A Simple Method for Assessing Tidal Barrage Energy Potential

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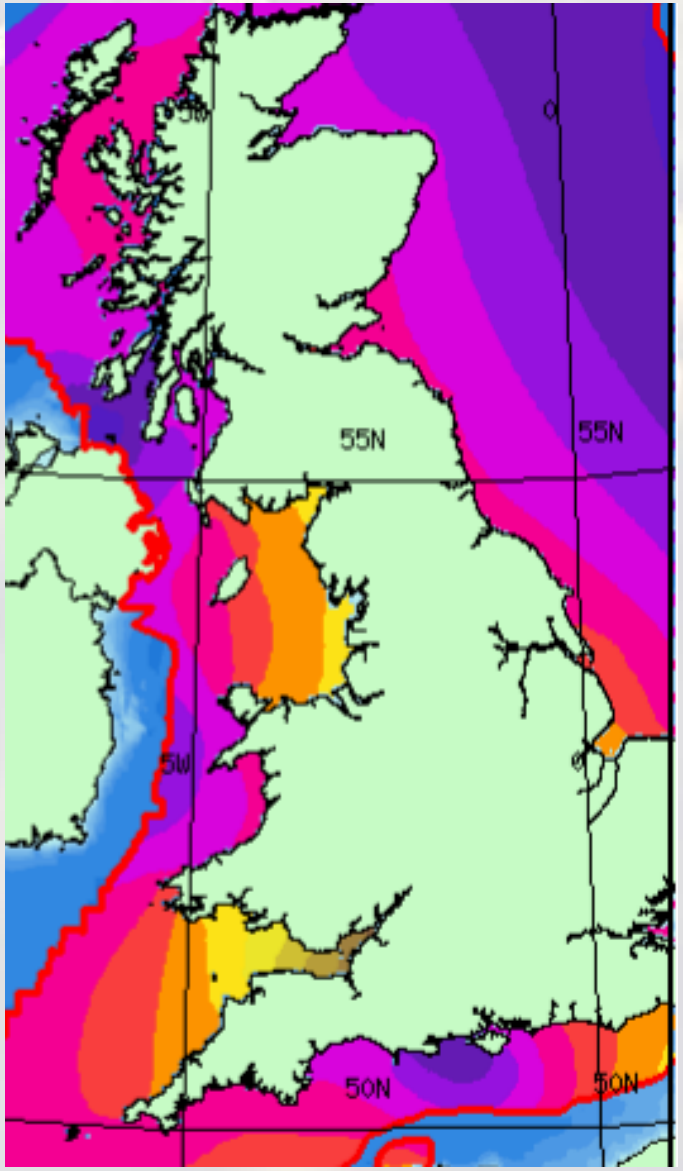
Context

- Global warming and energy demand increasing
- UK Government committed to reducing greenhouse gas emissions
- Aim for 32% renewable electricity by 2020
- UK has some of the best tidal power potential in the world
- An estimated 48% of European tidal range resource (Hammons, 1993)

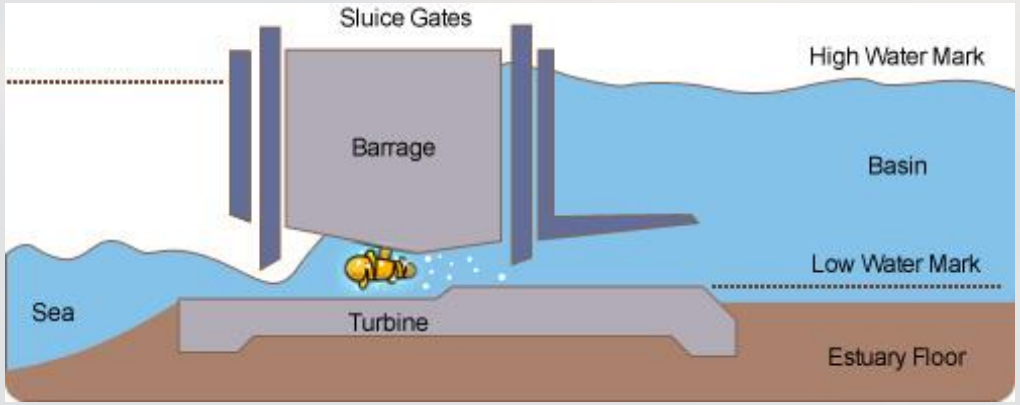


Scope

- Look at the potential of UK as a whole
- Ranking the relative merits of best UK estuaries
- Focus on **energy output** and **cost**
- Attempt to find relationship between geometrical parameters and energy/cost ratio

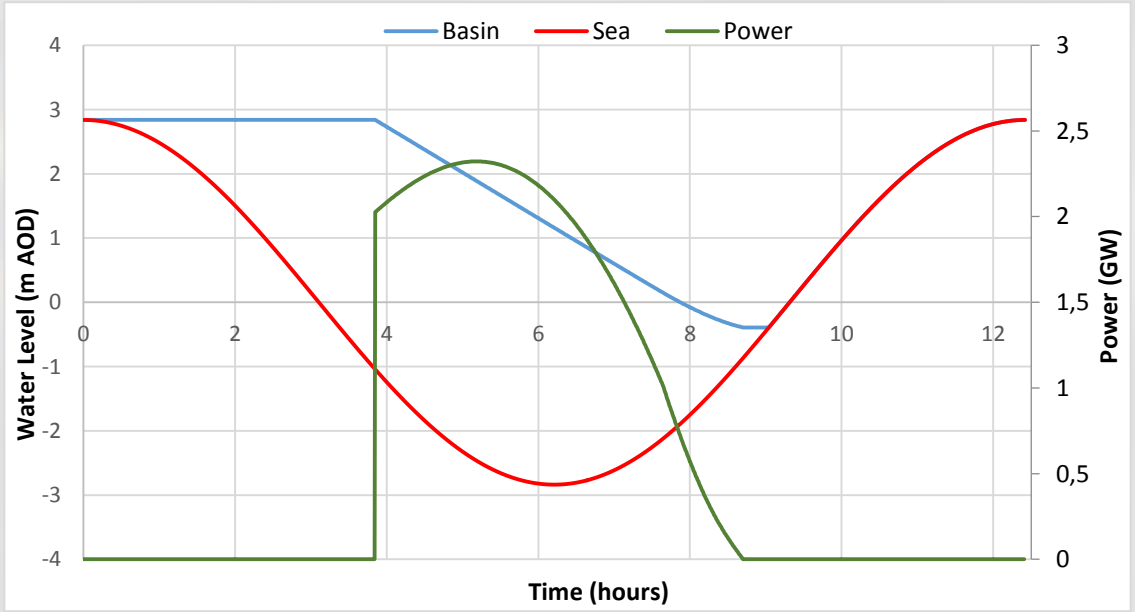
Tidal Barrages

- Proven technology
- Most reliable renewable energy source
- Predictable but non-constant output.
- Barrages consist of a barrier containing sluice gates and turbine-generators across a tidal estuary
- Three modes of operation: Ebb, Flood and Two-way.



Ebb Generation

- Estuary filled by flood tide through open sluice gates
- Sluice gates closed at high tide for given time period allowing differential head to form across the barrage
- Power generated related to head difference, flow rate and mechanical efficiencies



- First large-scale modern tidal power plant opened in 1966 in Brittany, France: 540GWh per year from 240MW capacity
- Sihwa Lake Tidal Power Station largest currently operating in South Korea: 550GWh annually from 254MW capacity
- Yet to be introduced in the UK
- Yet to be used at a large scale

Methodology

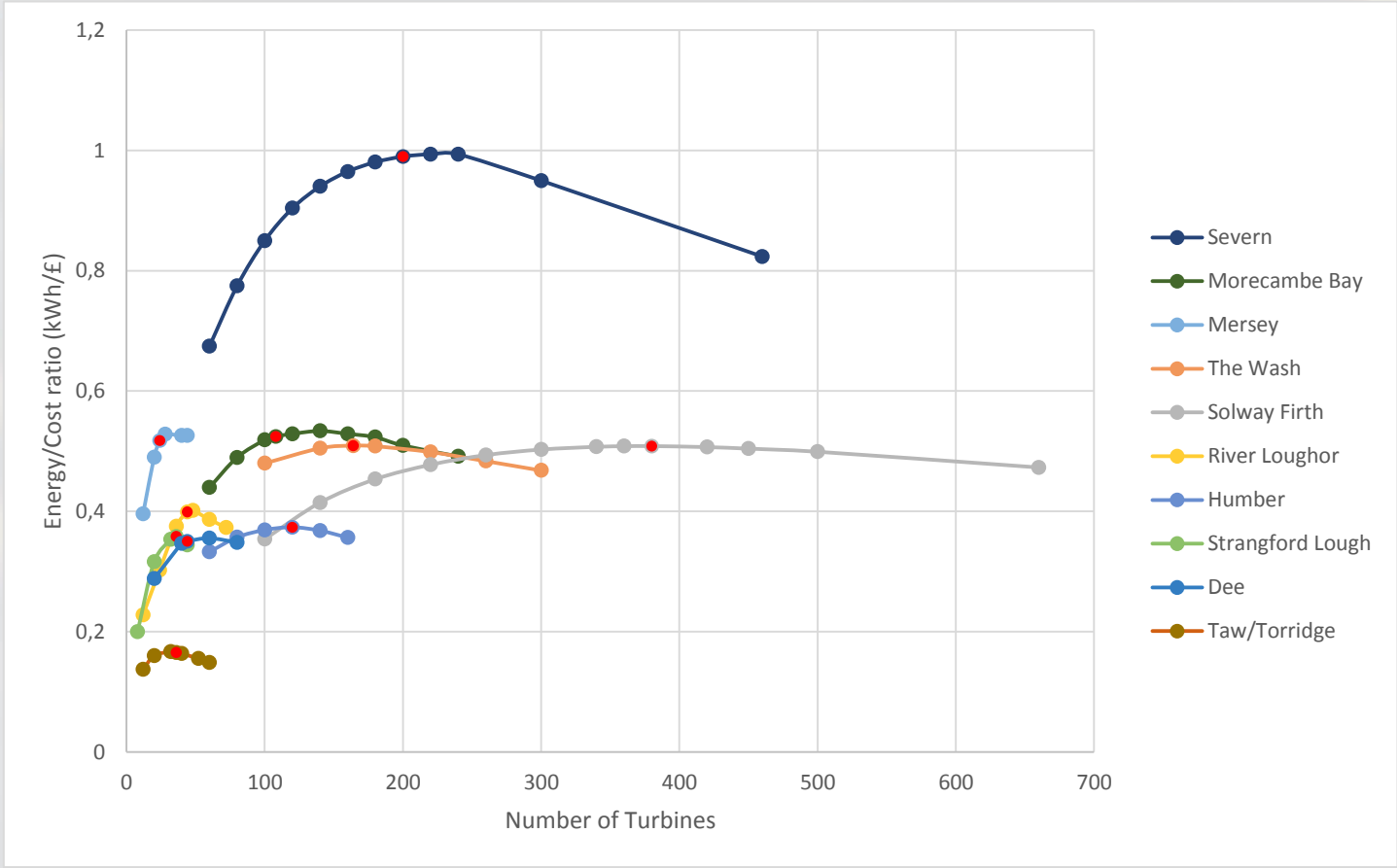
- Initial screening process found ten sites with best estimated potential

Methodology

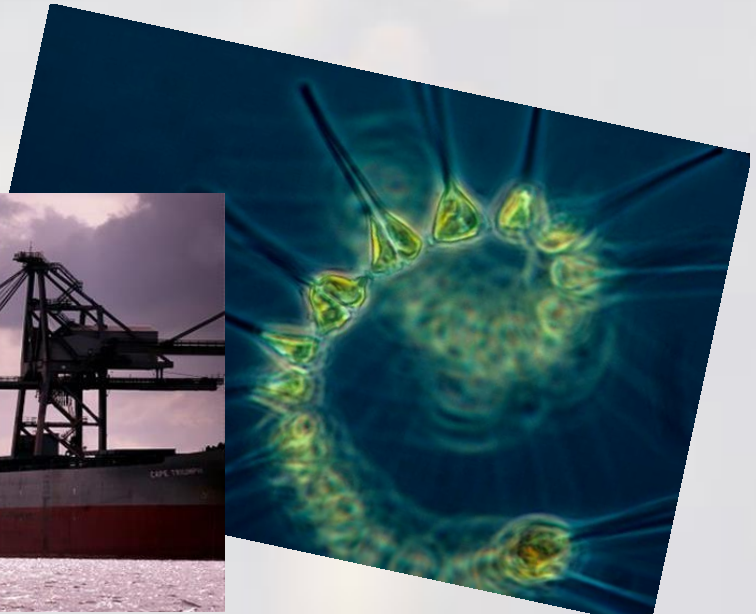
- Detailed ‘0-dimension’ spreadsheet analysis setup
- Input variables: tidal range, basin area, turbine diameter
- Optimisation exercise to find optimum number of turbines
- For each of these values, optimum turbine start time and rotational speed calculated
- Costs calibrated based primarily on 2008 DECC report into a possible Severn Barrage

Energy and Cost Results

- Energy/Cost ratio vs Number of Turbines
- Severn highest E/C ratio
- Larger schemes more beneficial
- Mersey the best of the smaller schemes



Environmental and Social Impacts



Ranking

Scheme	Energy Output (TWh/yr)	Energy/Cost (kWh/£)	Environmental Impact	Social Impact
Severn	17.02	0.981	Very Negative	Moderately Negative
Morecambe Bay	5.69	0.518	Very Negative	Slightly Negative
River Mersey	1.302	0.518	Slightly Negative	Moderately Negative
The Wash	6.00	0.509	Severely Negative	Slightly Positive
Solway Firth	12.89	0.495	Very Negative	Slightly Positive
Burry Inlet	0.771	0.399	Moderately Negative	Slightly Positive
River Humber	2.756	0.374	Very Negative	Severely Negative
Strangford Lough	0.696	0.358	Somewhat Negative	Moderately Positive
River Dee	1.764	0.350	Very Negative	Slightly Positive
Taw & Torridge	0.189	0.166	Slightly Negative	Slightly Positive

1. Severn
2. Mersey
3. Morecambe Bay
4. Solway Firth
5. The Wash
6. Burry Inlet
7. Strangford Lough
8. Dee
9. Humber
10. Taw & Torridge

- Together the ten locations produce 49TWh per year
- Equivalent to 13.5% of the UK energy demand
- Four largest schemes account for 86% of that figure

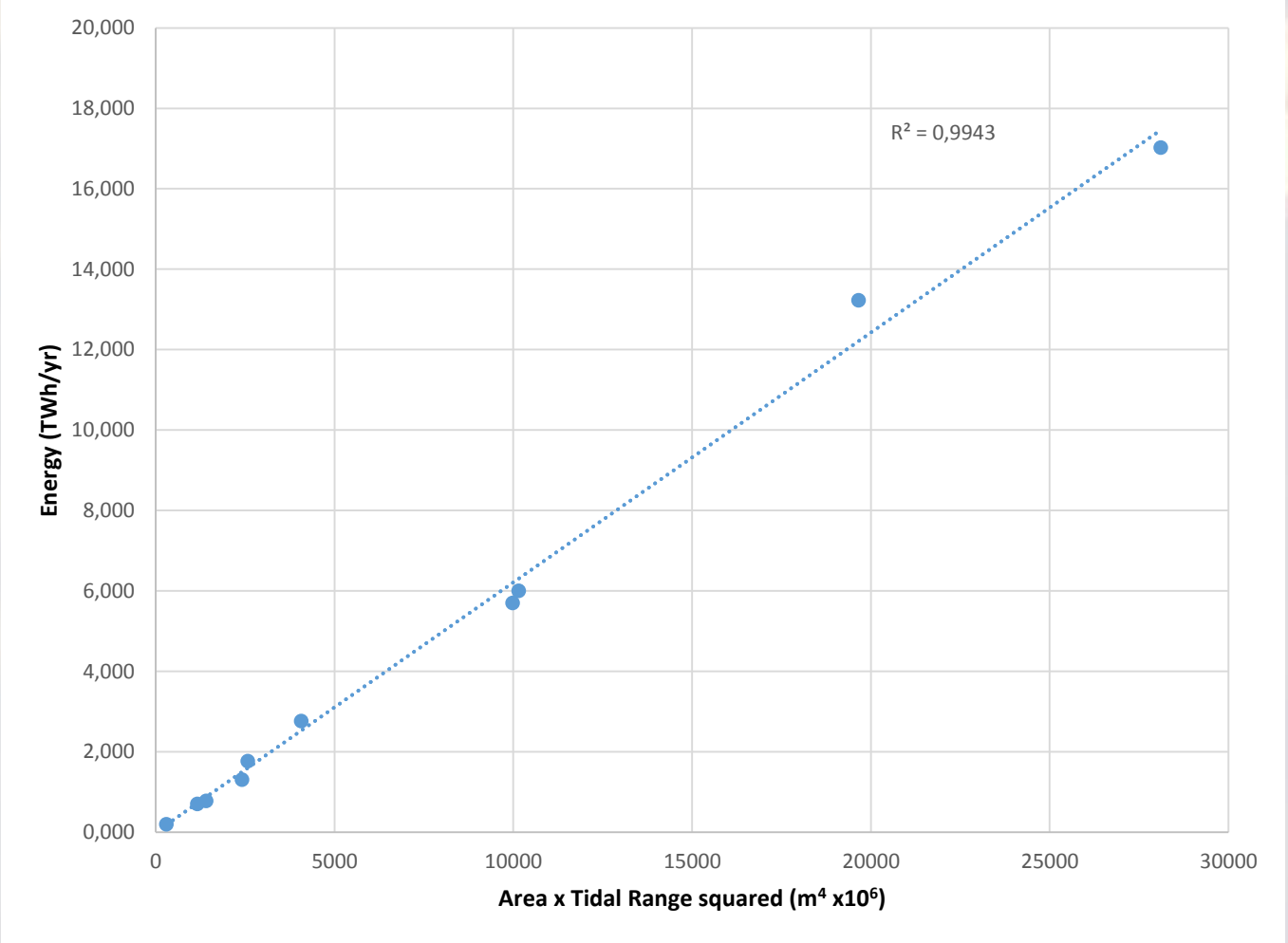
Effects of Location Paramaters

Energy

- Theoretical Energy Limit:

$$E_{max} = \frac{\rho_w g A H^2}{2}$$

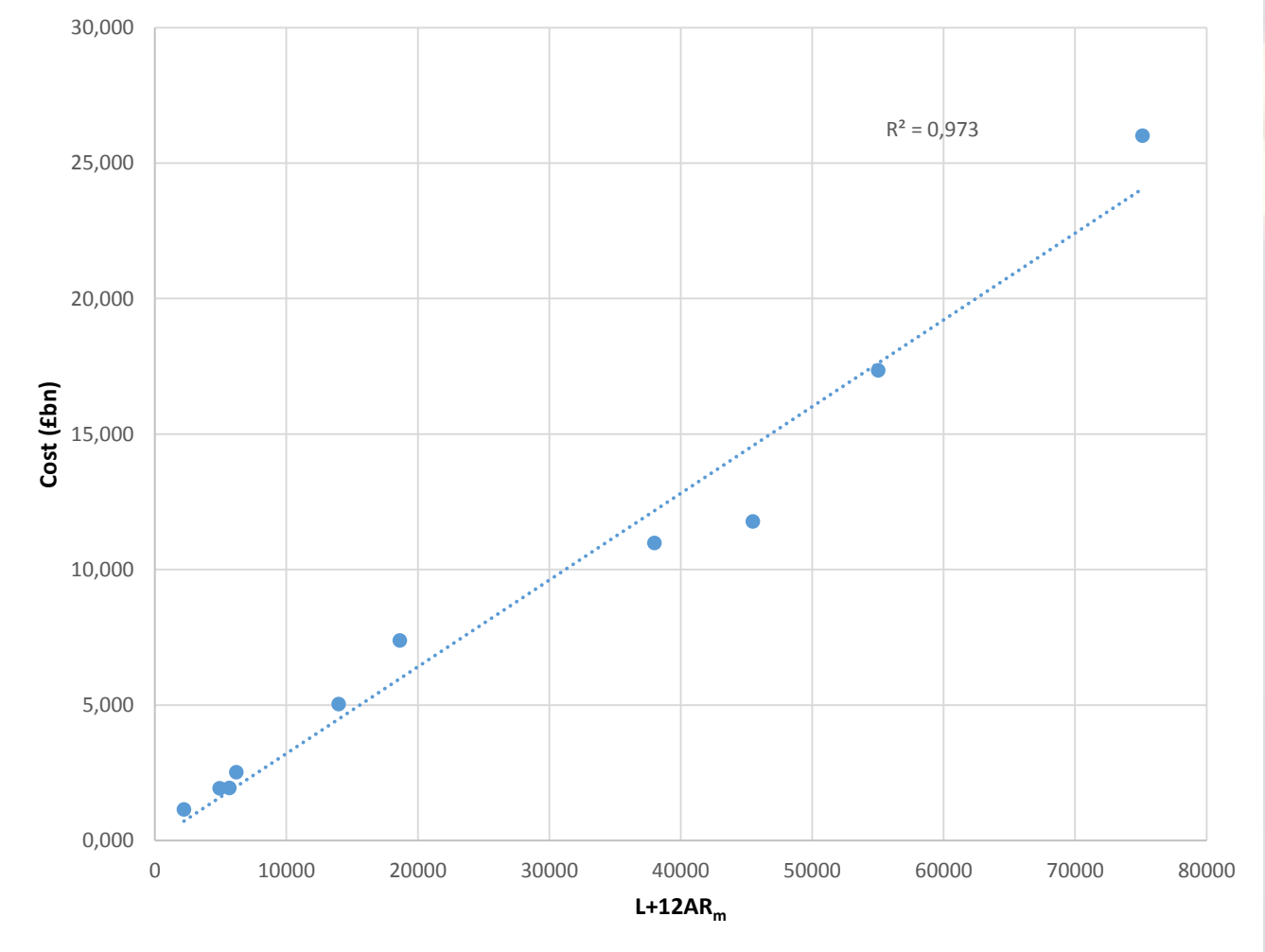
- Energy vs $AR_m{}^2$
- $R^2 = 0.994$
- Closely linear relationship



Effects of Location Paramaters

Cost

- More complex
- Based on Length, Area and Tidal Range
- Cost vs L + $12AR_m$
- $R^2 = 0.973$
- Closely linear relationship



Effects of Location Parameters

Energy

- $E = \frac{AR_m{}^2}{1610}$

Cost

- $C = \frac{L+12AR_m}{3123}$

$$\frac{E}{C} \propto \frac{AR_m{}^2}{L + 12AR_m}$$

(L and R_m in metres, A in km^2
E in TWh/year
C in £bn at 2008 prices)

Conclusion

- Top 5 UK Schemes: Severn, Mersey, Morecambe Bay, Solway Firth, The Wash
- Together could produce 12% of UK energy demand
- Proportional link between energy output and product of area and tidal range squared
- Proportional link between cost and area, tidal range and barrage length
- Relative merits of any estuary worldwide can be quickly estimated using the combined relationship

Thank you for listening,

Thank you EUREC!