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Morecambe Bay: Innovation for Clean Energy Generation

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ABSTRACT

The Carbon Trust Report CTC601 (2006) concludes that by 2020 up to 1 to 2.5GW of total installed capacity of tidal stream energy could be generated across Europe abating a total of up to 3.7 MtC02/y. The report also concludes that up to one sixth of the UK government aspiration of 20% renewable energy by 2020 could be met by marine renewables. Our proposition is that there is a worldwide opportunity for local and distributed renewable tidal energy from estuarine and other benign tidal settings. This paper discusses the proposal to evaluate a full-scale leading edge intelligent vertical axis turbine that is capable of energy extraction in flows of less than 2.5m/s and depths of less than 25m with negligible environmental impact. The technical innovation is the turbine design and related control instrumentation to improve device performance. The devices would be capable of integration into existing and new infrastructures producing savings in capital, deployment, operation and maintenance. The aim is to integrate and deploy these free-stream turbines as part of the development of a bridge across Morecambe Bay by 2020. This will accelerate learning about tidal farms and at the same time bring significant economic benefit to two deprived communities.

MARINE RENEWABLES IN EUROPE

Tidal energy conversion techniques exploit the natural rise and fall of the level of oceans caused principally by the interaction of the gravitational fields in the planetary system of the Earth, the Sun and the Moon. Tidal currents are predictable. The global tidal range energy potential is estimated to be about 3 TW, about 1 TW being available at comparatively shallow waters.

Marine currents have the potential to supply a significant fraction of future electricity needs and to abate a significant amount of CO_2. The Carbon Trust Report CTC601 (2006) concludes that by 2020 up to 1 - 2.5 GW of total installed capacity could be generated across Europe abating a total of 3.7 $MtCO_2/y$. Up to one sixth of the UK government aspiration of 20% renewable energy by 2020 could be met by marine renewables (about 3% of total UK electricity demand).

A recent report by the European Commission (2006) reviewing “Ocean Energy Conversion in Europe” concluded that tidal range energy conversion technology is considered mature and is very similar to the technology used in traditional hydroelectric power plants. But tidal stream technologies are in their infancy. Most devices being developed rely on horizontal or vertical axis (“cross flow” turbine concepts). These technologies are similar to those used for wind energy conversion.

Considerable research and development is still required before tidal stream devices will be commercially viable in a marine environment. The Carbon Trust estimated capital costs of prototypes and first models at between 10-15p/kWh. They stated "this is solely a depiction of current costs, and gives no indication of how the costs of...tidal stream energy may reduce" Carbon Trust 2006). It is estimated that the capital costs of a 500kW vertical axis device would be - floating at £0.734m and £0.822 piled. "These figures are within the "first farm" capital costs estimated by the Carbon Trust and are likely to fall with increased experience of production and operation" (Joule Centre 2007).

LOCAL AND DISTRIBUTED FREE-STREAM MARINE RENEWABLES

There are proposals for shoreline estuaries around the UK. Most of these are exploring the potential for tidal range (barrage) developments. Work is at different stages in the Severn Estuary, Mersey Estuary and Solway Estuary. These will be significant tidal energy projects. Estimates for the Severn identify a potential for an installed capacity of 8640 MW and for the Mersey of 700 MW. The trade-off is the major environmental risk associated with the changes of water levels, which would modify currents and sediment transport and deposit. Tidal range energy projects, also, require high capital investment at the outset, having relatively long construction periods and long payback periods.

The current leading free-stream tidal technologies in the UK are designed for offshore tidal flows in excess of 4m/s and for depths in excess of 25m because the energy potential in the UK in such areas is significant. An analysis of the DTI tidal energy atlas shows many sites around the UK where these conditions exist. Offshore developments traditionally have much higher maintenance and construction costs and difficulties getting energy ashore efficiently.

All this activity currently puts the UK in a very strong position to take (and keep) the lead on tidal energy worldwide. The market for renewables is estimated by the World Energy Council to see cumulative investment ranging from £150-400bn over the next 10-15 years.

Our proposal adds value to that position by promoting a third way. Deploying free-stream intelligent vertical axis turbines in shoreline settings to maximise the benefits of their locations -more competitive and easier maintenance and construction; minimal transmission losses; close proximity to grid connections; and above all minimal environmental impact. The devices would be capable of integration into existing and new infrastructures producing further savings in capital, deployment, operation and maintenance.

Local developments will also have the potential for local communities to have a stake in the operation of the development and to maximise the socio/economic impact. Local and distributed tidal energy (a source of long-term sustainable energy) could, in time, also support local businesses and communities in guaranteeing some of their energy supply.

The proposals for Morecambe Bay will give an opportunity to demonstrate these benefits.

MORECAMBE BAY

The Bay is the second largest embayment in the UK and comprises 45,462 ha total area (34,339 ha inter-tidal, 3,253 ha salt marsh, 266.5 km of shoreline). It has a tidal range of 8.4 m involving the exchange of 792,000,000 m^3 of water per day.

Morecambe Bay has received many conservation designations, nationally and internationally, reflecting the importance of the wildlife and landscape of the area. It is widely known as the "Wet Sahara" because of the significance of its sands and lagoons. It is a European Marine Site with SAC, SPA and RAMSAR designations.

THE CONCEPT

The proposal is to construct an 18km bridge across Morecambe Bay from Heysham in Lancashire to Barrow-in-Furness in Cumbria that is capable of producing renewable energy. It would be a "green bridge". The concept for the development is that the bridge would deploy a range of renewable energy technologies– tidal, wind, photovoltaics and passive tarmac. (This paper concentrates on the tidal energy.) The energy will produce a revenue stream to help to fund the capital cost. Our stated aim is to put the environment at the heart of our proposals and our intention is to minimise environmental impact. Our aspiration is to have a triple bottom line that provides commercial, environmental and socio/economic benefits.

One of the first stages identified in the Development Plan was to research the tidal energy resource in the Bay.

THE TIDAL ENERGY RESOURCE

The research undertaken included both measurement and modelling. Bathymetric and current measurement surveys were undertaken to provide the basic data needed for the modelling.

Because of the shallow depths and energetic nature of the tidal action in Morecambe Bay, there will normally be no stratification of temperature or salinity, and flows will generally conform to a standard velocity distribution. It was therefore considered that 2D, depth averaged, flow modelling was adequate to simulate the hydrodynamics of the bay for the purposes of estimating the tidal energy resource (HR Wallingford 2005).

If a barrage were to be constructed in Morecambe Bay it was estimated that the installed capacity would be between 2 and 3 GW.

However the environmental impact would be significant. The Significant Impact Factor (SIF) is unique to particular sites and may vary between 10% and 50% of energy flow. “For a sensitive area like Morecambe Bay the SIF is expected to be in the lower ranges” (Halcrow 2006). The SIF is a parameter that aims to quantify the amount of energy that can be extracted from a tidal stream without altering significantly the resource characteristics and subsequently the surrounding environment.

The research on Morecambe Bay identified that flows were strongest and most sustained within the deeper channels in the Bay. Peak flows under mean Spring tides reach up to 2.2m/s and under Neap tides reach up to 1.2m/s. At a localised scale, the presence of bridge piers was found to increase flow speed (by up to 0.25m/s) between the piers, whilst reducing the speed in the wake area downstream. At a larger scale, the presence of the bridge piers was found to increase speeds across the inter-tidal banks, and reduce speeds in the deeper channels. The bridge is predicted to have little effect on the broad scale flows of the whole Bay.

Desktop research to date has identified that a vertical axis tidal turbine would be best suited to the conditions in Morecambe Bay with deployment concentrated in the deeper channels.

INTELLIGENT DEVICES

Vertical axis turbines are not new technologies. The innovation is the proposal to evaluate a full-scale leading edge intelligent vertical axis turbine that is capable of energy extraction in flows of less than 2.5m/s and depths of less than 25m with negligible environmental impact. The technical innovation is the turbine design and related control instrumentation to improve device performance. The devices would be capable of integration into existing and new infrastructures producing savings in capital, deployment, operation and maintenance.

The Norwegian based company WPI (www.wpi.no) have already demonstrated a river-based full-scale intelligent vertical axis turbine in the Pikerfoss in Norway. This device was a 400 KW device standing at 8.5m high with a 20m diameter. The control instrumentation enabled it to demonstrate a performance with 45% efficiency. This research was evaluated by NTNU in Oslo. WPI have an ongoing research programme and are about to complete a CRAFT project (this will include another evaluated demonstration in a Norwegian river setting by the end of September 2007).

The next stage is to do further research and development and to evaluate a full-scale device in a tidal stream setting in the UK. As part of their commitment to the UK, WPI have just set up a UK based company. The research will appraise the most effective number of blades per device; design a more economical blade; assess complex multi-blade designs; further develop controls that mean blades can be continually adapted and state dependent; evaluate spacing to minimise impact; evaluate integration onto structure; evaluate modular structures; evaluate ability to move vertically and horizontally; evaluate use of environmentally neutral components and evaluate best form of electrical power take-off.

The aim is to have a device that can be deployed and operational in Morecambe Bay by 2020.

ENERGY EXTRACTION

Desktop research has been undertaken on assessing the maximum number of WPI turbines (based on what is currently known) that could be deployed and an estimation of power output (Halcrow 2006). This research assessed 4 areas and identified another 2 areas to be assessed.

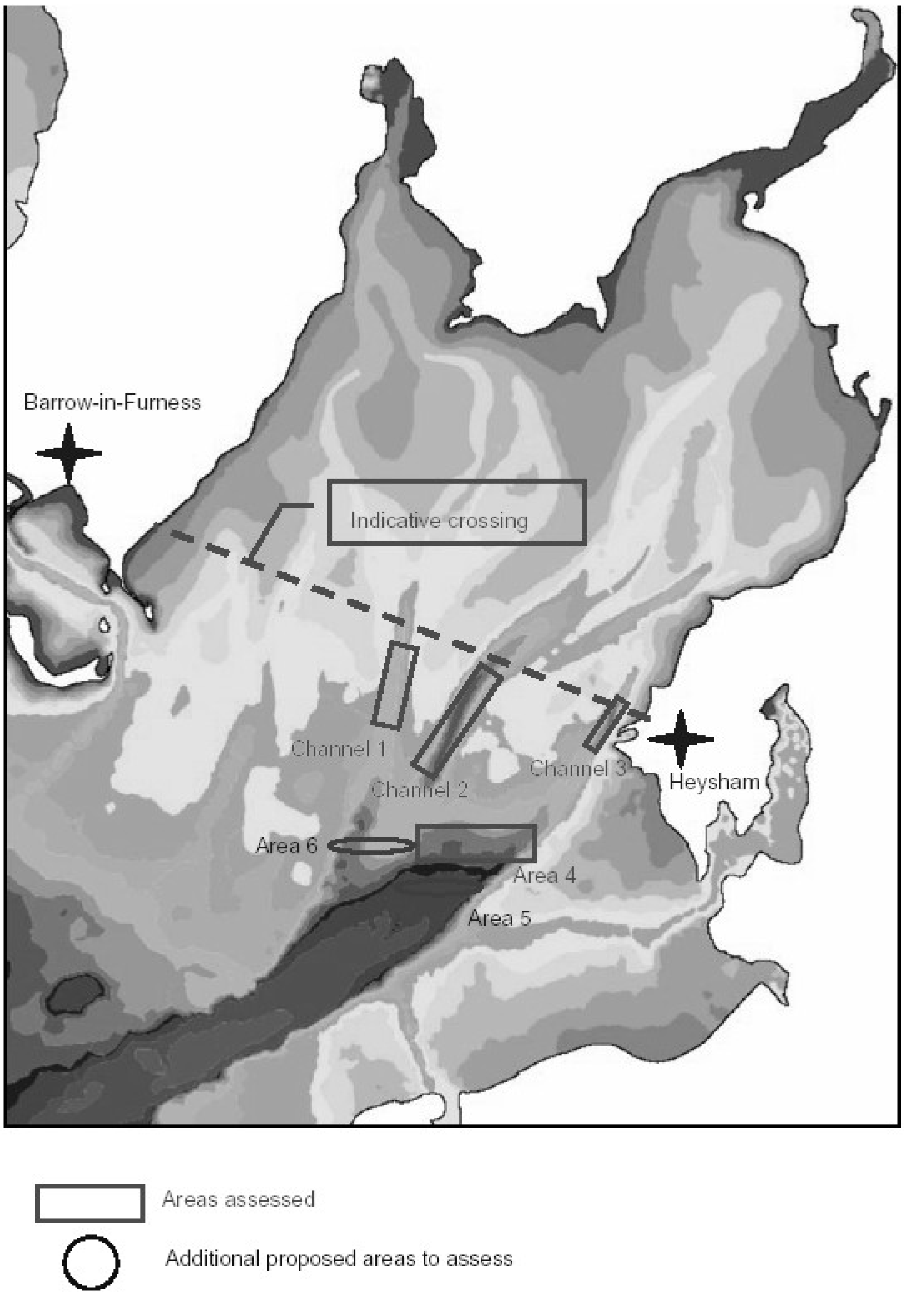

Figure 2.1 Location of areas assessed

The estimated annual energy yield for a 400kW WPI turbine assumes the deployment of turbines in arrays. And this has thrown up a number of issues because it is not known how turbines perform in arrays. The research had to make working assumptions (based on the best knowledge available) about the diameters of turbines (10D) for spacing in the direction of the flows and energy loss over the array. This will be the subject of further research.

The following table shows the estimated energy extraction for the 4 areas assessed and the SIF for each (Halcrow 2006):

	Channel 1	Channel 2	Channel 3	Area 4
Estimated annual energy content from tidal resource (MWh)	240,201	278,527	70,461	466,037
Estimated annual energy yield 400kW WPI turbine (MWh)	19,136	43,510	4,748	24,502
Significant impact factor (%)	**8.0%**	**15.6%**	**6.7%**	**5.3%**

Table 3.4 Estimated SIF for 400kW WPI turbines

The Joule Centre (March 07) undertook a desktop assessment of the Halcrow report from the perspective of the capacity of the channels. They looked at channels 1 and 2 only. They concluded that the approach to spacing produced a result of 36 MW installed capacity in Channel 1 and 48 MW in Channel 2 and that on the basis of the SIF alone "it is clear that no more than 75mW could be installed in Channel 1 and 100mW in Channel 2". But that this would require " confirmation that device spacing of less than 10D would not degrade device performance relative to the isolated case and that SIF values greater than 30% are acceptable for the Morecambe Bay site".

Our aim is to extract 150 MW of tidal energy from the channels in the Bay and based on the desktop research to date this is feasible. An outstanding issue is the economics of tidal energy in our timescale.

Joule Centre (March 07) concluded "that the capital costs of vertical axis tidal turbines are forecast to approach those of comparably rated horizontal axis turbines. Operating costs are likely to be similar in both cases and are typically estimated in the range of 5-10% capital cost". Continual research and review will be essential but most important will be the continued pursuit of cost reduction in tidal technology to ensure commercial viability.

NEXT STEPS

The early development of tidal stream farms is a critical factor is progressing and realising the opportunities presented by tidal energy. It will accelerate learning effects (Carbon Trust 2006). It is also essential to realise technology cost reductions. Morecambe Bay would need an estimated 400 devices to realise its aspirations for tidal energy. This would be a step change in production demand with consequent advantages for economies of scale and competitiveness.

Research will continue over the next 2-3 years into further development of the intelligent vertical axis turbine and performance. Public funding support will be essential to progress. Bids will be submitted to European Commission and UK relevant research funds.

And in parallel independent research will be commissioned to evidence the environmental, transport and socio/economic impacts. This is estimated to take 24 months at least to complete.

This will provide a robust evidence base for decision-making about progressing planning permissions by 2010 for the development in Morecambe Bay. The designations in Morecambe Bay mean that evidence of “overriding public interest” is essential. On either side of the Bay are two communities with some of the most deprived wards and districts in England. They have been identified as local, regional and national priorities for regeneration. The bridge will represent a step change in access for Barrow-in-Furness reducing journey times by over an hour. This will improve inward investment, competitiveness, and open up new markets. The bridge will be a signature tourism project in itself; the longest in the UK and the first to operate as a renewable power station spanning a mainly undiscovered beauty spot. Morecambe will consequently experience a step change in its visitor economy and the planned regeneration proposals for the waterfront development of a marina and marina village in Barrow-in-Furness will benefit too.

And the project has the potential through producing renewable energy and reducing journey times to offset its carbon footprint within 2 years and thereafter to reduce CO_2 emissions by 0.347million tonnes per annum a significant contribution to combating climate change.

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