidal lagoons can be an important and exciting new industry for the United Kingdom. We are blessed with some of the best resources in the world, which puts us in a unique position to be world leaders."

However – Government chose not to support this pathfinder project…..

The Value of what can be delivered?

TIDAL RANGE ALLIANCE

Energy security

- Harnessing the UK's Indigenous energy generation increases energy security offering resilience to the UK.
- Energy diversity = energy resilience (diverse generation profiles & geographic locations)
- Long term assets give discounted cost to future generations

Resource Adequacy

- Available every day for the majority of the day.
- Back-up requirements are therefore short term (measured in hours rather than days);

The Grid

- Close to centres of population with shorter, less exposed transmission links.
- Contribute to grid stability, fast response start-up times, spinning mass contributes to the grid inertia dampening frequency fluctuations, as more wind and solar comes onto the system and an element of pumped energy storage;

Long term value for money

- Reduced exposure to energy inflation therefore giving ongoing reduction in its contribution to wholesale electricity costs in real terms.

Co-benefits

Large scale energy assets such as Tidal Range can have a portfolio of benefits.

- **Inherent Energy Systems benefits:**
  - There are benefits in a diverse mix of energy projects with different technologies displaying different attributes.
  - Tidal Range offers reliability and grid system benefits such as inertia, predictability, resilience, reduction in carbon intensity.

- **Co-benefits:** These will be site specific and require bespoke consideration, but can aggregate to major non-price benefits for UK plc such as;
  - Onshoring and growth of manufacturing and construction supply chains;
  - Growth in demand for and investment in upskilling, research, and innovation;
  - Flood risk management (protection and mitigation) and reduced coastal erosion;
  - Water management through eco-engineering and sustainable construction; and
  - Investment in growth of eco-services through environmental management systems to protect habitats and wetlands, and deliver biodiversity net gains.

Levilised Cost of Energy

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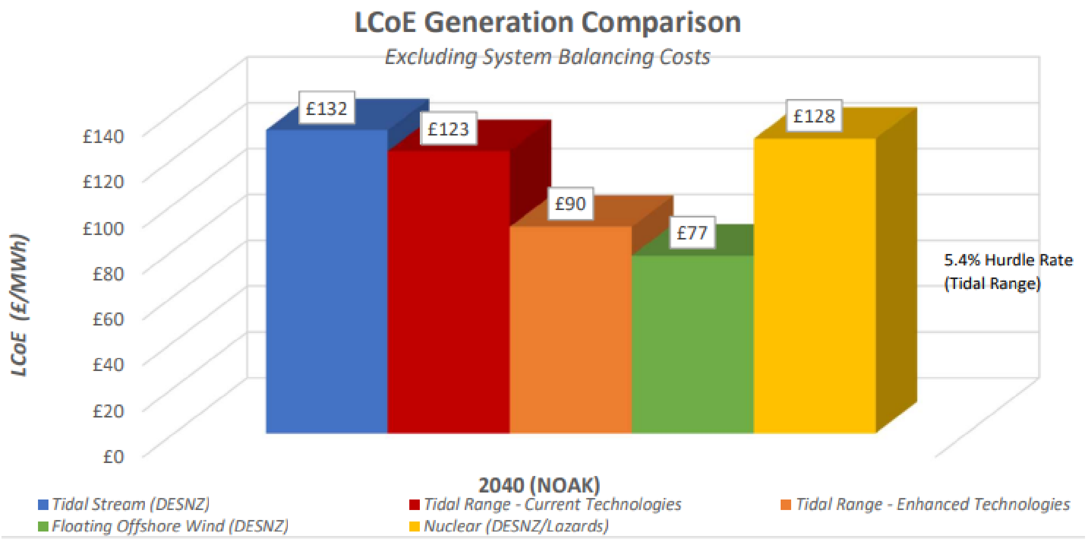
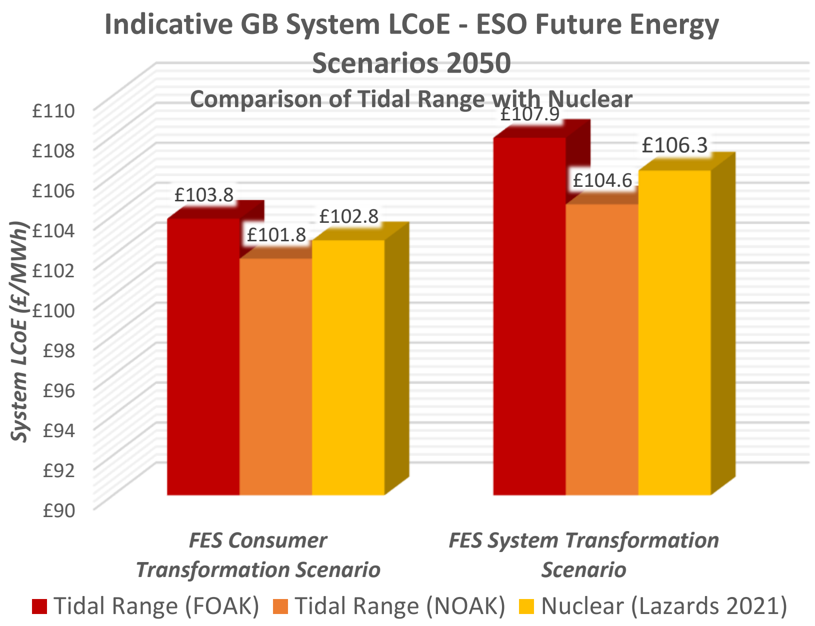
- Levelised cost of energy (LCOE) is a very blunt instrument to help measure the value of energy generation technologies;
- It does not measure the ability to bring forward a decarbonised, stable and operable grid, fit for the future.
- The LCOE fails to include the costs of additional factors to give real end to end costs, including lifecycle costs, additional grid transmission costs & constraints, rebalancing costs, curtailment costs, storage costs.
- However, the perception that LCOE will always come down has diminished as no offshore wind came through Auction Round (AR) 5 and the Administrative Strike Prices (ASPs) have been adjusted upwards for AR6.
- TRA commissioned Jacobs to undertake work to look at the LCOE of Tidal Range.

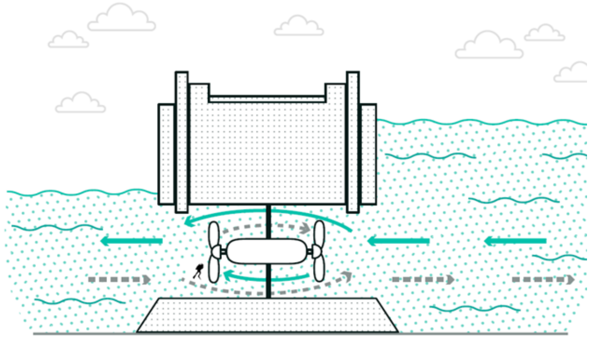


Using enhanced turbines technologies, the LCoE can be reduced further to £90/MWh, below that of nuclear and approaching that of floating offshore wind

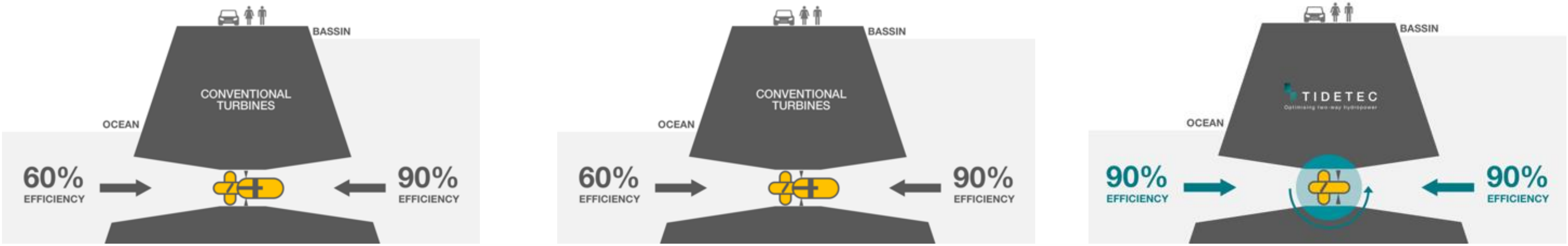


Innovation

- Tidal Range is a well-established technology
- Engineers & developers will continually strive to innovate to increase efficiencies, extract more energy, bring costs down and increase the cost benefits.
- Historically, Tidal Range has been developed using 'bulb' turbines which give efficient generation on the Ebb tide but can also generate on the flood tide with lower efficiency.
- A focus of research is to increase efficiency in the reverse flow direction and improve generation potential at lower heads through developing new bi-directional turbines and symmetric Very Low Head Tidal Turbines.
- A recent Innovate UK Smart grant is enabling laboratory testing of a bi-directional, Very Low Head Tidal Turbine (VLHTT).



Bi-directional turbine to maximise ebb and flood generation, turbine height 8-9m



Tidetec turbine solution which is optimised for two-way production due to its rotating turret.

Creation of an Industry

- In the British Energy Security Strategy, 2022, the government committed to "aggressively explore" Tidal Range technology as a source of energy security".

- To date, there has been only one step forward with the publication of "Tidal range projects: criteria and how to submit a proposal" issued by DESNZ, 19th December 2023.

- To **unlock** the industry, we need a strong Government policy commitment to gain investor confidence, this can be enabled in 4 ways.

1. Working with Industry to look at barriers and how they may be addressed. A first step could be a DESNZ Call for Evidence.

2. Through a strategic taskforce between industry and Government which could emulate the one set up for off-shore wind.

3. Through the creation of a route map and industrial strategy for accelerated deployment.

4. Through the development of a price stabilisation mechanism that supports long term energy generation from Tidal Range.

A price stabilisation mechanism

Supportive Government policy and a price stabilisation mechanism will act as a key catalyst for broader funding enabling a lower cost of capital.

- Contracts for Difference
  - Short term projects (<30 operating years) are compatible with 15-year contract for differences, but long-term projects (>50 years) require longer term financing methodologies. Hence Government proposing different financing mechanisms for new nuclear projects.

  - CfD’s are market-based devices evaluated on a contract period of 15 years (typically 60% of a wind or solar project lifespan). If a CfD was permitted for an 80-year period, no long-term value would be recognised after 35 years at private sector hurdle rates, so the tidal range sector has to consider other, longer term financing methodologies.

A price stabilisation mechanism

Longer life, high capital cost projects therefore require a long-term financing methodology such as RAB.

- The Regulated Asset Base:
  - Focuses only on costs and securing advance payments from electricity consumers based on the asset value of the project during construction.
  - Minimises financing costs rather than energy costs
  - This advance payment effectively offsets compounding of interest, thereby reducing the financing costs over time.
  - A Green Book analysis at the social discount rate shows the benefits of the advance payment to the consumer, compared with a more traditional financing cost.
  - Energy from tidal range is almost constant in annual terms, and value will increase with rate of energy inflation (with only very small cost inflation over its lifetime).

In the UK, the Industry has successfully lobbied for a Cap and Floor mechanism to bring forward Pumped Storage Hydropower which should come into effect in 2025.

Summary: Price stabilisation mechanism

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- Regulated Asset Base (RAB) is suggested as a suitable mechanism, with comparison to infrastructure projects like the Thames Tideway Tunnel and future nuclear projects.

- The RAB model involves a regulator and specific legislation (Primary and Secondary) to ensure long-term value and reduced costs for consumers.

- The RAB model is also a mechanism that can capture co-benefits, such as flood defence benefits, providing a comprehensive approach to project valuation. Work should be undertaken to review Impact on household bills using the same methodology that BEIS used when considering RAB for Sizewell C.

Summary: Government strategic support

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TIDAL RANGE ALLIANCE

- Government Support and Ownership: The role of the government is crucial, with the potential involvement of government funds like GB energy, or a sovereign fund or potential for government guarantee to buy back assets.

- Innovation Incentives: The importance of incentivising innovation and considering the UK's opportunity to export solutions. This could include seed funding, an accelerator fund, and a focus on exporting clean infrastructure solutions.

- Collaboration with Industry Players: include engaging with major energy companies (Centrica, EDF, RWE, BP) and exploring their preferences or potentially negotiating bilateral deals.

- Geographical Sequencing: A regional strategy for tidal range projects considering different geographical locations and sequencing based on regional characteristics.

Tidal Range Alliance ‘asks’

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- A commitment from Government that tidal range power is an essential part of the UK generation mix going forward – issue a Ministerial statement
- Government to issue an ‘Understanding the barriers to the deployment of Tidal Range: Call for Evidence’.
- More resource within Government department to work on Tidal Range (currently 1 FTE).
- Create a Government/ Industry taskforce, similar to offshore wind in 2012.
- Work with Industry to continue to look at RAB as a mechanism to bring forward Tidal Range projects and give investor confidence;
- Develop a road map to accelerate Tidal Range;
- Create an Industrial Tidal Range strategy, ensuring the supply chain is on-shored in the UK
- Build on work undertaken through the Tidal Lagoon Challenge;
- Develop an innovation turbine test site;
- Geographical Sequencing: A regional strategy for tidal range projects considering different geographical locations and sequencing based on regional characteristics.

Aspiration is that tidal range can travel in the slipstream of PSH – bespoke, large infrastructure, Multi £Bn intergenerational assets.

Conclusion: Tidal Range Energy: Opportunities and Challenges

Opportunities:

- Tidal Range could be the cornerstone of a decarbonised Grid in the UK
- Timetabled energy generation, next to centres of population demand, circumventing transmission constraints
- Inter-generational assets – we know Hydropower continues to give value after 100 years
- Builds resilience into the energy system (grid stability and inertia as more thermal plant comes offline).

Challenges:

- Political Will
- Large infrastructure projects can be a political ‘hot potato’ – HS2 (High speed 2 rail project/ Hinkley C nuclear) – over run and over budget…
- Government like modular solutions where costs come down
- There aren’t enough engineers in Government (~9% of civil servants have a STEM background) Energy transition is a complex engineering (and social) problem.

Easy wins will dissipate and the harder to deliver will become necessity – Tidal Range’s time is coming…

Q&A Discussion

MODERATOR: FANG YENN TEO

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