Scientific Facts on

The potential of tidal energy production

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GreenFacts

Level 2 - Details on The potential of tidal energy production

This is a faithful summary of the leading report
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"IRENA Ocean Energy Technology Brief 3 June 2014 "

The full Digest is available at: https://www.greenfacts.org/en/tidal-energy/

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1. What are the technologies used to obtain tidal energy?

Tides are the result of the interaction of the gravity of the sun, earth, and moon. The rise and fall of the tides – in some cases by more than 12 m – creates potential energy, and the ebb and flow currents create kinetic energy. Both forms of energy can be harvested by tidal energy technologies as renewable energy.

Tidal energy is predictable, as the energy production is not influenced by weather conditions but rather by the cycles of the moon, sun and earth, providing a predictable bi-week, biannual and annual cycle.

Tidal mills have been used in Europe from around the year 700. Since the 1960s, five projects have been developed commercially.

Tidal range technologies harvest the potential energy created by the difference between low and high tides. The highest tides are usually found in locations where large water masses flow into compounded areas or bays and estuaries.

In those areas, most conventional tidal range schemes use bulb turbines, which are comparable to hydropower turbines that are installed in a dam (run of rivers hydro power plant). Technology developments are comparable to the development of wind turbines. There are a number of other designs that are in the research and development stage. This category includes rotating screw-like devices and tidal kites that carry turbines below their wings.

2. What are the advantages and the potential of tidal energy among renewable energy sources?

An advantage of both tidal range and tidal current energies is that they are relatively predictable with daily, bi-weekly, biannual and even annual cycles over a longer time span of a number of years. Energy can be generated both day and night. Furthermore, tidal range is hardly influenced by weather conditions. Meanwhile, due to tidal cycles and turbine efficiency, the load factor of a conventional tidal barrage is around 25%, which leads to high cost of energy. Improvement in turbine efficiency, in particular innovative reversible turbines for ebb and flood generation, should provide a significant increase in energy yield.

Worldwide, the tidal resources are considerable and also largely unmapped. However, global resources are estimated at 3 TW. The technically harvestable part of this resource, in areas close to the coast, is estimated by several sources at 1 Terrawatt (TW), which is equivalent to the current installed capacity in hydropower. Total tidal range deployment in 2012 was around 514 MW, and around 6 MW for tidal current (of which 5 MW is deployed in the UK).

The first tidal barrage was completed in the Rance River in north-western France (Brittany) in 1966, but due to plans for greater use of nuclear energy, the further pursuit of tidal energy was abandoned. Between 1966 and 2011, a number of small tidal plants were built in other countries where tidal energy resource is abundant.

Extensive plans exist for tidal barrage projects in India, Korea, the Philippines and Russia adding up to around 115 gigawatts (GW). Deployment projections for tidal current up to 2020 are in the range of 200 MW.

3. Are these tidal technologies economical competitive?

Tidal energy technologies have advanced considerably over the past few years and there are a number of ongoing full-scale demonstration projects. Horizontal and vertical axis tidal turbines currently use blades that are positioned either in parallel (horizontal) or perpendicular (vertical) to the direction of the flow of water. The turbines are similar to designs used for wind turbines, but due to the higher density of water the blades are smaller and turn more slowly than wind turbines. Furthermore, they have to withstand greater forces and movements than wind turbines.

Tidal range technology has a number of options for power generation:

1. One way power generation at ebb tide: A reservoir is filled at flood tide through sluice gates or valves that are closed once the tide has reached its highest level. At the ebb tide, the water in the reservoir is released through the turbines and power is generated. With this single cycle, power is generated for only four hours per day. Annapolis in Canada is an ebb generation plant.
2. One way power generation at flood tide: At flood tide the sluice gates are kept closed to isolate the reservoir while at its lowest level. When the tide is high, the water from the sea-side flows into the reservoir via the turbines, thus generating power. The disadvantage of this cycle is that it has less capacity and generates less electricity, and it may be ecologically disadvantageous as the water level in the impoundment is kept at a low level for a long time. Sihwa is a flood generation plant.
3. Two way power generation: Both incoming and outgoing tides generate power through the turbines. This cycle generates power for four hours twice daily. However, reversible turbines are required. La Rance is an ebb and flood generation plant; bulb turbines can also pump water for optimisation.
4. Tidal lagoons are similar to tidal barrage, except that they are not necessarily connected to the shore but could sit within the ocean. Environmental impact assessments of the proposed tidal lagoon in Swansea Bay suggest that lagoons would have lower environmental impacts than tidal barrages.
5. Ultra-low-head tidal techniques is a new application under development, which focused on harvesting energy from low head tidal differences of less than 2 metres (m). As for example, the tidal barrage project in the Gravelingen Lake in the Netherlands.
6. The use of tidal fences would consist of a number of individual vertical axis turbines that are connected to each other within a fence structure (Godfrey, 2012). The fence itself could be placed between the mainland and a nearby island, or between two islands (as proposed at the San Bernardino Straits in the Philippines). These applications are in their early stages of development and there are no prototypes being tested in the water at present.
7. Hybrid forms of tidal energy can be found in the form of multi-purpose platforms where both tidal current and tidal range technologies are used for electricity generation. These platforms are in an early developmental and innovative stage.

Another technical aspect for tidal current technologies is their deployment in the form of farms or arrays. Individual generator units are limited in capacity, therefore multi-row arrays of tidal turbines need to be built to capture the full potential of tidal currents. However, turbines have an impact on the current flows, so the configuration in which they are placed is a critical factor to determine their potential yield and output.

Tidal current technologies can also be used to generate electricity from ocean currents. Ocean currents, although slow, are a continuous flow that can provide a steady production that is not driven by the tidal cycles. Although there are currently no on-going projects, studies have been widely undertaken, for example in Florida.

The concept of floating offshore platforms is currently being studied but no commercial application is foreseen in the near future. A recent development is called "dynamic tidal power" (DTP). It consists of a 30-60 kilometre (km) long dam that runs perpendicular to the coast line. At the end of the dam, there is a barrier forming a large "T" shape. The dam interferes with the oscillating tidal waves on either side of the dam and creates a height difference between the water levels. This height difference creates potential energy, which can be converted into electricity using the low-head turbines that are being used in tidal range generators.

The largest and newest multi-functional tidal barrage in the world is the Sihwa dam in north-eastern South Korea, which became operational in 2012 with a capacity of 254 MW in a formerly closed sea-arm by creating openings in an existing sea defence and installing hydro-turbines. This project is a relevant example for a combined tidal range solution, where in the end the priority was placed on ecological water quality improvement.

4. What are the barriers and drivers of tidal energy production?

Cost estimates are projected to decrease with further deployment. Estimates from across a number of European studies for 2020 for current tidal technologies are between EUR 0.17/kWh and EUR 0.23/kWh, although current demonstration projects suggest a cost in the range of EUR 0.25-0.47/kWh. These costs are very site specific and the costs for both tidal range and tidal stream technologies can fall by up to 40% in cases where they are combined and integrated in the design and construction of existing or new infrastructure.

Presently, tidal range power generation is dominated by two large plants in operation, the 'La Rance' barrage in France and the 'Sihwa dam' in South Korea, where electricity production costs are EUR 0.04 per kilowatt-hour (/kWh) and EUR 0.02/kWh, respectively. Tidal range technologies can be used for coastal projection or water management, which would reduce the upfront costs. On the other hand, additional operational costs may occur due to the control, monitoring and management of the ecological status within the impoundment.

5. Who is presently developing tidal energy projects?

Technological.
Improvement in turbine efficiency should provide a significant increase in energy yield. For tidal current technologies, the basic technologies exist but technical challenges continue to arise due to insufficient experience.

Besides the conversion technology, there are a number of additional technological aspects that determine the performance and costs of tidal current technologies: 1) support structures, 2) array formation, and 3) electrical connections to shore.

For tidal current technology to become a challenging alternative to conventional energy sources, increased attention needs to be paid to technical risks in design, construction, installation and operation. Moreover, importing knowledge and experience from other industry sectors, such as offshore oil and gas installations and offshore wind farms, including risk assessments, environmental impact assessments and engineering standards, is of great importance.

Ecological.
The potential for traditional tidal range technology, which closes streams or river arms with dams or in impoundments, is limited due to ecological constraints. Additionally, experiences with artificially closed compounds have demonstrated that the costs of managing an artificial

tidal basin are high and need careful monitoring and planning. A more innovative type of tidal range technology, which does not close impoundments completely, is currently in the developmental phase and will also be of interest. The ecological impacts for tidal stream technologies are deemed to be less than tidal range technologies, but environmental regulators lack the appropriate expertise or tools to assess the environmental risks such as the impact on biodiversity in sea waters.

Societal.
The installation of tidal range technology leads to several important societal benefits besides renewable energy. These include flood defence, improved environmental and ecological water quality, and fisheries and tourism functions.

Industrial.
The development of tidal stream technologies has been linked to small and micro enterprises, many of which have been spin-offs from university projects. Consequently, there is a lack of cohesion within the industry, with many different designs and a number of small-scale producers. However, large turbine manufacturers have entered this emerging sector by becoming involved in the start-up phase. Another new development in tidal energy is the move towards integration of renewable energy technologies, such as tidal energy, within coastal defence infrastructures, road connections or other designated purposes. The involvement of large and multi-disciplinary industries can be expected to promote synergies, which will generate economies of scale and reduce costs.

Financial.
The greatest barriers to tidal range technology advances are the relatively high upfront costs related to the developments of the dykes or embankments, and the ecological implications of enclosures or impoundments. According to reports, costs need to be brought down to at least 50%, which is comparable to offshore-wind energy generation costs. Most project costs for tidal stream technologies are provided through government funds or by technology developers themselves. The need for new finance mechanisms is particularly relevant for the tidal stream technologies that have been tested at full scale, but will require market pull mechanisms to deploy at scale.

Infrastructural.
In Europe, the European Commission together with industry and Member States is supporting the development of an integrated offshore grid structure to deliver offshore wind to consumers.

Planning and licensing procedures.
Coastal communities and those engaged in more traditional marine activities tend to be critical of the impact of new, innovative technology. Planning and licensing processes for ocean energy therefore need to be open and comprehensive enough to take these concerns into account. However, in contrast to spatial planning on land, countries generally have limited experience with, and sometime inadequate governance and rules for, planning and licensing in the marine environment. This is particularly true for sensitive areas in relation to environmental protection and nature conservation.

6.

Leading countries are regions with good tidal resources, such as South Korea with tidal range differences of 9 m to 14 m, and Canada at various locations along the Lawrence River. Similarly, tidal range projects are explored in Western Australia. New test sites are planned in Chile, China, New Zealand, Portugal, Spain, and the USA.

There are many potential sites for tidal barrages worldwide, but the upfront construction costs of the tidal barrage and associated environmental impacts are a major obstacle to further development. In addition to focusing on power generation, a number of new initiatives also focus on water management, flood defence, and the improvement of ecological water quality to enhance the economic and environmental functions around such basins (tourism, fisheries, better flood protection management of protected sites and reduced eutrophication).

Most of these initiatives are typically multi-stakeholder projects, seeking finance from the public as well as private partners. Furthermore, current tidal range projects appear to have great benefits in cases where existing dams or compounds are used, and where the objective of energy production is combined with water quality improvement.