Institution of MECHANICAL ENGINEERS

Lancaster University

Morecambe Bay Tidal Barrage

Thomas Lowe Gray Lecture 2022

Tuesday 24th May 2022

EUR ING Professor

George Aggidis

FIMechE, FIMarEST, FEI, FIET

Head of Energy Engineering

g.aggidis@lancaster.ac.uk

Overview

1. Introduction
2. Resource
3. Past
4. Present
5. Next Steps
6. Conclusions

Overview

1. Introduction
2. Resource
3. Past
4. Present
5. Next Steps
6. Conclusions

Introduction – Tidal Range

- Energy prices are high.
- No easy fix.
- A barrage makes UK independent with long-term cheap clean power.

Introduction – UK Policy

- The UK Government has multiple policy commitments.
- Funds limited - need prioritizing.
- Barrages are multi-functional and cost effective.

Introduction - Engineering

Engineering offers solutions….

… why haven't we already got a tidal scheme barrage?

Improving the world through engineering

Introduction - Environment

In the past – environment was the barrier…

…now the barrier (a barrage) is the solution!

It is essential to save our environment;

It can be considered an Ark.

Introduction - LTEM

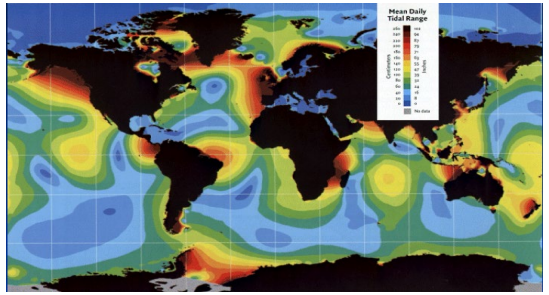
The **Lancaster Tidal Energy Model (LTEM)** delivers environmental engineering for an uncertain future.

- Under-pinned by economics.
- A simple 0-D model for 'what if' assessment.
- Ideal for comparing schemes and management options.
- Government's reputation is not good at joined up thinking; LTEM will help.

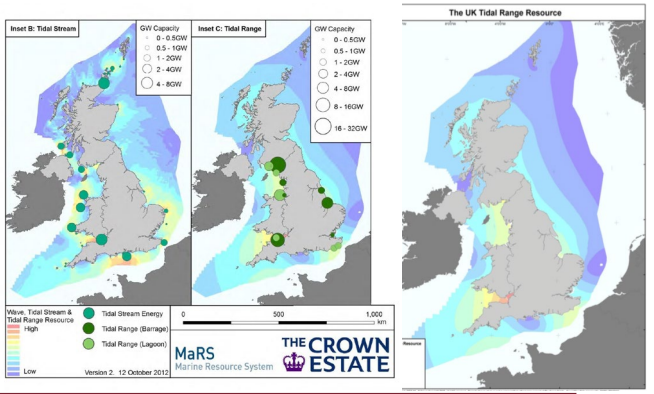
Introduction - Potential

Morecambe Bay has one of the world's best tidal resources…
….LTEM shows its potential.

- Tidal range projects currently under development promise 10 GW installed capacity, delivering over 20TWh/y, about 5% of UK energy use.
- Predictable resource avoiding intermittency and storage problems.
- UK tidal range potential can easily increase multiple times.



Electric Power Research Institute (EPRI).



Introduction – Replace Fossil Fuels

- Supports UK strategy to reduce carbon emissions.
- UK total generating capacity is 42.8 GW

Source	Capacity	Percent
Fossil fuels	19.2GW	44.9%
Renewables	16.5GW	38.5%
Low carbon	7.1GW	16.6%

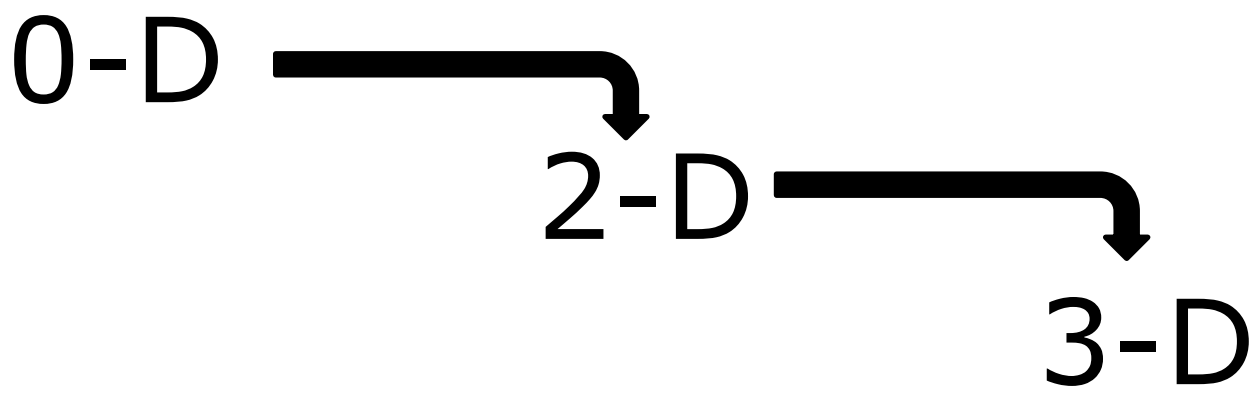
- La Rance Tidal Range plant (France) is their cheapest operating plant.
- Investment covers 120 years.

Introduction – Environment

- Morecambe Bay is a unique asset with extensive intertidal mudflats & wading birds.
- Government designations RAMSAR, SPA, SAC, SSSI, AONB & others.
- Sea level rise existential threat; Government must safeguard what they have agreed.
- Not *Precautionary Principle* but *Responsibility to Protect*.
- Morecambe Bay offers more:
  - transport,
  - innovation,
  - links to Eden North,
  - social benefits,
  - load balancing, etc.

Introduction – Solution

- Maintain current tidal range – minimise flooding.
- Work with conservation agencies.
- A cascade approach to decision making but action is needed now.



"Net Zero" by 2050

- The UK government have announced a climate emergency with targets to decarbonise by 2050.
- We need to reach "net zero" far sooner than 2050 – we're already seeing the catastrophic effects of climate breakdown both across the globe and here in the UK.
- We have just a short window of opportunity left to avoid irreversible damage.
- We need to live greener and more sustainable lives.
- We need to reduce UK dependence on imports of dirty fuels like coal, oil and gas.
- The UK should be powered by a home-grown renewables sector, providing jobs and clean energy at affordable prices for homes, heating, transport and industry.

What has changed?

- Technology
- Environment
- Politics
- Energy demand
- Economics
- Modelling

- Turbines
  - Largely the same
  - Two way generation
  - Triple regulation
- Civil engineering
  - Novel construction techniques
  - Floating casements
  - Use of local materials
  - Improved technology for concrete and reinforcements

What has changed?

- Technology
- Environment
- Politics
- Energy demand
- Economics
- Modelling

- Climate change
  - Firmly established
  - GHG emission reduction essential
- Sea level rise
  - Development more urgent
  - Barrage an environmental safeguard
- Eden Project North
  - Information

What has changed?

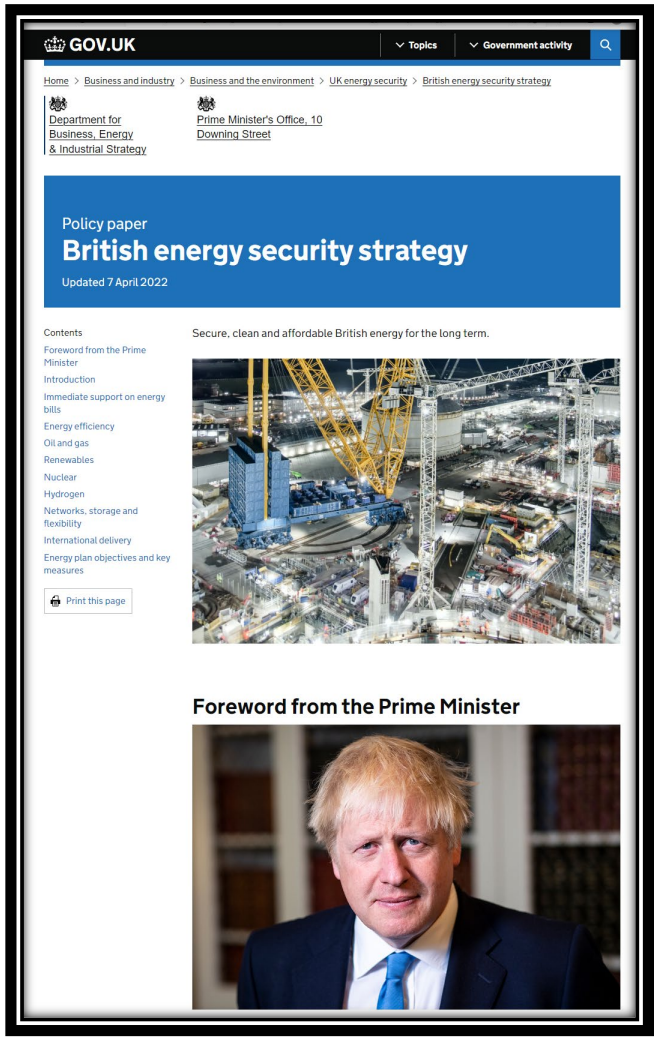
- Technology
- Environment
- Politics
- Energy demand
- Economics
- Modelling

- British Energy Security Strategy
  - Nuclear – 8 new reactors by 2030
  - Offshore wind – target to generate 50GW by 2030
  - Oil & gas – new licensing round (fracking?)
  - Solar – target 14GW by 2035
  - Hydrogen – target 10GW production by 2030

What has changed?

- Technology
- Environment
- Politics
- Energy dema
- Economics
- Modelling

Has Boris missed the bus again?



What has changed?

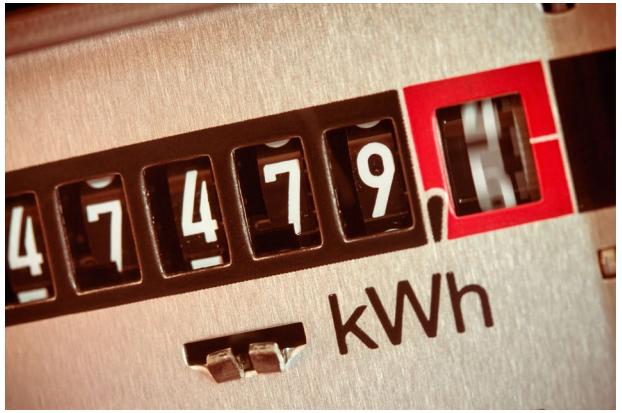
- Technology
- Environment
- Politics
- Energy demand
- Economics
- Modelling

Frustration - growing daily!

- Frustration!

What has changed?

- Technology
- Environment
- Politics
- Energy demand
- Economics
- Modelling



- Reduced supply
  - Oil & gas from Russia
- Changing demand
  - Electric cars and heating
- Increasing prices

What has changed?

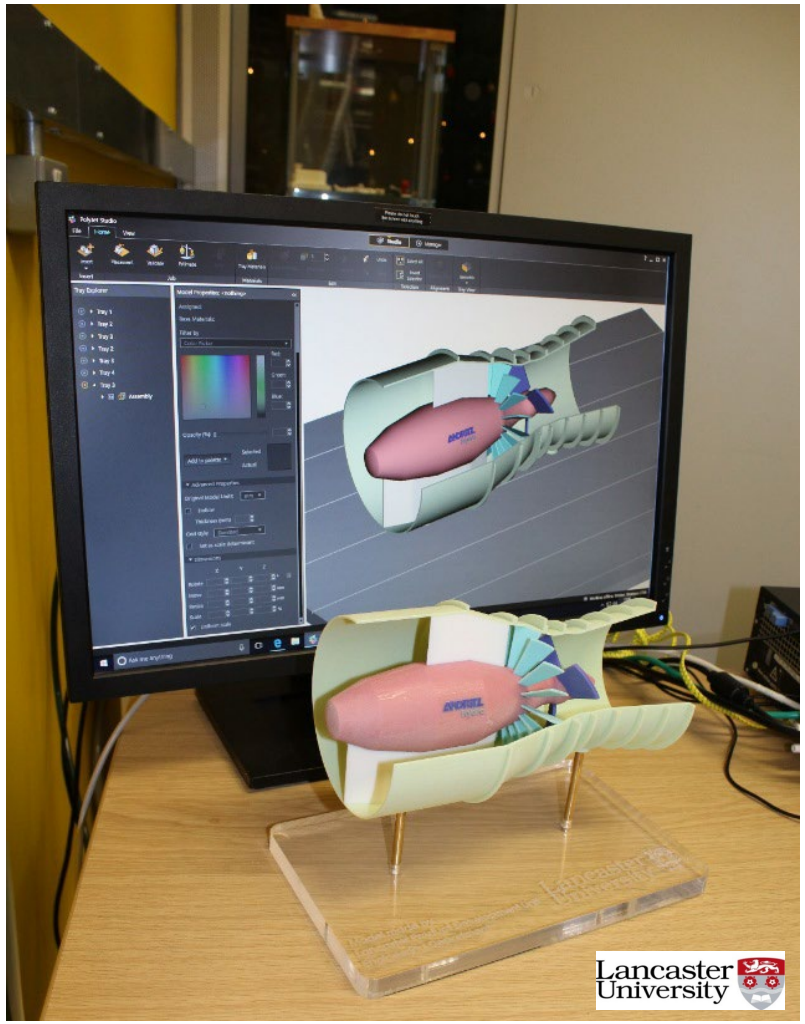
- Technology
- Environment
- Politics
- Energy demand
- Economics
- Modelling

- Cost of living crisis
  - Driven by energy prices
- Government debt
  - Covid-19

What has changed?

- Technology
- Environment
- Politics
- Energy demand
- Economics
- Modelling

Lots to tell you about!



BHA Tidal Range Alliance

HOME ABOUT JOIN THE BHA NEWS & INFO TIDAL RANGE ALLI

For firm power, we need look no further than our coast. The UK is blessed with some of the world's best tidal range resources. Tidal range projects, with barrages and impoundments proposed along much of the UK's west coast, will deliver totally reliable, industrial scale low-carbon power generation and help maintain grid security and stability and protect coastal communities from storm surges and rising sea levels and provide thousands of jobs in places where employment is hard to find.

With an operating life of over 120 years, at least double that of a nuclear plant and three to four times the life of wind and solar farms, and many whole-system benefits, tidal range energy generation is cost competitive and should have a significant role to play in the UK's Green Recovery.

6 Oct 2020

Mission

Promote the multi-disciplinary features and benefits of tidal range projects to key stakeholders across Government, industry and the media

24 May 2022

Henry Dixon, Chair, 2020

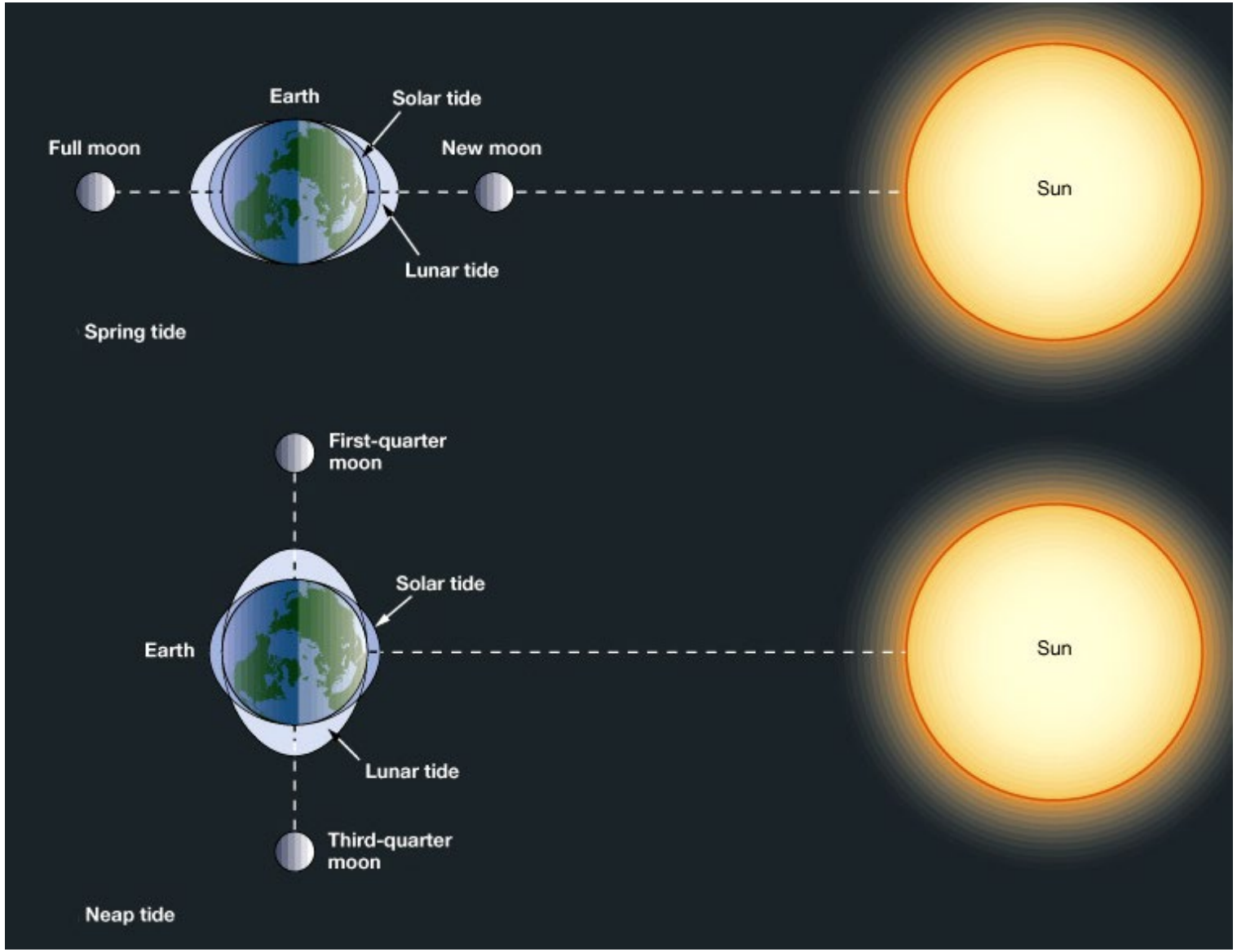
Ioan Jenkins, Chair, Oct 2021

Overview

1. Introduction
2. Resource
3. Past
4. Present
5. Next Steps
6. Conclusions

Earth-Moon-Sun Gravity

Tidal energy exploits the **natural ebb and flow** of coastal tidal waters caused principally by the interaction of the **gravitational fields of the earth, moon and sun.**



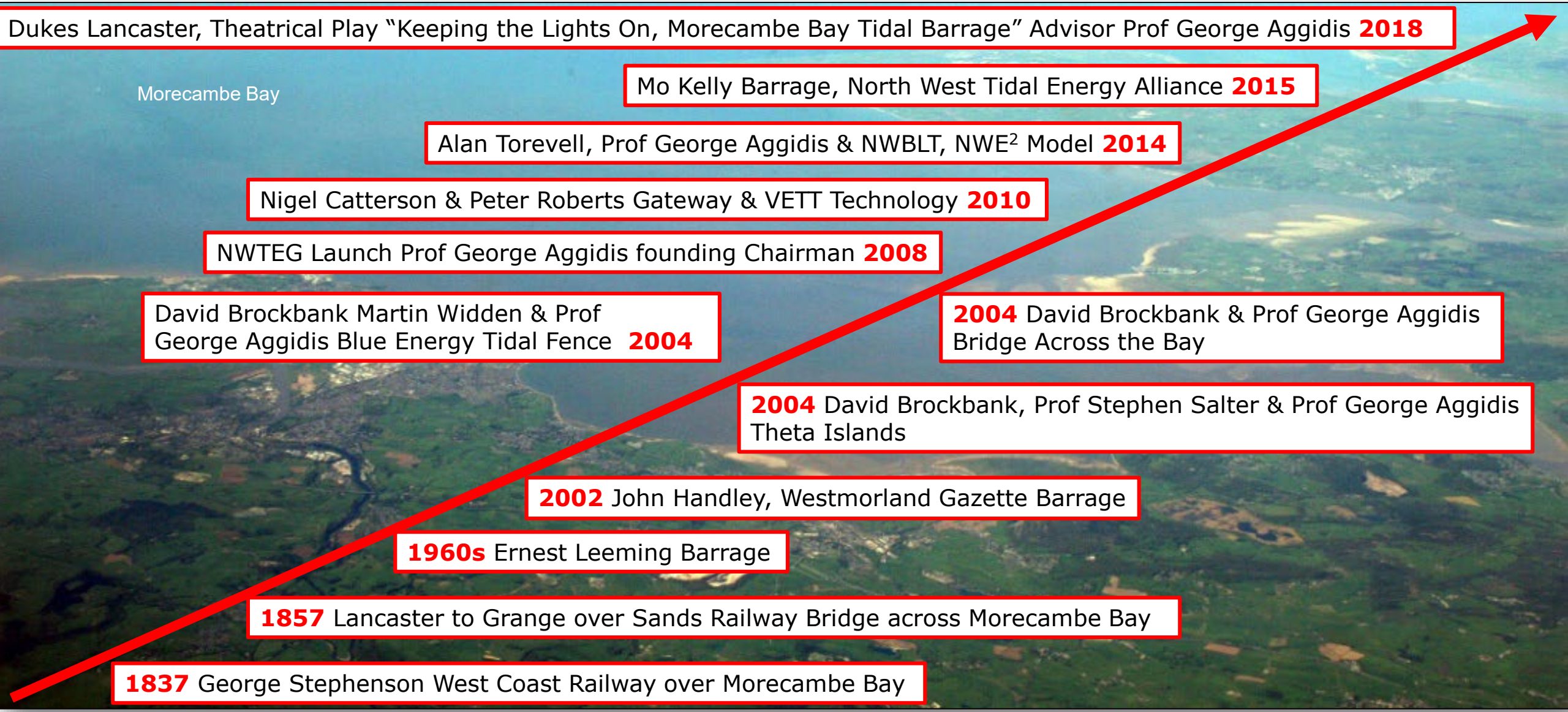
Tidal Range Energy Resource

Neill, S.P., Angeloudis, A., Robins, P.E., Walkington, I., Ward, S.L., Masters, I., Lewis, M.J., Piano, M., Avdis, A., Piggott, M.D. and Aggidis, G., 2018. Tidal range energy resource and optimization–Past perspectives and future challenges. *Renewable energy*, *127*, pp.763-778.

Overview

1. Introduction
2. Resource
3. Past
4. Present
5. Next Steps
6. Conclusions

Morecambe Bay Proposals To Date



Global References (Tidal Range)

- Existing tidal references world wide include:
  - **La Rance, France, 1967**
    - Alstom Hydro
    - 5.4 m Dia. 24 Turbinesx10 MW
    - 240 MW total capacity
  - **Kislaya Guba, Russia, 1968**
    - 1 Turbine × 0.2 MW
    - 1 Turbine × 1.5 MW
    - 1.7 MW total capacity
  - **Annapolis, Canada, 1980**
    - Andritz VaTech Hydro
    - 7.6 m Dia. Straflo Turbine
    - 1 Turbine x 20 MW
    - 20 MW total capacity
  - **Jiangxia, China, 1980**
    - 1 Turbine × 500KW
    - 1 Turbine × 600KW
    - 3 Turbines × 700KW
    - 3,200 KW total capacity
  - **Sihwa, South Korea, 2011**
    - Andritz Hydro
    - 7.5 m Dia. 10 Turbines x 26 MW
    - 260 MW total capacity

Markus Schneeberger
ANDRITZ Hydro &
Prof George Aggidis

Sihwa, South Korea tidal power plant 2011

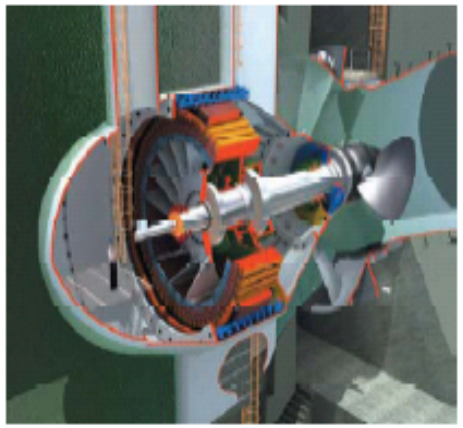
Overview

1. Introduction
2. Resource
3. Past
4. Present
5. Next Steps
6. Conclusions

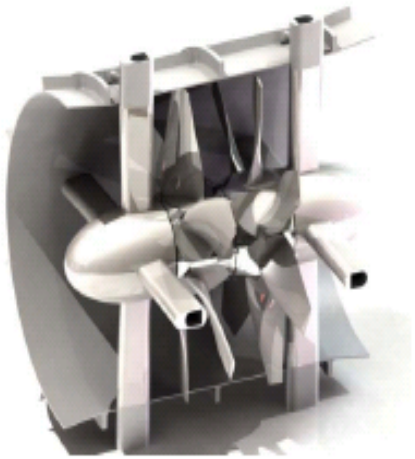
Range of Technologies

Both forms of energy (potential & kinetic) can be harvested by tidal energy technologies as renewable energy.

Increasing environmental impact



- Uni-directional operation.
- High axial flow speed.
- 50 metre downstream diffuser.
- High solidity rotor.
- Steady flow conditions.
- Deep cavitation submergence.



- Bi-directional operation.
- Low axial flow speed.
- Straight walled support structure.
- Twin low solidity rotors.
- Steady flow conditions.
- Modest cavitation submergence.

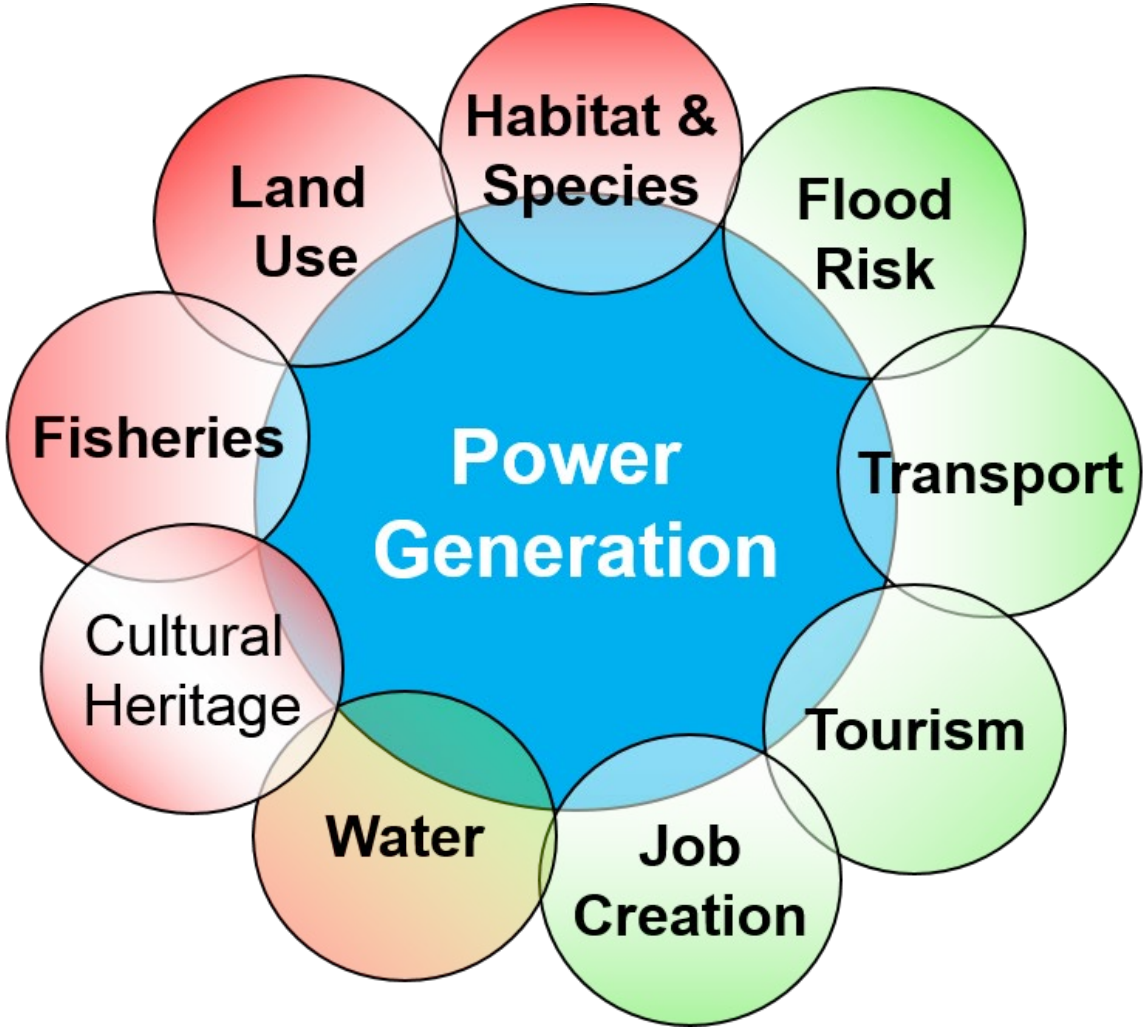
- Bi-directional operation.
- Low axial flow speed.
- No enclosing support structure.
- Low solidity rotor.
- Unsteady flow conditions.
- Modest cavitation submergence.

Decreasing power density

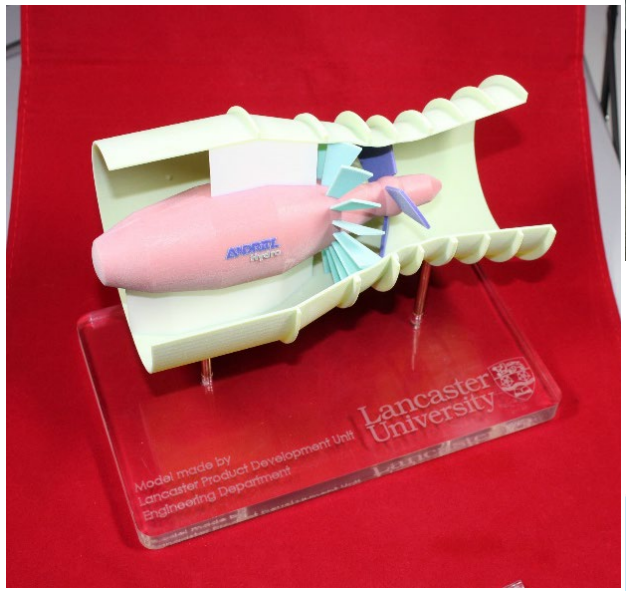
Waters, S. and Aggidis, G., 2016. Tidal range technologies and state of the art in review. *Renewable and Sustainable Energy Reviews*, *59*, pp.514-529.

Multi Functional Infrastructure & Power Generation

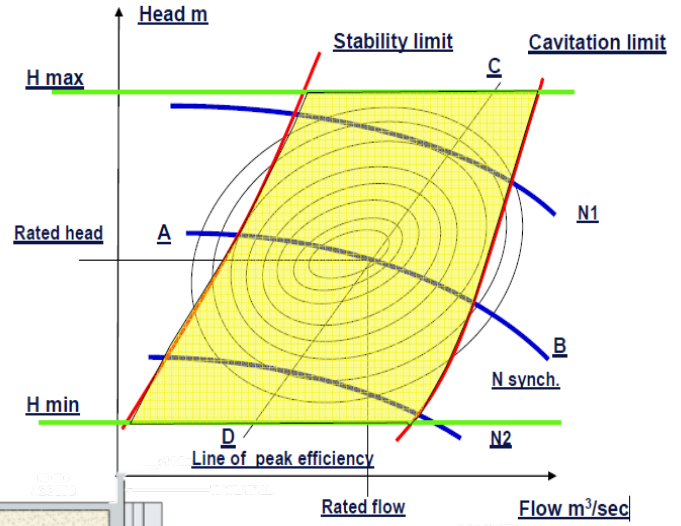
- Protecting the local landscape from flooding (terrestrial and marine)
- Providing skilled jobs in a long term industry
- Offering improved transport for the coastal settlements
- Creating new attractive landscape features (tourism)
- Delivering power when it is needed (a bit more by chance due to the timings of spring tides!)
- Potential for new energy storage facilities (lagoons and onshore reservoirs)
- Paying for itself through power generation.



Triple Regulation Turbine (2017)

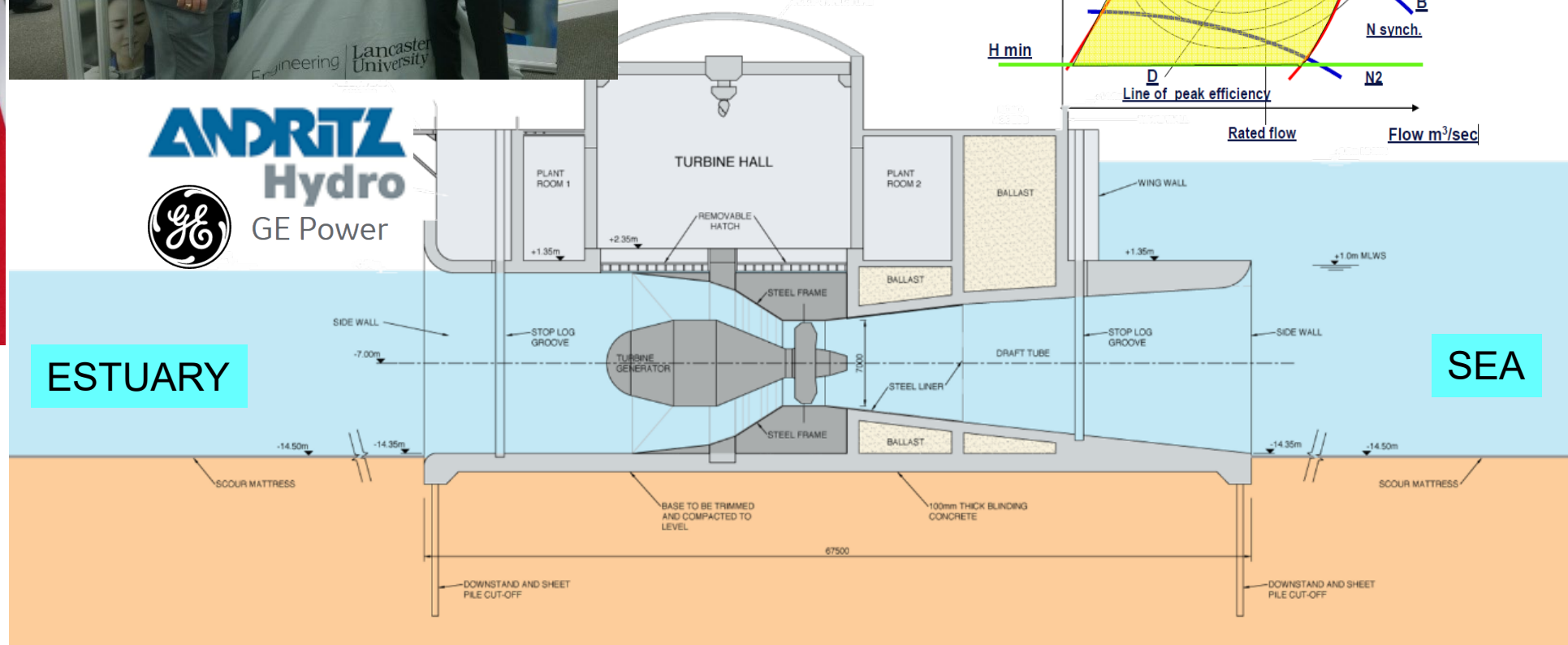


Prof George Aggidis
& Bernd Hindelang
ANDRITZ Hydro

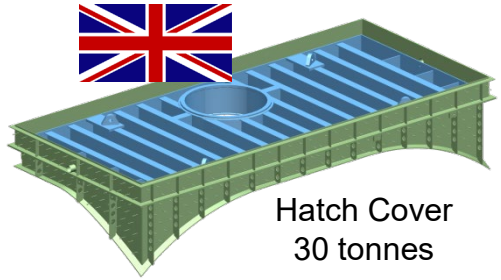


ANDRITZ Hydro

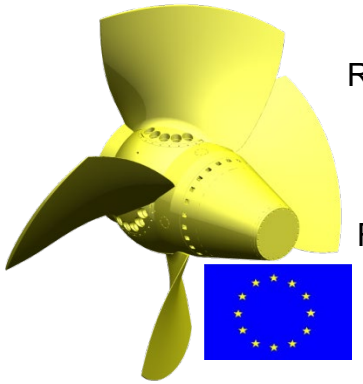
GE Power



Industrial Opportunities (2017)



Hatch Cover
30 tonnes

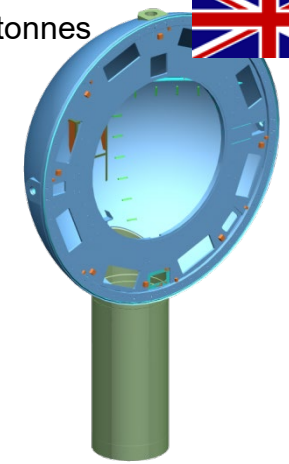


Runner blade
18 tonne

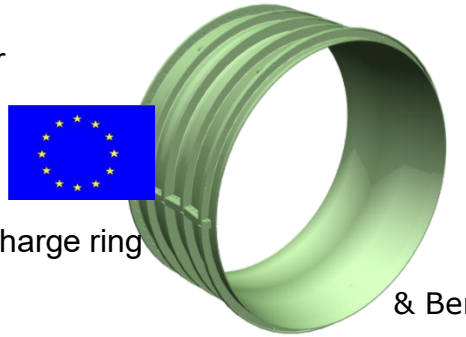
Runner hub
45 tonnes

Prof George Aggidis
& Bernd Hindelang, John Epps
ANDRITZ Hydro

Bulb Nose
20 tonnes

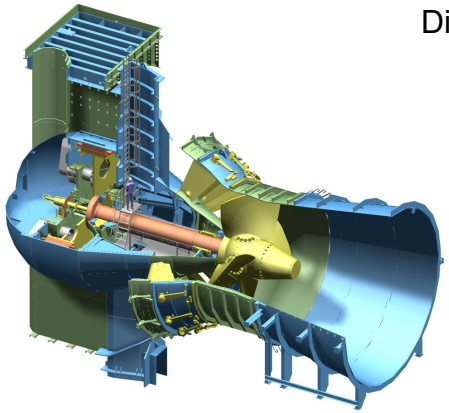


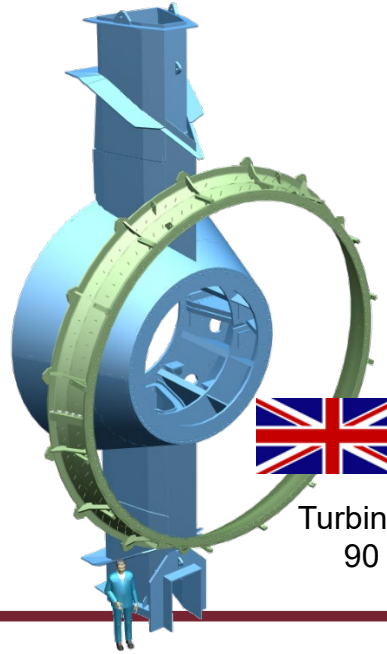
Runner



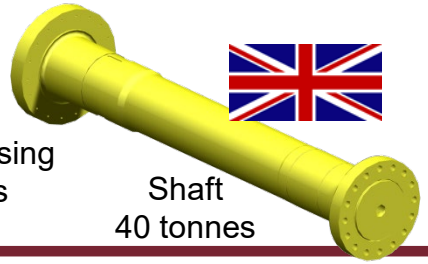
Discharge ring

Distributor
90 tonnes

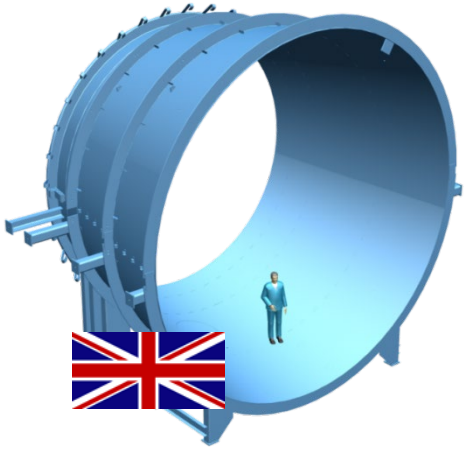




Turbine Housing
90 tonnes

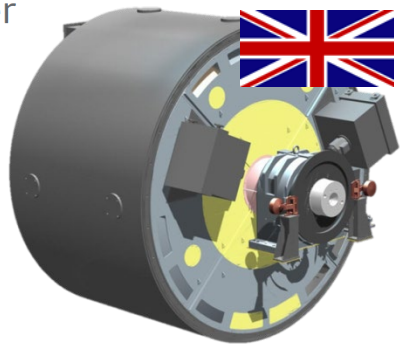


Shaft
40 tonnes



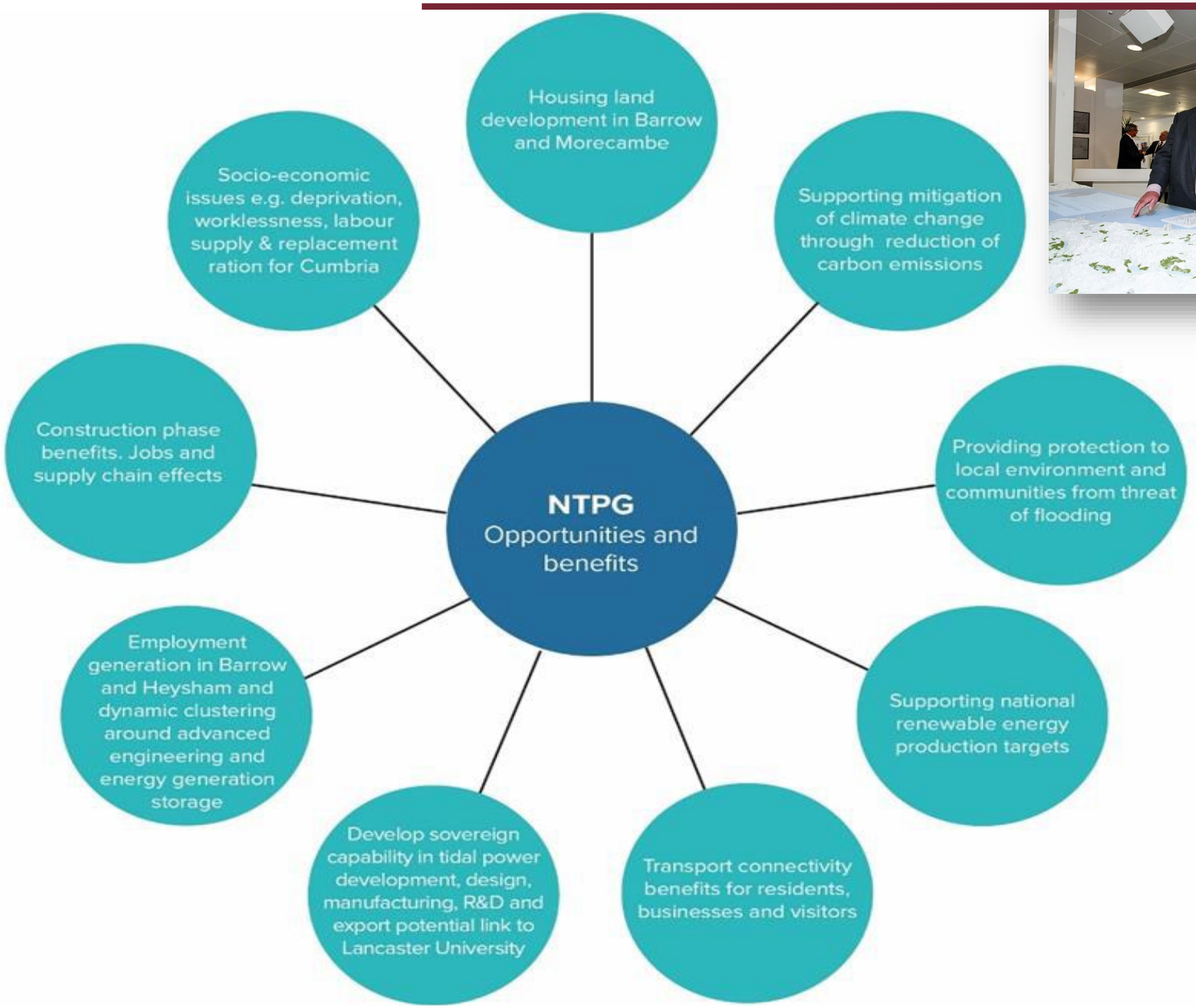
Draft Tube
40 tonnes

Bernd Hindelang
ANDRITZ Hydro &
Prof George Aggidis

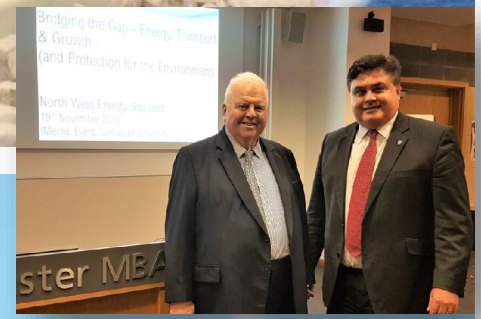


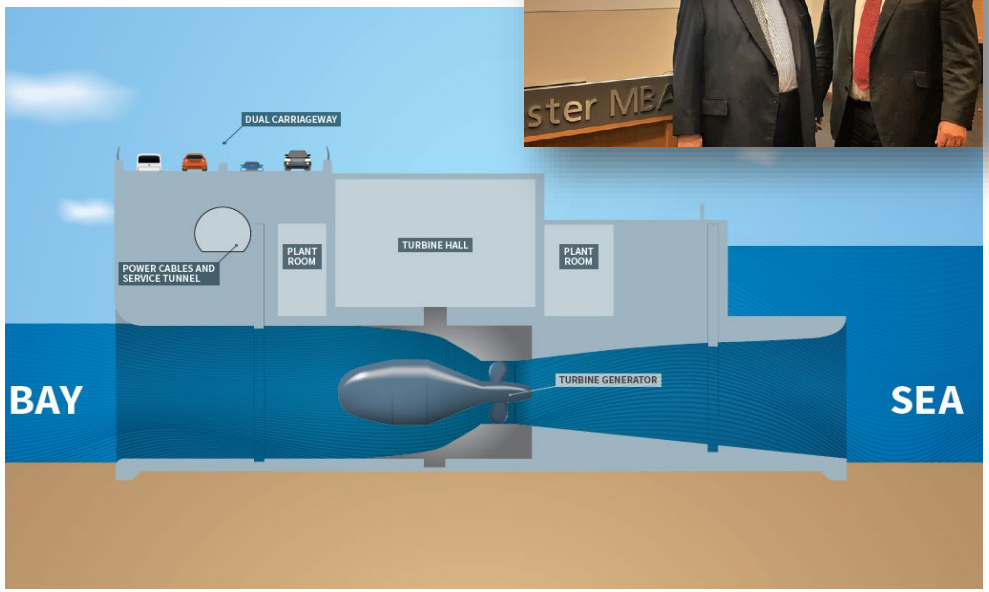
Generator

NTPG Morecambe & Dutton Barrages



Alan Torevell &
Prof George Aggidis





Overview

1. Introduction
2. Resource
3. Past
4. Present
5. Next Steps
6. Conclusions

Energy - LUREG Research

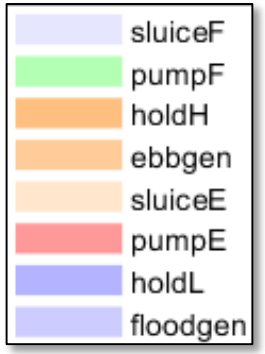
- Research on Renewable Energy & Fluid Machinery
  - Generic & Applied
- Energy & Renewables
  - Computational & Experimental Modelling
  - Device Development & Power take off
  - Computational Fluid Dynamics & Control
  - Economics, Resource & Condition Monitoring
- Novel Topology Fluid Machinery & Turbines
  - Computational Fluid Dynamics, Turbine Design & Analysis
  - Direct Drive & In Line Turbines
  - Siphonic Low Head & Low Cost Turbine Research
  - Fluid Machinery reliability & Energy Efficiency
- Funded by EPSRC, Carbon Trust, EU, RDAs, Utilities and Industry

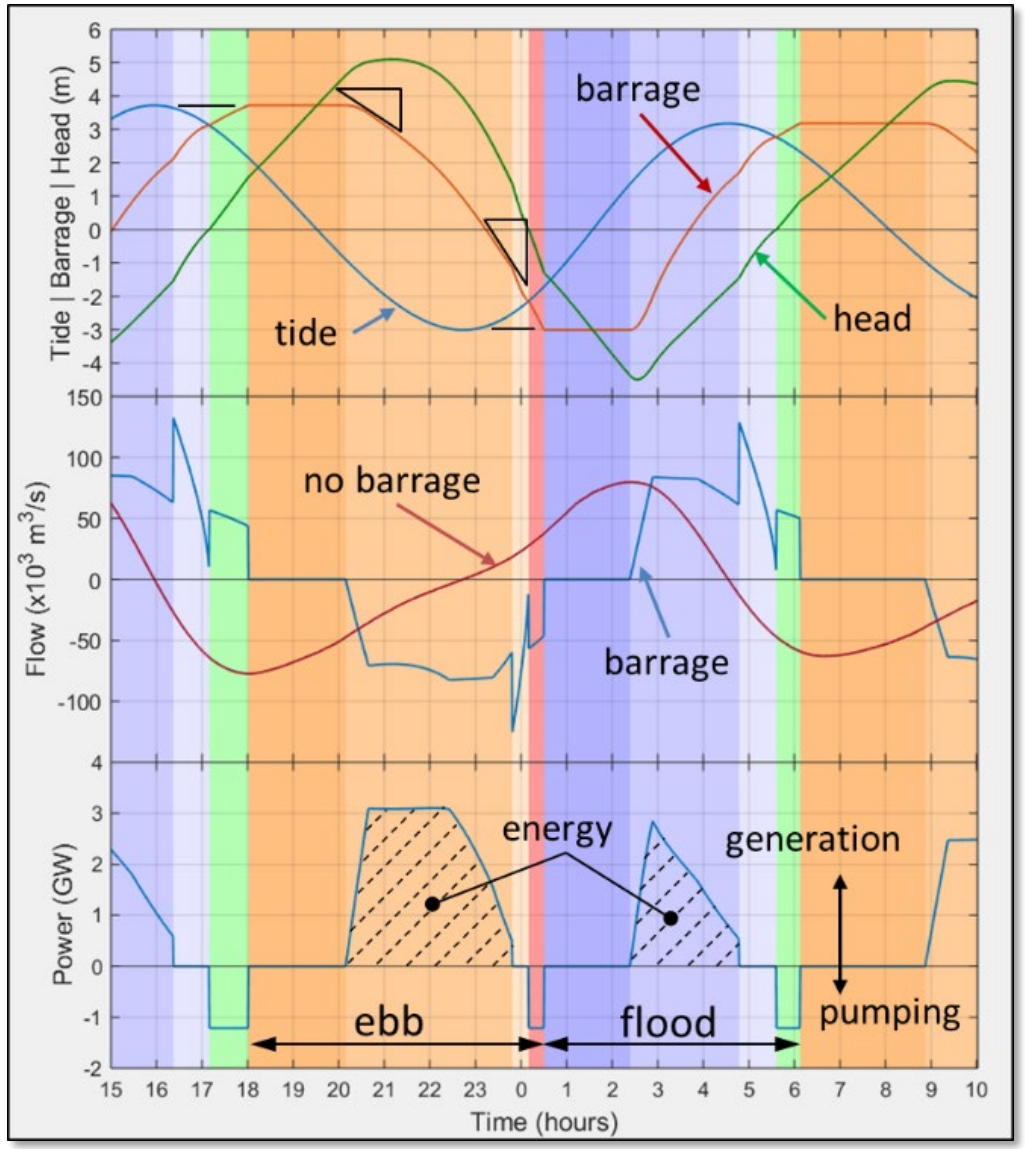
Lancaster University Engineering Building

Barrage operation

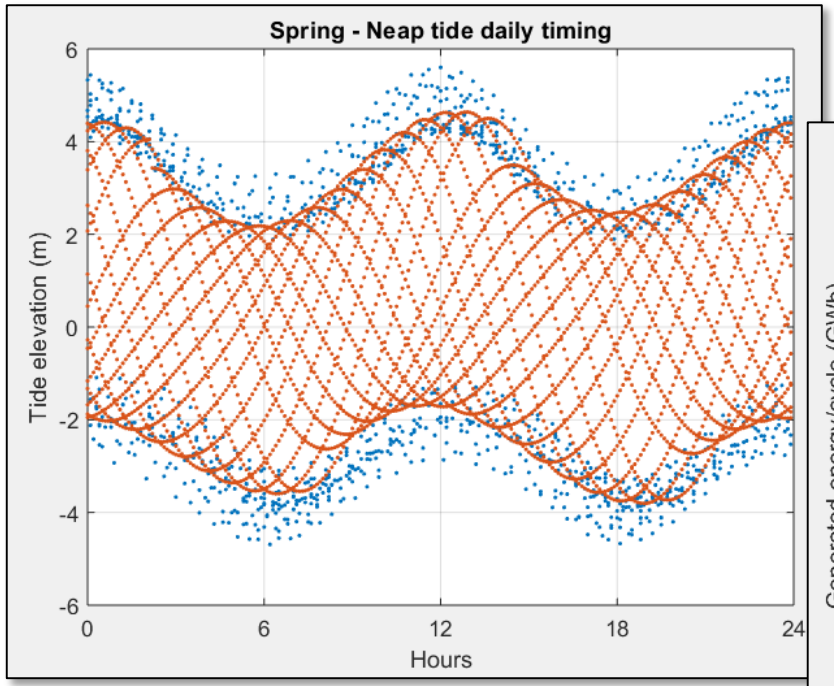
Pumping and tide matching

- Tidal flows and barrage fill is asymmetric due to the variation in wetted area with height - ebb and flood energy generation is different.
- Pumping occurs at low head and released at a higher head for nett energy gain
- The hold periods allow time for the head to build as the tide changes.
- The transition between phases is triggered when various head limits are reached.
- Overall control is achieved via a series of optimised operational parameters.

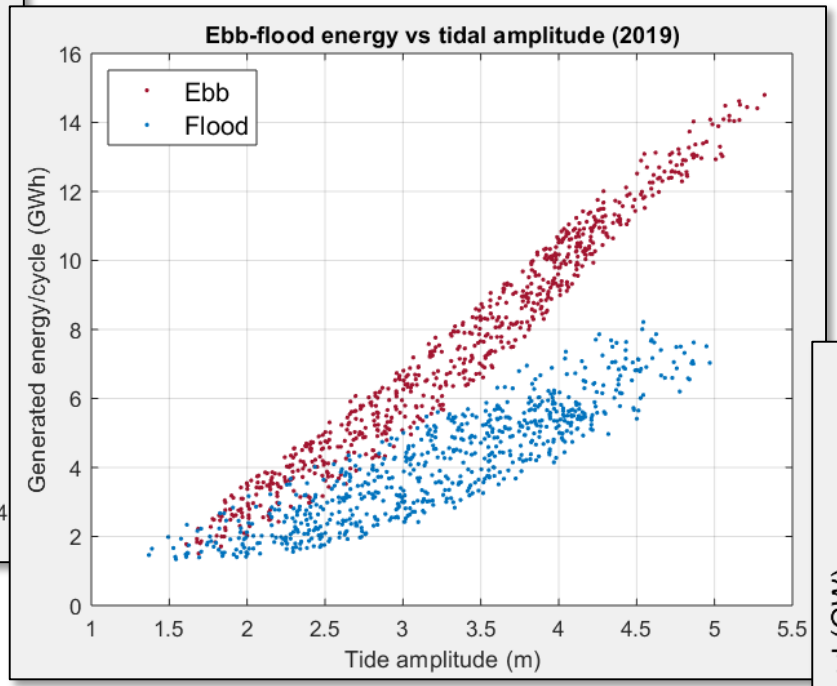




Variable generation

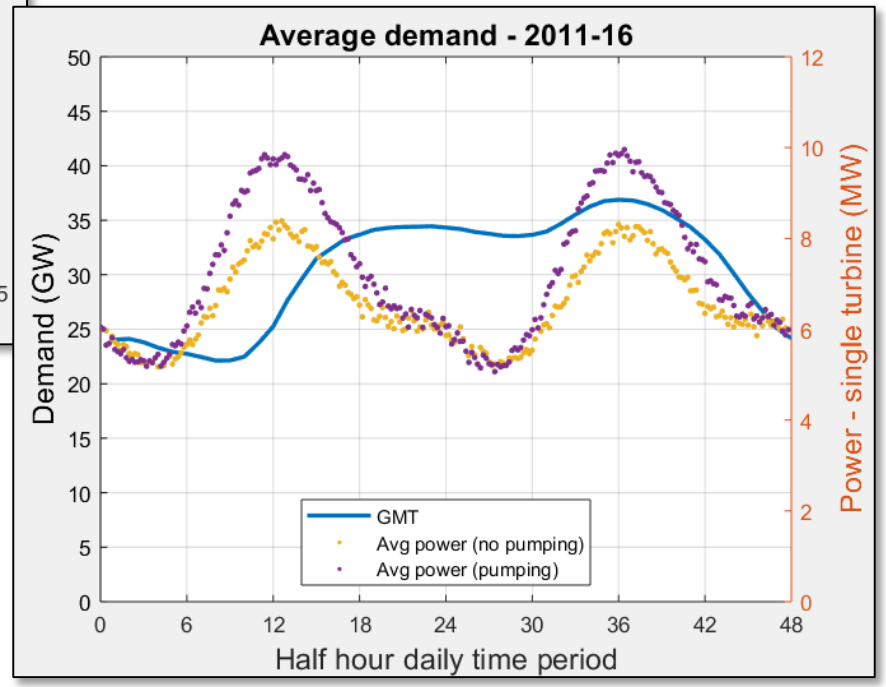


- Spring tides occur at the same time of day



- Significantly more energy in the spring tides
- Significantly more energy in the ebb tide

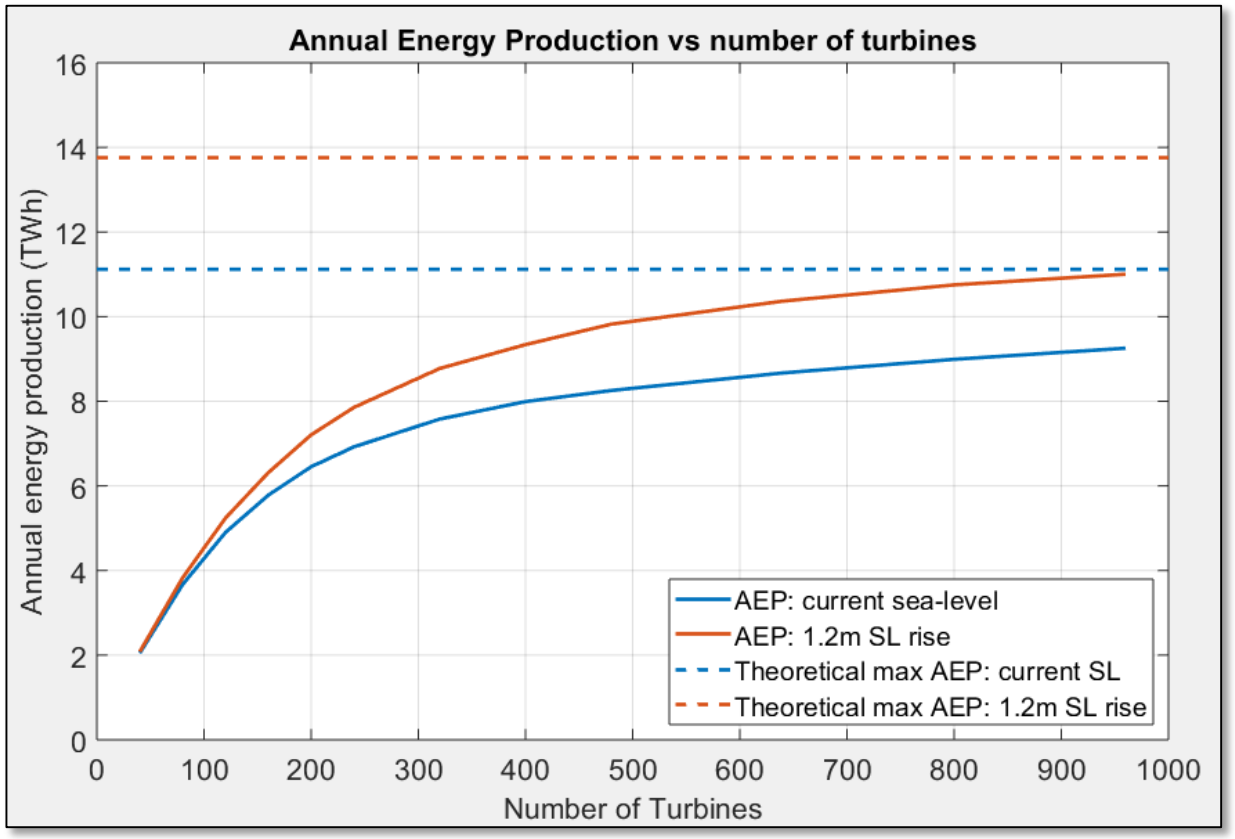
- Average daily supply profile dominated by the spring tide
- At Morecambe Bay supply peaks coincides well with demand



How many turbines?

The number of turbines is dictated by:

- Cost
- Space (with sufficient water depth)
- Flow velocity (sediment transport)
- Power and energy generation
- Future proofing (sea-level rise)
- Environment (tide matching?)

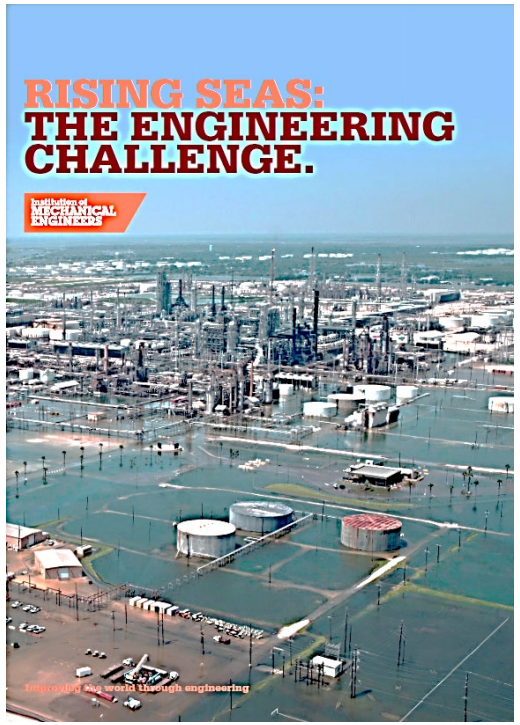


- Tidal range uses the potential energy of the water
- Maximum theoretical energy assumes the reservoir is dissipated instantly at maximum head
- More turbines => more energy, with diminishing cost benefit

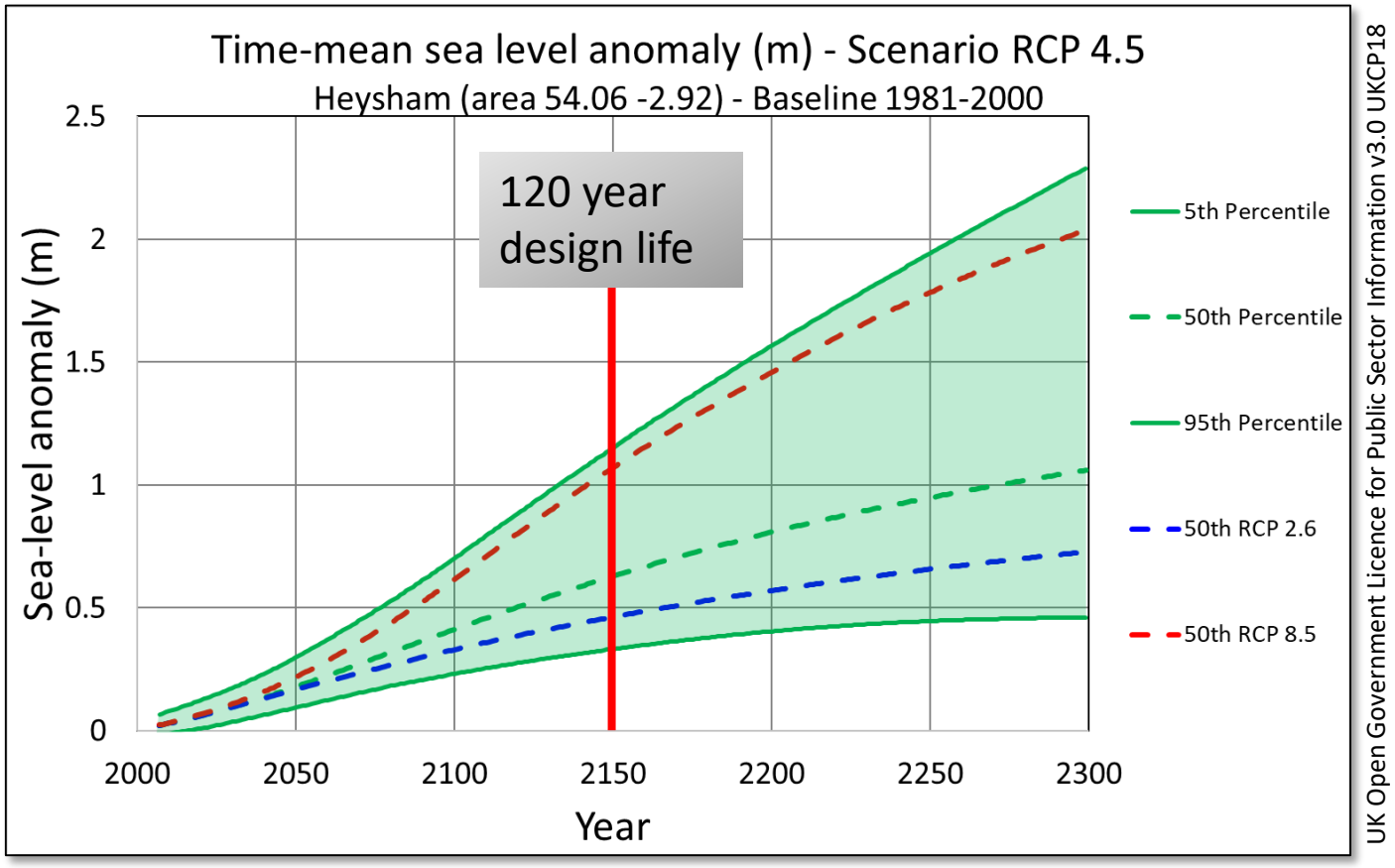
Sea-level rise

A **Representative Concentration Pathway** (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC for its fifth Assessment Report (AR5) in 2014.

Emissions in RCP 4.5 peak around 2040, then decline.

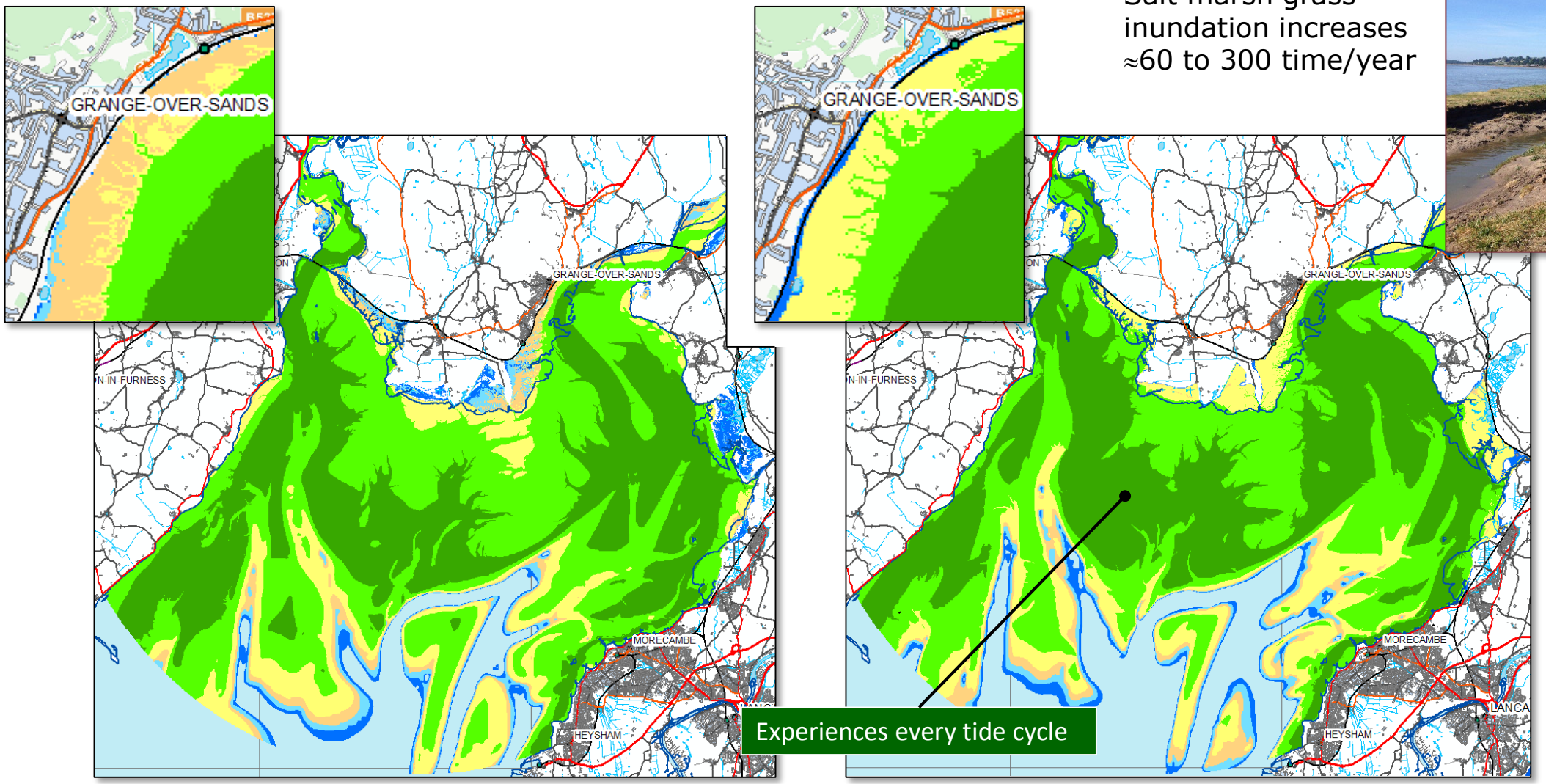


"…. prepare for a minimum of a 1 metre rise in sea level this century but plan for three metres of rise."



SL rise – inter-tidal zone

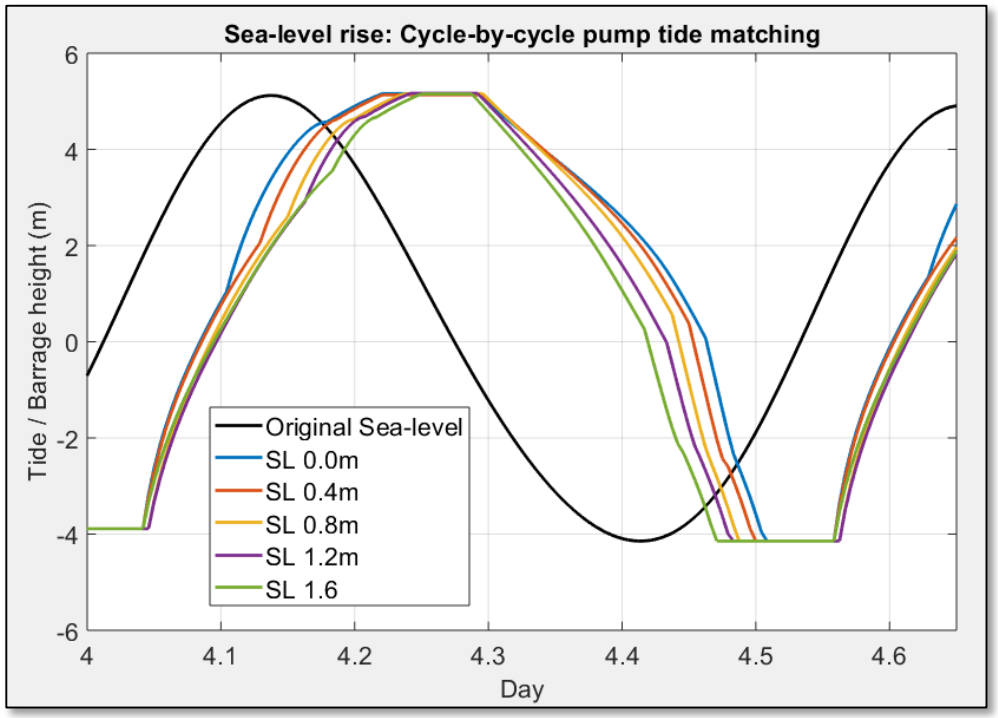
Salt marsh grass inundation increases ≈60 to 300 time/year



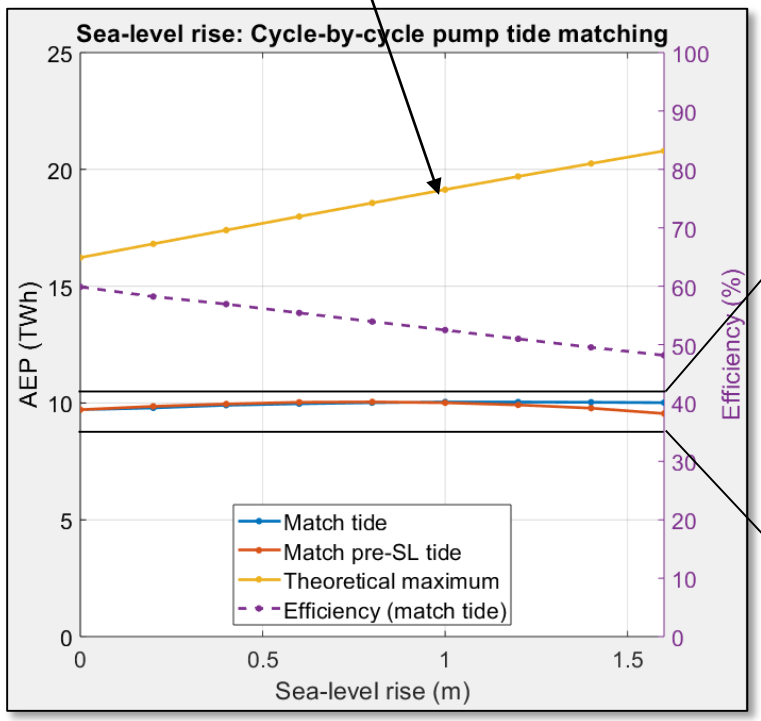
Current sea-level

+1.0 m SL rise

Sea-level rise: design implications

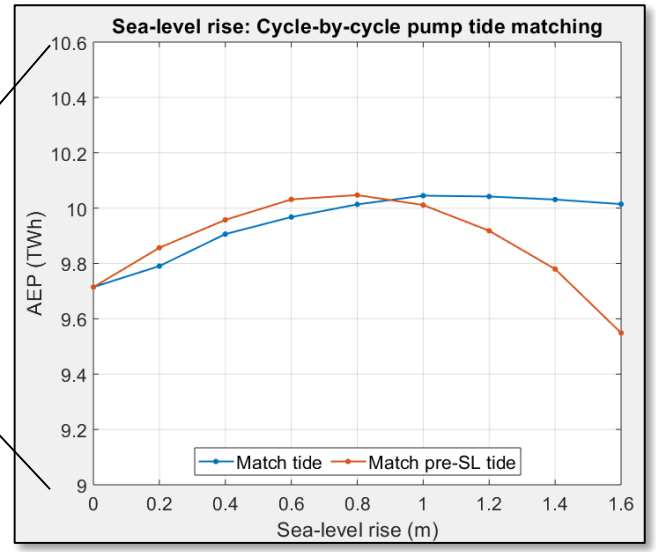


Significant increase in resource potential with SL rise



Initial increase in AEP with SL rise due to increasing resource

Increased pumping demand on limited number of turbines



Effect of increasing sea-level rise on AEP when tide matching (same number of turbines)

Tide matching only possible in some cases by forcing the generation phase to end early.

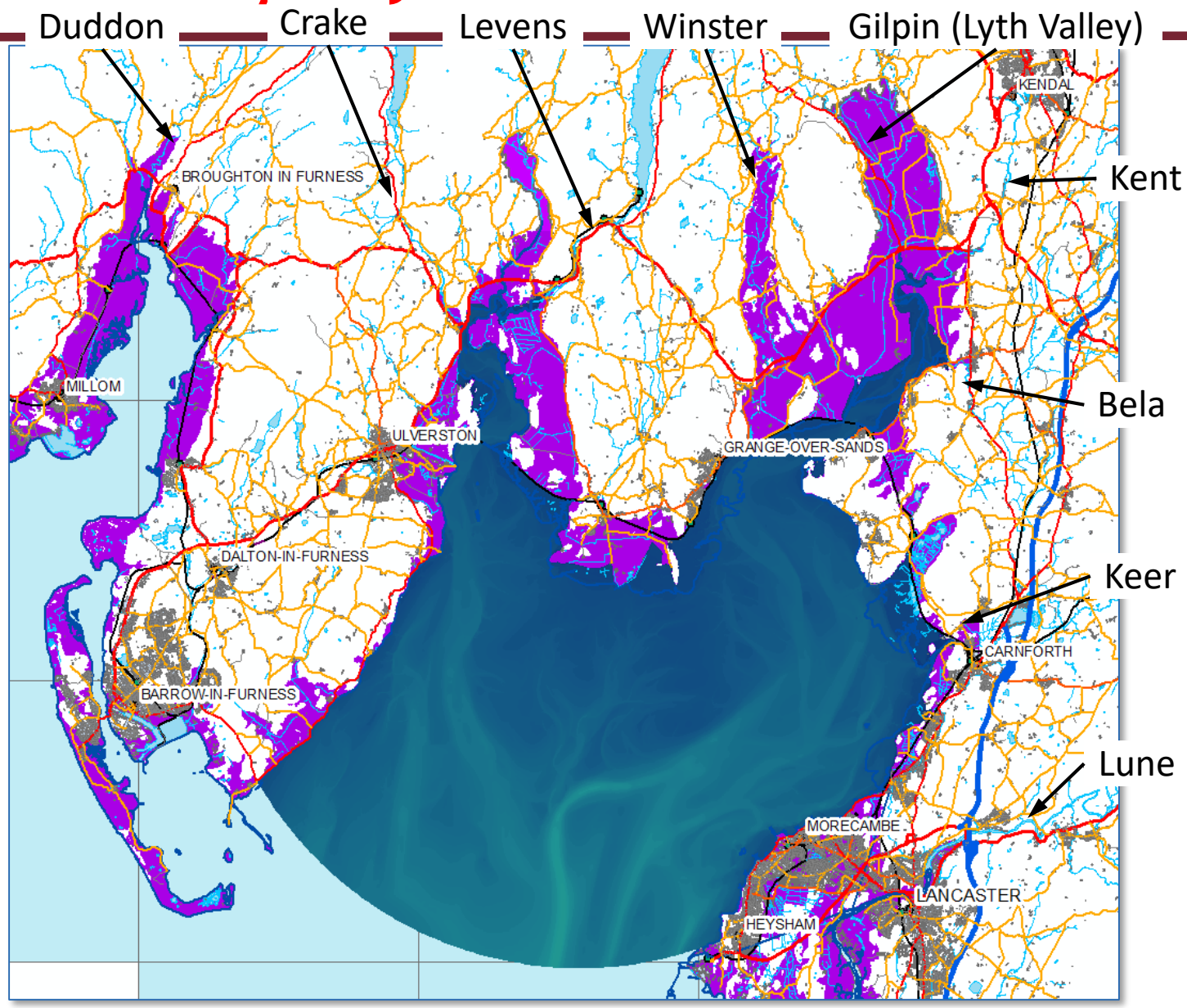
AEP penalty with tide matching at current sea-level.

Add more turbines to exploit the increased resource / to achieve tide matching

Low lying land <10m

The purple areas indicate land below 10m elevation

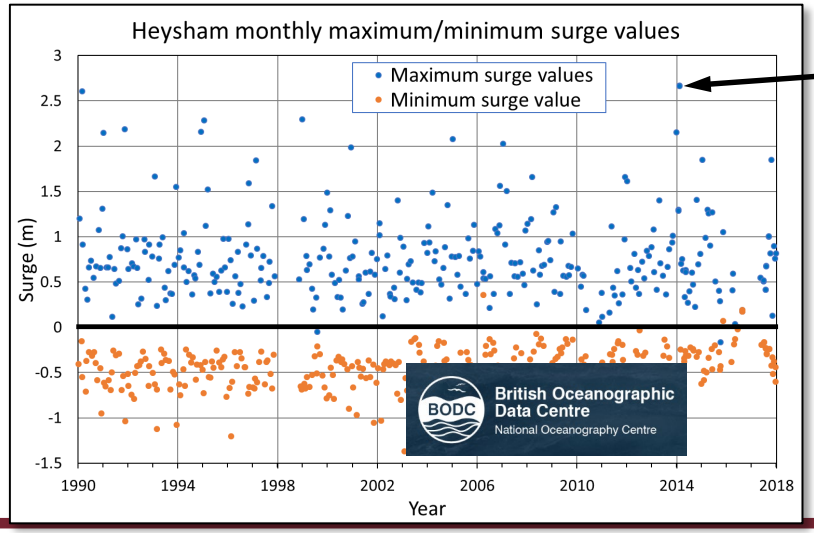
Dark blue area is the confined tidal area of the bay:
316 km^2



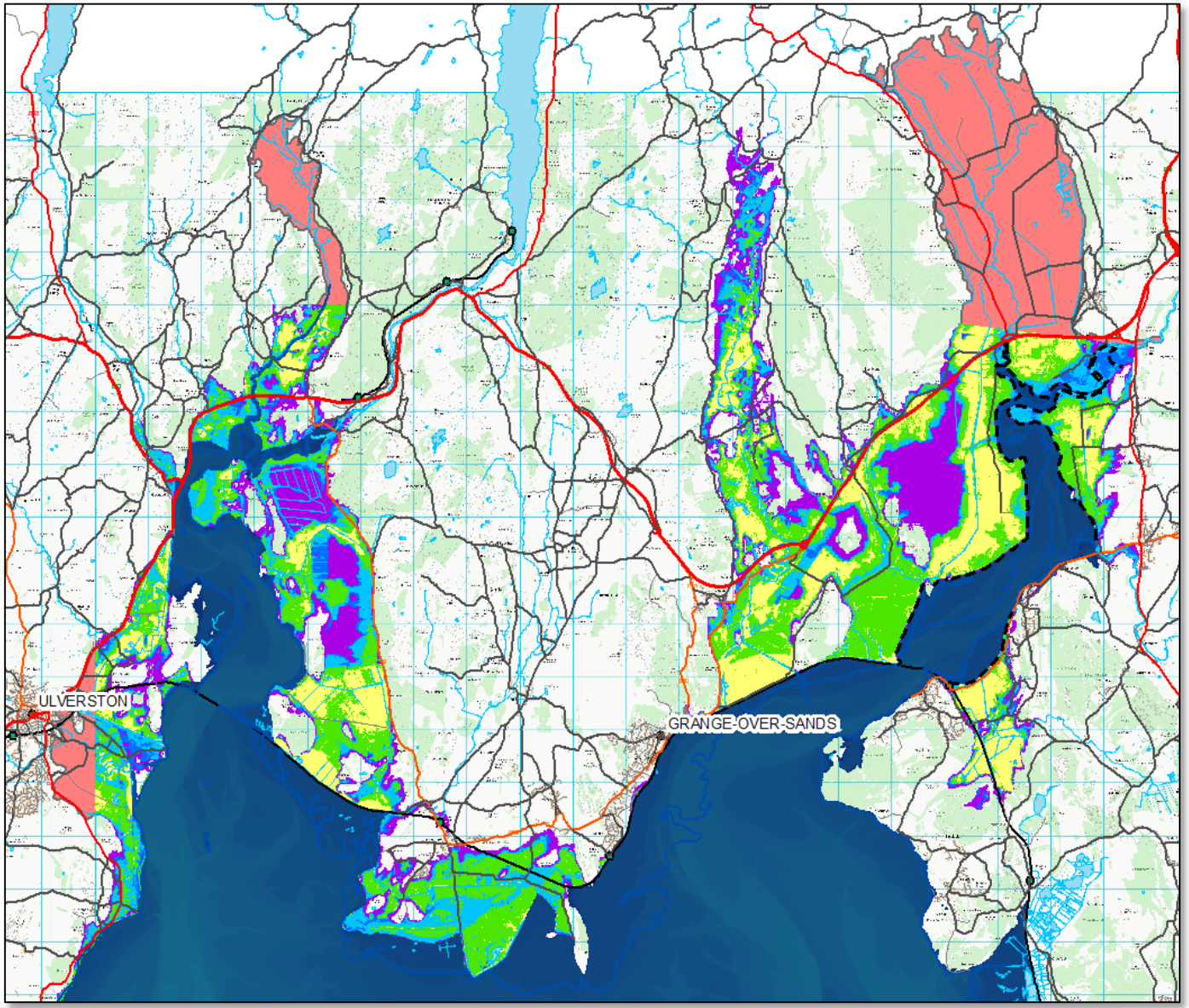
Land area < 10m

Height (m)	Area (km^2)	Cum. Area (km^2)
<= 4.8m (MHWS)	14	14
4.8 - 5.8m (HAT)	19.6	33.6
5.8 - 6.8m (+1m)	10.5	44.1
6.8 - 7.8m (+2m)	4.9	49
7.8 - 10m	9.8	58.8
No Lidar data	17.7	76.5

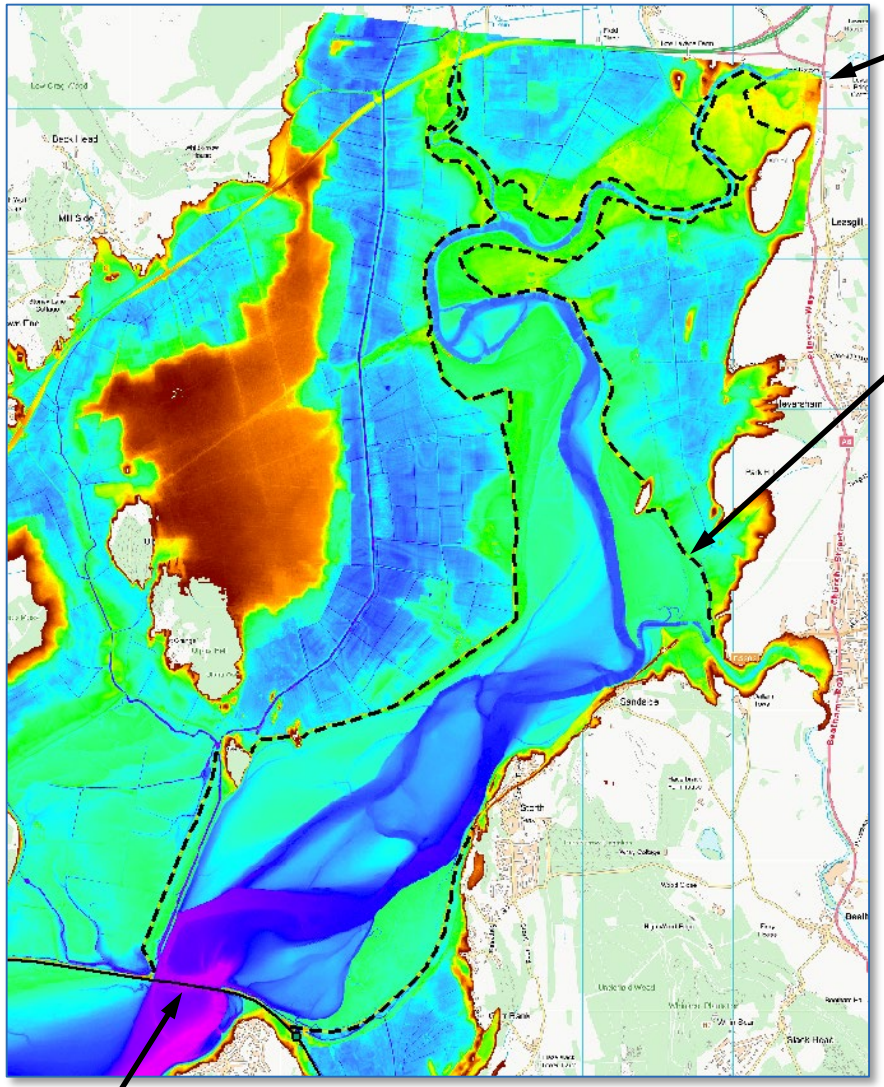
MHWS: Mean High Water Spring
HAT: Highest Astronomical Tide



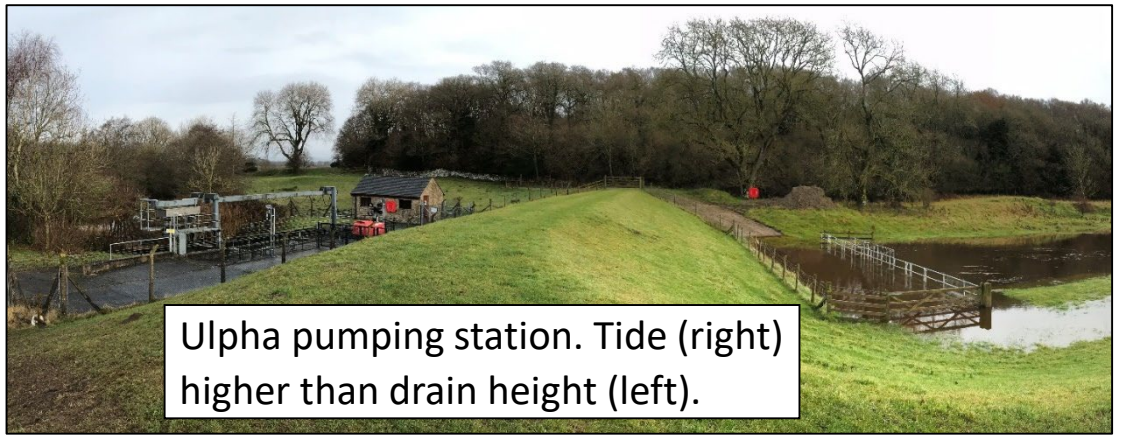
>2.5m surge



Extensive flood defences

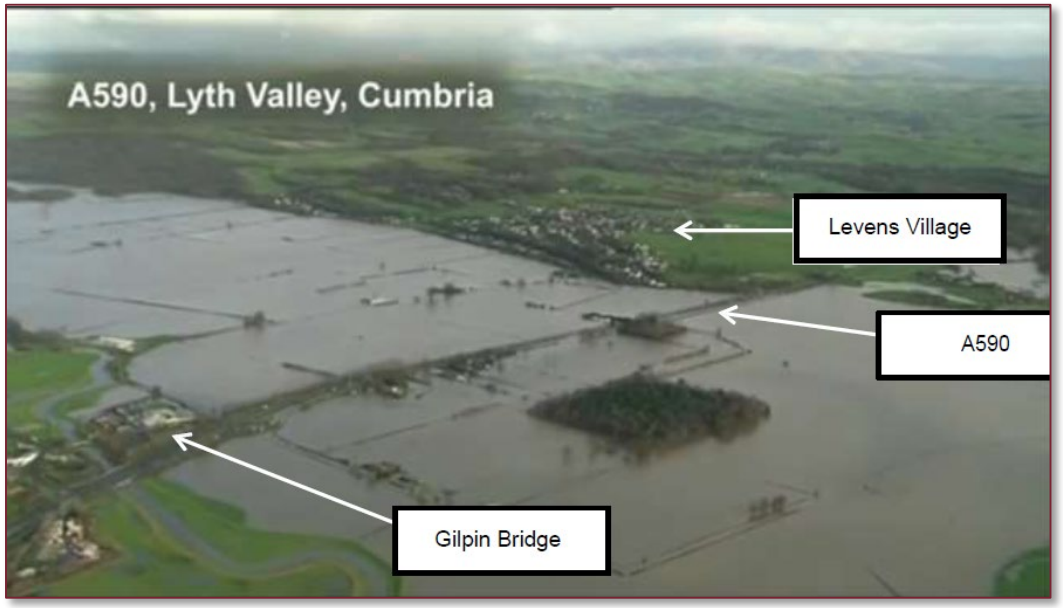


- 22 km embankments around the Kent estuary alone
- Roughly similar for the Levens estuary



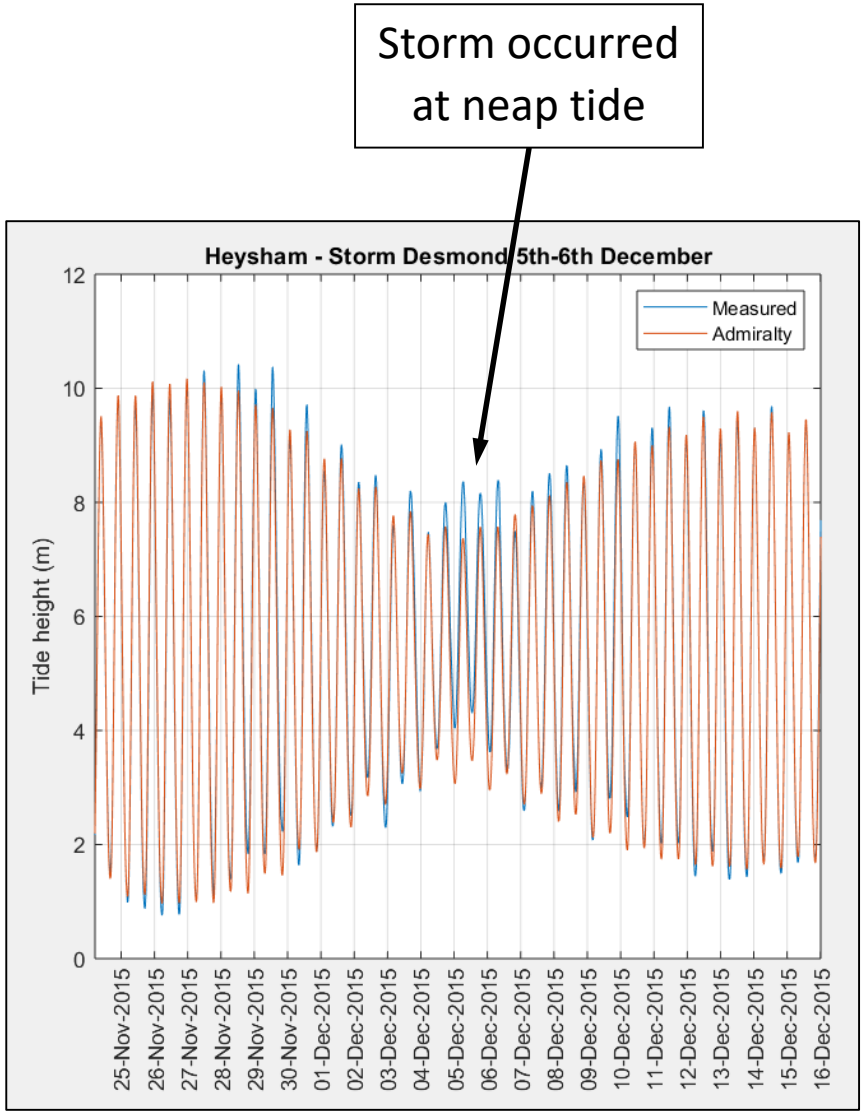
Ulpha pumping station. Tide (right) higher than drain height (left).

Storm Desmond (2015)



"The volume of floodwater combined with the restriction caused by the high tide, resulted in overtopping of the right bank of the River Kent in the area around Levens Hall and Levens Moss."

Lyth Valley Flood Investigation Report - Environment Agency



Morecambe Bay Flooding & Defences

Barrage & Natural Changes

- With no Barrage and no intervention Nature will take it's course

- Is the Environment better protected with a Barrage?

Revenue

- Prior to 2021 the average wholesale price of electricity was around £45/MWh.
- The rapid rise in 2021 has been explained as the post-Covid demand increase.
- Due to the war in Ukraine, the 2022 average price to date is £185/MWh.
- To put these figures into context, the Swansea Bay tidal range scheme was looking for a CfD of £95/MWh.

Half-hourly wholesale system sell price from Elexon best view prices
https://www.elexon.co.uk/data/open-settlement-data/

Year	Sell price, £/MWh		
	Average	Maximum	Minimum
2016	40.0	1,528.7	-100.0
2017	45.1	1,509.8	-73.1
2018	57.4	990.0	-150.0
2019	41.9	375.0	-88.0
2020	34.9	2,242.3	-70.5
2021	113.2	4,037.8	-70.0
2022 to date	185.1	4,036.0	-90.3
Average	74.0	2,102.8	

Research & Eden North

- Lancaster University's work suggests:
  - Further research and modelling needed to optimise and balance the requirements of climate change, environment & energy generation, energy storage & grid supply against energy demand. In addition to triple regulation & modelling accuracy (0D, 2D & 3D).
  - More pumps are required to successfully maintain the environmental status sea level rise and mitigate serious flooding.
- Due to the proposed recommendation by the Benyon Report 2019 and its status as a Highly Protected Marine Area, Morecambe Bay is now an unlikely location in NW England for a power only project.
- We welcome this report which has helped further development of the holistic benefits of Morecambe Bay Tidal Barrage project.
- Establish links with the Lancaster University Eden North Project. A unique and ambitious project that seeks to reimagine the seaside resort for the twenty-first century. The project has far-reaching environmental, social and economic ambitions.

Overview

1. Introduction
2. Resource
3. Past
4. Present
5. Next Steps
6. Conclusions

Benefits today

1. Opportunity to establish a British lead in the sector.
2. Protecting the local landscape and habitats from flooding (terrestrial and marine).
3. Providing skilled jobs in a long term industry.
4. Offering improved transport for the coastal settlements.
5. Creating new attractive landscape features (tourism).
6. Delivering power when it is needed (a bit more by chance due to the timings of spring tides!).
7. Potential for new energy storage facilities (lagoons and onshore reservoirs).
8. Paying for itself through power generation.

Potential beyond Morecambe Bay

a. A network of tidal energy sites along the west coast of GB.

b. Protection from flooding and sea level rise.

c. Delivering distributed power along the west coast.

d. Improved transport links (with some schemes).

e. Reduced reliance on foreign fossil fuels.

f. Funded through power generation.

Conclusions

1. Primary Focus

Health, Wellbeing, Green Jobs & Environment - Climate Emergency

- This is why we need to build a Morecambe Bay Tidal Barrage
- All UK estuaries will be seeing same pressures from **rising sea level**
- **Therefore a Barrage across the Bay is now essential**

2. Secondary Focus

Energy, Storage and Grid

Institution of MECHANICAL ENGINEERS

Lancaster University

Thank you

Thomas Lowe Gray Lecture 2022

Morecambe Bay Tidal Barrage

EUR ING Professor

George Aggidis

FIMechE, FIMarEST, FEI, FIET

Head of Energy Engineering

g.aggidis@lancaster.ac.uk