2. Tidal Impoundment

Energy extraction by tidal impoundment involves the impoundment of seawater behind a barrage or lagoon. Power is generated when water is let into or out of the impoundment.

2.1. History and Development

Tidal energy has been used for over a thousand years, mainly for grinding grains in ‘tide mills’. These early tide mills were a type of water mill which would be situated on a tidal inlet or river estuary. A basin would be filled on the rising tide, and the water impounded as the tide began to fall. The water would then be released to turn a water wheel.

This concept has remained largely unchanged in modern tidal power plants; however the early water wheels have given way to highly-efficient hydroelectric turbines first developed during the 19th century. Since then, the idea of constructing dams to exploit tidal power on a much larger scale has emerged. Construction of the first commercial-scale modern tidal power plant was completed in 1967, situated on the Rance Estuary in Brittany, France.

2.1.1. Level 2

Tidal Barrage Projects

The first commercial-scale tidal power plant, the La Rance barrage, in France, has an installed capacity of 240MW. The full-scale experimental plant uses 24, 10MW bulb-type turbine generator sets developed by Électricité de France, which were designed to generate energy on either the incoming or outgoing tide. The second commercial-scale tidal barrage was constructed in 1982 on Canada’s Atlantic coast. The Annapolis Royal pilot tidal power plant in the Bay of Fundy, in the province of Nova Scotia, has an installed capacity of 18MW and was built in order to demonstrate the functioning of the STRAFLO turbine, invented by Escher-Wyss of Switzerland.

A number of other tidal barrage power plants have been considered around the world since the construction of the La Rance plant, some with several gigawatts of generating capacity, including a 15GW scheme in Brittany, France, and an 8.64GW plant in the Severn estuary, between England and Wales in the UK.

The only other significant tidal barrage plants built to date are a 400kW unit in the Bay of Kislaya, 100 km from Murmansk in Russia, completed in 1968; and a 500kW unit at Jangxia Creek in the Zhejiang province in China (Boyle, 2004).

Tidal Lagoons

Despite more than 40 years of successful operation, only one other commercial scale tidal impoundment power plant has been built since the construction of the La Rance barrage in 1967, due to uncertainties and concerns over the potential environmental effects, and the high capital costs of the tidal barrage plants. This has lead to the development of the concept of ‘Tidal Lagoons’ situated offshore in high tidal range areas. To date, there are no
existing tidal lagoons; however Tidal Electric, a US based company, plans to test the concept in Swansea Bay, Wales, UK, with a 60MW output plant. They have also received support from the Chinese government for a 300MW offshore tidal lagoon near the mouth of the Yalu River which forms part of the border between China and North Korea. If completed, the Yalu River project will be the world’s largest tidal impoundment power plant, topping the 240-megawatt plant in La Rance, France. Other potential sites for the tidal lagoons are being investigated in Alaska, Africa, Mexico and India.

2.2. Energy Source and Location

Tides are caused by the gravitational pull of the moon and sun on the seas. This creates a daily cycle of rise and fall in sea level, and the resultant upstream flows and downstream ebbs in tidal inlets and river estuaries. Tidal impoundment technologies use the gravitational potential energy of heads of water trapped in basins to generate power.

Tidal impoundment technologies are best located in shallow waters with a high tidal range. Tidal ranges increase substantially towards the coast. Local topography can enhance the tidal range in places to produce local hot spots, particularly in large estuaries where the best tidal ranges tend to be found. This is mainly caused by shelving of the seabed and funnelling of the water by the estuaries.
Key energy processes:

Tidal ranges can be increased substantially in areas such as estuaries, where the upstream tidal flows are funnelled into a relatively narrow channel.

Useful heads of water can be created in areas with a high tidal range by impounding the inflow or outflow of water, as the tide rises or falls.

2.2.1. Level 2

Geographical Factors

The tidal cycles, created by the gravitational pull of the moon and sun on the seas, may be semidiurnal (i.e. two high tides and two low tides each day), or diurnal (i.e. one tidal cycle per day). In most locations, tides are semidiurnal, with each cycle lasting nearly 12 and a half hours, making the tides a variable, and yet highly predictable, resource.

Tidal cycles also vary over a 14-day spring-neap cycle. Tidal ranges are at a maximum at the full and new moon when the Sun, Earth and moon form a line - the spring tide. When the moon is at first or third quarter, the tidal range is at a minimum - the neap tide. There is a seven day interval between spring and neap tides.

The shelving of the sea bed towards the coast, and the funnelling of water in areas such as estuaries, causes a substantial increase in tidal amplitudes. In some cases the tidal range can be further amplified by reflection of the tidal wave by the coastline or by tidal resonance. This can also combine with the ‘Coriolis effect’ (which can cause tides to be modified in
some locations due to the spin of the earth) and friction. These factors mean that the tidal range, and times of high and low water, can vary substantially between different points on a coastline.

2.2.2. European Resource Map

Across Europe, generally the highest tidal ranges are around the western coasts, influencing particularly the west coasts of England and Wales in the UK, and France. Local topography enhances the tidal ranges in places to produce localised hot spots in large estuaries; such as the Severn estuary between England and Wales, which has the second-highest tidal range in the world at 13m (the highest being in the Bay of Fundy in Canada, where the height of the tide can reach over 16m), and the Rance estuary in France, which has an average tidal range of 8m. The Iberia, Baltic, Norwegian coasts and Mediterranean have little potential due to the low change in sea level between low and high tide levels.

The map below indicates the level of resource across Europe.
2.3. Technology Types

The concept of tidal impoundment power plants is to impound large volumes of water in an area in which a head difference can be created, and then to let water flow in to or out of this area through low-head hydroelectric turbines. The plants can be operated on ebb or flood tide generation, or both. The most commonly used method is ebb generation. Here, as the tide comes in, water would flow in through sluice gates. The sluices are then closed and the tide begins to ebb. When the water level outside the barrage is low enough to create a suitable head, the sluices are opened and the water in the impounded area is released back to the sea through the turbines.

There are two broad technologies used to impound tidal waters – **barrages** and **lagoons**.

Tidal lagoons can be further differentiated into **bunded lagoons** and **offshore lagoons**.

**Tidal Barrages** involve building a dam across an estuary with a high tidal range, therefore creating an impoundment upstream of the barrage. Tidal barrage power plants employ largely the same concept as conventional low-head hydro dam power plants and are similar in appearance.
**Bunded Tidal Lagoons** are impoundments constructed against the banks of a tidal estuary or basin, in shallow water areas. They operate in a similar way to tidal barrages except that they would not fully obstruct an estuary.

**Offshore Tidal Lagoons** are the most recent proposal which, if proven, would be capable of moving beyond the strict geographic walls of tidal estuaries and basins. They are a completely artificial offshore impoundment, and would be built on tidal flats in high tidal range areas.
2.3.1. Level 2

Operation Modes

As well as the variety of tidal operating regimes used for tidal impoundment power plants (e.g. ebb tide generation, flood tide generation, or two-way generation), there are two other proposed major modes of operation: **single-basin schemes** and **multiple-basin schemes**.

Single-basin schemes use one impoundment wall to create a single basin. In double, or multiple-basin schemes, the impounded area is subdivided into segments, with each being filled and emptied in turn. These systems have a main basin which behaves essentially like an ebb generation single-basin system. Additional basins have water pumped to and from them using a proportion of the electricity generated during the ebb phase, allowing an element of storage and therefore a more continuous output.

Flood or ebb pumping can also be used in both schemes to raise or lower basin levels to increase the energy potential of the subsequent generating phase. For example, in flood pumping, extra water is pumped into the impounded area during high tide to give extra volume to drive the turbines during ebb-tide generation.

Basic operation of the proposed Severn barrage showing changes in water levels

![Diagram of basic operation of proposed Severn barrage](image-url)

The proposed tidal barrage scheme for the Severn Estuary in the UK is expected to be the most efficient using ebb tide generation with flood pumping. This will consist of four stages:

1) Fill the basin during the rising tide, with pumping of additional head into the basin during this stage.

2) Hold the water in the basin until the falling tide creates sufficient head for generation.
3) Empty the basin through turbines (generation stage) until minimum operating head is reached.

4) Hold the lagoon until the tide has risen sufficiently to repeat stage one.

2.4. Lifecycle
The key factors to consider at each of the four lifecycle stages of a tidal impoundment power scheme are identified below:

- Design and Planning
- Construction and Installation
- Operation and Management
- Decommissioning

2.4.1. Design and Planning
Siting is crucial for the viability of any tidal impoundment power plant and needs to be considered early in the design and planning stage. The power output from a tidal range scheme is proportional to the volume of water impounded, and approximately proportional to the square of the tidal range; even small differences in tidal range therefore, can make a significant difference to the viability of a new scheme. A mean tidal range of at least 5 meters is generally considered to be the minimum for viable power generation.

Tidal barrages and lagoons are large single installations, unlike other technologies such as wave devices or offshore wind turbines which are relatively small modular devices often installed in arrays or groups. The size of the area which may be impounded in both barrage and lagoon schemes is very site specific, and will depend mainly on local topography, environment, and cost. In barrage and bunded lagoon schemes, the shape of the natural coastline will influence the size of the impoundment basin; tidal lagoons are optimally sited in shallow tidal flat areas.

2.4.1.1. Level 2
As well as suitable site selection, other issues which need to be considered at the design and planning stage are listed below:

Although tidal power is intermittent, and the timing of the power output may not be optimal in terms of power demand, it is predictable. Influences on the timing of the electricity output from a tidal impoundment power scheme include the natural tidal cycle, and the operating regime. A decision needs to be taken at the design and planning stage whether to operate the plant on ebb or flood tide generation, or both, and whether to include flood/ebb pumping.
The use of multiple-basin schemes, once proven, will allow a more reliable output and flexibility to respond to local demand.

External constraints need to be considered, such as grid accessibility, or competing use issues, such as shipping lanes or the local fishing industry. Environmental sensitivity of the site is also an important factor.

Construction of the impoundment walls for both barrages and lagoons requires large volumes of aggregates. This could be a significant issue in terms of extraction and transportation; however, it also presents the opportunity for usage of local inert waste.

Tidal barrages can act as transportation corridors, supporting roadways or rail lines as at the La Rance plant. This could offer a significant incentive for development.

2.4.2. Construction and Installation

The basic elements of tidal impoundment barrages and lagoons are caissons (i.e. large concrete chambers), embankments, sluices, turbine/generator sets, and ship locks. The sluices, turbines and ship locks are housed in the caissons, which in modern plants would be pre-fabricated before being floated into place. The turbine/generator sets are hermetically protected so that the whole electromechanical set can be fully submerged in the water duct. Embankments seal the basin where it is not sealed by caissons and can be constructed from rock and other aggregate materials which are placed directly onto the sea bed. This can then be covered with rock armour where necessary, to dissipate wave attack and maintain the integrity of the structure. In multiple-basin schemes the impoundment basin will be subdivided into segments using the same methods.

2.4.2.1. Level 2

A tidal barrage must span an entire estuary and be able to cope with depths on the site. Hydrostatic and hydrodynamic forces increase markedly with depth, which can add to the costs and materials needed for a barrage. Conversely, tidal lagoons are optimally sited on near-shore, shallow water tidal flats. However, although tidal lagoons can be sited to avoid deeper areas of water, they need more material per cubic metre of impounded water than tidal barrages. This is because tidal lagoons require the construction of all or most of the impoundment walls, whereas tidal barrages only require the construction of one side of the impounded area, using the natural geographic walls of the estuary for the remainder.

2.4.3. Operation and Management

The operation of a tidal impoundment power plant includes the management and integration of the electricity output into the local power grid. Generation times of tidal range schemes vary depending on the location and the operation mode. The tidal cycle causes a natural variation of power output; the neap tide electricity output may be only 25% of the spring tide output depending on location. With ebb or flood only generation, power output could be
expected three hours after high water, and could be produced for five to six hours during spring tides, and three hours during neap tides. Peak power generation would be expected at different times of the day depending on the location of the scheme.

Typical variation in output from tidal range power due to spring-neap cycle

(Sustainable Development Commission, 2007)

Survivability

Tidal Electric, a US based company who are developing tidal lagoon technology, estimate that damage to a tidal lagoon impoundment is most likely from earthquake or erosion. The most likely type of damage would be a breach of the impoundment structure the consequences of which would not include safety issues or collateral property damage. The principle consequence of failure would be economic (i.e. temporary interruption of service). In such events, the damage can be repaired by adding more aggregate to the impound structure. The same will generally be true for barrage impoundments; however where transport links are incorporated into the barrage wall, repairs will be more costly and safety issues will be important. Vulnerable aggregates, such as sand, can be protected from erosion by covering with a layer of rock, or by installing artificial reefs.
2.4.3.1. Level 2

Maintenance

Tidal impoundment power plants use similar technologies to hydropower dams. They are relatively mature and perceived to have low technology risk. Low-head turbines are a well-proven, long-lasting technology and aggregates have an unlimited lifespan. Tidal barrages in France and Canada are still in good condition after 40 years of operational service with a working life of well over one hundred years. Tidal impoundment schemes may require periodic maintenance and replacement of some of the plant and equipment, which would most likely occur every 30 to 40 years. This estimation is supported by the La Rance barrage in France where, in 1996 after 30 years of operation, management overhauled all the equipment over a ten-year period as a preventative measure.

During operation, as with any dam which interrupts tidal movement, accumulations of silt are very likely to occur. In tidal impoundment power plants, a vigorous tidal movement is essential for the plant's performance. The problem will not be as great as is for solid dam structures which halt tidal flow completely, and can result in massive accumulations of silt. Silt levels will be site specific; however some sedimentation at the head of the plant basins is unavoidable and may need to be periodically dredged.

2.4.4. Decommissioning

Tidal impoundment power plants, given normal maintenance, are expected to last for well over one hundred years. Given the limited number of existing tidal impoundment power plants, and their long working life, no projects have yet been decommissioned and there has been very little discussion of decommissioning in existing research. At the end of its useful life the turbine/generator equipment would be removed, however, it is unlikely that the impoundment structure would be removed if power generation were to cease at the site. This is due to the high costs of decommissioning, and the disturbance to the local environment, which would have changed during the lifetime of the project. It may become necessary to remove the entire structure, for example, if the scheme had a more serious environmental impact than expected, and the area needed to be restored to its previous state. To date, decommissioning approaches are still uncertain.

2.5. Economical Factors

Tidal impoundment power projects are characterised by high capital costs, long construction periods, and extensive payback periods. Once the construction is complete however, there are very small maintenance and running costs and the main structure should last for more than one hundred years.

There are uncertainties over the cost of future tidal impoundment developments; however, a number of economic feasibility studies have been carried out for proposed projects. These studies highlight the high capital costs of construction, sensitive to the discount rate used when estimating the cost of electricity output, and the difference in cost estimates depending on the construction methods used, particularly for tidal lagoons.
The following case studies from the Sustainable Development Commissions 2007 report, Turning the Tide: Tidal Power in the UK demonstrates this.

**Economical Factors: Future Project Costs Case Studies**

The following case studies are from the Sustainable Development Commissions 2007 report, Turning the Tide: Tidal Power in the UK. The report includes case studies of other potential options for UK tidal impoundment projects, with estimated costs.

**Tidal barrages**

For the Severn Estuary in the UK, a number of different barrage options have been proposed. The power output and cost summary of two of these are shown in the table below. The Cardiff-Weston scheme which would have a generating capacity of 8.64GW, and the Shoots scheme (which would run further inland of the estuary) and would have a generating capacity of 1.05GW. Both barrages would be operated on the ebb tide, with the addition of flood pumping.

<table>
<thead>
<tr>
<th></th>
<th>Cardiff-Westen</th>
<th>Shoots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of embankments</td>
<td>16.1km</td>
<td>4.1km</td>
</tr>
<tr>
<td>Generating capacity</td>
<td>8.64GW</td>
<td>1.05GW</td>
</tr>
<tr>
<td>Annual average electricity output (2006 data)</td>
<td>17TWh</td>
<td>2.75TWh</td>
</tr>
<tr>
<td>Contribution to UK electricity supply (2006 data)</td>
<td>4.4%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Estimated cost of construction</td>
<td>£15bn</td>
<td>£1.5bn</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated cost of output at various discount rates (high case scenario)</th>
<th>2%</th>
<th>3.5%</th>
<th>8%</th>
<th>10%</th>
<th>15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiff-Weston</td>
<td>2.31p/kWh</td>
<td>3.68p/kWh</td>
<td>9.24p/kWh</td>
<td>12.37p/kWh</td>
<td>22.31p/kWh</td>
</tr>
<tr>
<td>Shoots</td>
<td>2.58p/kWh</td>
<td>3.62p/kWh</td>
<td>7.52p/kWh</td>
<td>9.54p/kWh</td>
<td>15.38p/kWh</td>
</tr>
</tbody>
</table>

The high capital cost of a barrage project leads it sensitive to the discount rate. At a low discount rate of 2%, which could be justified for a climate change mitigation project, the cost of electricity output from both barrage proposals is highly competitive with other forms of generation. However, at commercial discount rates of >8%, these costs escalate significantly, making private sector investment unlikely without significant market intervention by government (Sustainable Development Commission, 2007).
Tidal Lagoons

No tidal lagoons exist to date; the best construction methods are subject to debate. There are different estimations of material requirements, capital costs and likely electricity output of tidal lagoon projects. “The impact of these assumptions is illustrated well by comparing estimates of the capital cost of a tidal lagoon in Swansea Bay (UK), as proposed by Tidal Electric Ltd. The developer estimates a total capital cost of £81.5m, compared to the £255m estimate given by a DTI-funded study... Such differences in capital cost estimates lead to very large variations in estimates for the unit cost of electricity output” (Sustainable Development Commission, 2007).

<table>
<thead>
<tr>
<th>Unit cost of output (p/kWh)</th>
<th>Capital cost (£m)</th>
<th>Annual output (GWh/y)</th>
<th>Discount rate 3.5%</th>
<th>Discount rate 8%</th>
<th>Discount rate 10%</th>
<th>Discount rate 15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal Electric Ltd</td>
<td>£81.5m</td>
<td>187</td>
<td>2.05</td>
<td>4.15</td>
<td>5.13</td>
<td>7.67</td>
</tr>
<tr>
<td>DTI-commissioned review</td>
<td>£255m</td>
<td>124</td>
<td>8.7</td>
<td>18.39</td>
<td>22.91</td>
<td>34.63</td>
</tr>
</tbody>
</table>
2.5.1. Level 2

Financing Projects

Due to the high capital costs of tidal impoundment projects, and the length of time needed for project development and construction, there has been limited private sector interest in developing such schemes. In addition, a lot will depend on the perceived risk of a technology, which relates not only to its technological feasibility, but also to concerns over obtaining development consent. Uncertainties in the consent process, particularly for tidal lagoon scheme proposals where the concept remains unproven, may be making private investors cautious. However, once consent for an initial tidal lagoon project has been secured then private funding may be more readily available. In particular, there is concern over the cost of compliance with any environmental designations, and uncertainties over design and construction methods and possible delays.

The consent process will vary by country across the EU, and there may also be financial incentives and grant funding available in some countries for development. Please see the ‘Specific Country Information’ section of this website for more information.

The potential for cost reductions as a result of innovation are limited for tidal impoundment power schemes, as the technologies are mature. However, there could be substantial opportunities, especially in tidal lagoon schemes, for learning from experience in the construction and maintenance methods. This could then reduce costs.

2.6. Environmental Interactions

Tidal Impoundment developments will have various interactions with the surrounding environment. Some may have potentially positive outcomes: such as helping to combat global warming, providing coastal flood protection, and creating new jobs. Some may have potentially negative outcomes: such as changing the intertidal zone of an estuary, disrupting fish migration routes, and impeding navigation by boats.

Tidal estuaries are amongst the world’s most productive and sensitive ecosystems and the construction of barrages and lagoons in these areas can cause a great disruption to their natural processes. Many of the possible effects are very site-specific, and as there are few examples of operating tidal barrages, and no current examples of tidal lagoons, the exact nature and extent of their possible interactions with the local environment is not yet fully understood.

Matrices of the key interactions between Tidal Impoundment installations and the receiving environment can be found on the following pages.
### Potential key interactions between tidal barrage installations and the receiving environment

<table>
<thead>
<tr>
<th>Development phase</th>
<th>Activity</th>
<th>Impact mechanism</th>
<th>Interactions with the physical environment</th>
<th>Interactions with the biological environment</th>
<th>Interactions with conservation (ecological designations, natural heritage, anthropogenic heritage etc.)</th>
<th>Interactions with the socio-economic environment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electricity generation</strong></td>
<td>Reduced wave action</td>
<td>Reduced wave action: in the upper basin can lead to changes in water movement and erosion patterns. Sediment flows and deposition patterns can be affected by reduced wave action. For example, sandy sediments can become replaced by mud.</td>
<td>Intertidal and intertidal community structures may be altered due to reduced wave action and storm effects.</td>
<td>Protected intertidal and intertidal community structures may be altered due to reduced wave action and storm effects.</td>
<td>The effects of erosion from wave action will be reduced.</td>
<td>Activities which rely on wave patterns will be affected for example, surfing and beach bathing. More garbage may accumulate in the basin due to reduced wave action and lateral coastal processes.</td>
</tr>
<tr>
<td></td>
<td>Alteration to water chemistry</td>
<td>Chemicals from industrial outflows and other emissions may accumulate in the basin area due to changes in local flow patterns. Water may become stratified. Nutrient inputs from agricultural run-off may lead to waters becoming oxygen depleted.</td>
<td>Subtidal and intertidal flora and fauna may suffer from the effects of reduced water quality. Plants and animals may be exposed to low oxygen levels. Bioaccumulation of chemicals may occur up the food chain. Algal blooms may be observed.</td>
<td>Mudflats etc. may become oxygen depleted affecting invertebrate levels and associated protected bird species may also be affected.</td>
<td>Amenity value of local water body is lost as water quality is compromised. Local fisheries may be affected. e.g. shell fisheries and fish farms may be exposed to high chemical levels and the effects of stratification.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Energy extraction</td>
<td>Introduction of moving mammad structure into the environment altering water flow and sediment transport</td>
<td>Marine wildlife may be harmed by moving parts in the water column.</td>
<td>Protected species foraging and migrating within the water column may be harmed/disrupted.</td>
<td>Local fisheries may be disrupted. Moving parts may pose a risk to divers.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduction of greenhouse gas and exhaust emissions from fossil fuel combustion</td>
<td>Reduction in air pollution and atmospheric anthropogenic greenhouse gases</td>
<td>Ecological effects resulting from greenhouse gas emissions and air pollution will be reduced.</td>
<td></td>
<td>Local communities may benefit from any revenue generated from the development. Employment for maintenance and administrative staff. The social and economic impacts of climate change will be mitigated.</td>
<td></td>
</tr>
<tr>
<td><strong>Accidental events</strong></td>
<td>Incident leading to chemical spill</td>
<td>Chemical pollution: Local/widespread changes in water and sediment chemistry.</td>
<td>Species and habitats may be harmed and damaged by chemical pollution.</td>
<td></td>
<td>Chemical pollution may affect other estuary users for example; fish farmers, tourists and mariners etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incident leading to oil/fuel spill</td>
<td>Oil pollution: Transitory oil slicks on surface waters and risk of long-term seabed and shoreline pollution.</td>
<td>Species and habitats may be harmed and damaged by oil pollution.</td>
<td></td>
<td>Oil pollution may affect other estuary users for example; fish farmers, tourists and mariners etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of equipment structural components</td>
<td>Disruption to the seabed from sinking debris: Changes to the seabed profile and sediment composition.</td>
<td>Localised disruption to seabed species and habitats.</td>
<td></td>
<td>Additional hazard to navigation, disruption of fishing grounds.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pollution of surface waters and shorelines from floating debris</td>
<td>No significant impact</td>
<td>Disruption to shoreline habitats through smothering and harm to species through ingestion/entanglement.</td>
<td></td>
<td>Loss of amenity value, disruption to intertidal fisheries.</td>
<td></td>
</tr>
<tr>
<td><strong>Decommissioning</strong></td>
<td><em>It is most likely that tidal barrage systems will not be decommissioned to any extent as the costs of doing so and environmental effects resulting from such an operation would be immense. It is more likely that the system would be upgraded i.e. with more efficient turbine systems. Alternatively, should the barrage also be used for transport, the turbines may be removed and the bridge maintained. There is no instance to date of a tidal barrage undergoing any degree of deliberate decommissioning. However, should the barrage no longer be used for active power generation, ecosystems established after barrage commissioning would be significantly altered.</em></td>
<td></td>
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</tbody>
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www.aquaret.com
# Potential key interactions between tidal barrage installations and the receiving environment

<table>
<thead>
<tr>
<th>Development phase</th>
<th>Activity</th>
<th>Impact mechanism</th>
<th>Interactions with the physical environment</th>
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<th>Interactions with conservation (ecological designations, natural heritage, anthropogenic heritage etc.)</th>
<th>Interactions with the socio-economic environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of equipment/structural components</td>
<td>Disruption to the seabed from sinking debris</td>
<td>Changes to the seabed profile and sediment composition</td>
<td>Localised disruption to seabed species and habitats.</td>
<td></td>
<td>Additional hazard to navigation, disruption of fishing grounds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pollution of surface waters and shorelines from floating debris</td>
<td>No significant impact</td>
<td>Disruption to shoreline habitats through smothering and harm to species through ingestion/entanglement</td>
<td></td>
<td>Loss of amenity value, disruption to intertidal fisheries</td>
<td></td>
</tr>
</tbody>
</table>

 Decommissioning: The extent to which tidal lagoon systems will be decommissioned is uncertain. However, if completely removed, due to the relatively low impact on local ecosystem structure, hydrology and water chemistry, it is quite probable that pre-installation environmental conditions would become re-established after an extended period of time.
## Potential key interactions between bunded tidal lagoon installations and the receiving environment

<table>
<thead>
<tr>
<th>Development phase</th>
<th>Activity</th>
<th>Impact mechanism</th>
<th>Interactions with the physical environment</th>
<th>Interactions with the biological environment</th>
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<td><strong>Preparatory works</strong></td>
<td>Surveying</td>
<td>Disturbance of seabed through sampling</td>
<td>Minor impacts may result from baseline environmental surveys for example, localised loss of substrates and plants and animals on the estuary floor through coring, boring and grab sampling, disruption to mammals from seismic and other vessel-based surveys.</td>
<td></td>
<td>Local contractors and scientific experts can be employed to conduct and support baseline surveys for example, vessel operators, consultants and divers etc.</td>
<td>No key interactions anticipated</td>
</tr>
<tr>
<td></td>
<td>Site preparation</td>
<td>Noise disturbance through increased vessel activity and sonar / seismic surveying</td>
<td>No key interactions anticipated</td>
<td>Potential harm to fish species</td>
<td>Disruption of marine mammal behaviour</td>
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</tr>
<tr>
<td><strong>Construction and installation</strong></td>
<td>Foundation construction</td>
<td>Disruption to seabed and water column during and after dredging</td>
<td>Large areas of the estuary floor may be dredged affecting seabed morphology and increasing water turbidity</td>
<td>Plants and animals may be removed and directly impacted by any dredging of the estuary floor prior to construction</td>
<td>Protected migratory fish species and associated predatory bird species may be affected.</td>
<td>Temporary disruption to other sea users and navigation resulting from vessel activity and marine works.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resuspension of existing sediments into the water column during marine construction works</td>
<td></td>
<td>Smothering / crushing of plants and animals on the estuary floor during construction</td>
<td>Protected migratory fish species and associated predatory bird species may be affected.</td>
<td>Temporary disruption to other sea users and navigation resulting from vessel activity and marine works.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Introduction of additional particulate matter from building materials</td>
<td>Disruption to feeding and breeding patterns of fish, birds and mammals from marine obstacles, temporary works and increased levels of activity in the area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Commissioning, operation, and management</strong></td>
<td>Completion of lagoon</td>
<td>Changes in water flow around and within installation</td>
<td>Localised changes in water flow may lead to sediment settlement and lower levels of turbidity in the water column.</td>
<td>New species may become established in the area as existing resident species may be out-competed by more opportunistic species which are more suited to the new environmental conditions.</td>
<td>Protected species may be affected as the result of competition from more opportunistic species which are better suited to environmental conditions created by the changes in water flow. Additionally, there may be indirect effects resulting from a shortage in food and habitat.</td>
<td>Businesses dependent on the species affected by changes in tidal currents will also be affected.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alteration of tidal patterns at the coast</td>
<td>A reduction in tidal range can lead to mean low water becoming higher and mean high water becoming lower. This can result in the loss of significant intertidal areas including mudflats and saltmarshes.</td>
<td>Species dependent on existing intertidal areas and submergence patterns for feeding and breeding may be disrupted and displaced.</td>
<td>Numbers of protected intertidal species may decrease.</td>
<td>Amenity / economic / conservation value of protected species and habitats may be compromised.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intertidal submergence patterns may be affected: i.e. some intertidal areas will be underwater for longer / shorter periods.</td>
<td>Higher ground, previously only flooded by the highest tides may become colonised by terrestrial vegetation.</td>
<td>Protected intertidal habitats may be reduced in size / lost e.g. mudflats and saltmarshes resulting in.</td>
<td>Intertidal areas used for recreation may be reduced / lost.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Higher mean low water may result in the saltwater contamination of local groundwater sources.</td>
<td>Intertidal areas previously exposed during lowest tides, may become subtidal.</td>
<td>Shoreside areas used for recreation may be affected by change in water levels.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduced wave action at the coast</td>
<td>Reduced wave action in the upper basin can lead to changes in water movement and erosion patterns.</td>
<td>Intertidal and foreshore community structures may be altered due to reduced wave action and storm effects at the coast.</td>
<td>Protected intertidal and foreshore habitats may be altered due to reduced wave action and storm effects.</td>
<td>The effects of erosion from wave action will be reduced.</td>
<td>Coastal amenities within the site and the immediate area will be affected.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sediment flows and deposition patterns can be affected by reduced wave action. For example, sandy sediments can become replaced by mud.</td>
<td></td>
<td></td>
<td>More garbage may accumulate in the area due to reduced wave action and lateral coastal processes.</td>
<td></td>
</tr>
</tbody>
</table>
### Potential key interactions between bunded tidal lagoon installations and the receiving environment

<table>
<thead>
<tr>
<th>Development phase</th>
<th>Activity</th>
<th>Impact mechanism</th>
<th>Interactions with the physical environment</th>
<th>Interactions with the biological environment</th>
<th>Interactions with conservation (ecological designations, natural heritage, anthropogenic heritage etc.)</th>
<th>Interactions with the socio-economic environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily operations</td>
<td>Alteration to water chemistry</td>
<td>Water within the installation may become stratified</td>
<td>Subtidal and intertidal flora and fauna may suffer from the effects of reduced water quality. <em>Plants and animals may be exposed to low oxygen levels.</em> <em>Bioaccumulation of chemicals may occur up the food chain.</em></td>
<td>Mudflats etc. may become oxygen depleted affecting invertebrate levels and associated protected bird species may also be affected</td>
<td>Local fisheries may be affected downstream.</td>
<td></td>
</tr>
<tr>
<td>Daily operations</td>
<td>Energy extraction</td>
<td>Introduction of moving manmade structure into the environment altering water flow and sediment transport</td>
<td>Marine wildlife may be harmed by moving parts in the water column.</td>
<td>Protected species foraging and migrating within the water column may be harmed/disrupted</td>
<td>No key interactions anticipated.</td>
<td></td>
</tr>
<tr>
<td>Electricity generation</td>
<td>Reduction of greenhouse gas and exhaust emissions from fossil fuel combustion</td>
<td>Reduction in air pollution and atmospheric anthropogenic greenhouse gasses</td>
<td>Ecological effects resulting from greenhouse gas emissions and air pollution will be reduced.</td>
<td></td>
<td>Local communities may benefit from any revenue generated from the development. Employment for maintenance and administrative staff. The social and economic impacts of climate change will be mitigated.</td>
<td></td>
</tr>
<tr>
<td>Accidental events</td>
<td>Incident leading to chemical spill</td>
<td>Chemical pollution</td>
<td>Local/widespread changes in water and sediment chemistry</td>
<td>Species and habitats may be harmed and damaged by chemical pollution</td>
<td>Chemical pollution may affect other estuary users (e.g., fish farmers, tourists and mariners etc.).</td>
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<tr>
<td>Accidental events</td>
<td>Incident leading to oil spill</td>
<td>Oil pollution</td>
<td>Transitory oil slicks on surface waters and risk of long-term seabed and shoreline pollution</td>
<td>Species and habitats may be harmed and damaged by oil pollution</td>
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</tr>
<tr>
<td>Accidental events</td>
<td>Loss of equipment/structural components</td>
<td>Disruption to the seabed from sinking debris</td>
<td>Changes to the seabed profile and sediment composition</td>
<td>Localised disruption to seabed species and habitats.</td>
<td>Additional hazard to navigation, disruption of fishing grounds.</td>
<td></td>
</tr>
<tr>
<td>Decommissioning</td>
<td>The extent to which tidal lagoon systems will be decommissioned is uncertain however, the costs of doing so and environmental effects resulting from such an operation would be considerable. It is more likely that the system would be upgraded i.e. with more efficient turbine systems. There is no instance to date of a tidal lagoon undergoing any degree of deliberate decommissioning. However, should the lagoon be decommissioned, ecosystems established after commissioning would be altered.</td>
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</tbody>
</table>
### Potential key interactions between offshore tidal lagoon installations and the receiving environment

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<td>Preparatory works</td>
<td>Surveying</td>
<td>Disturbance of seabed through sampling</td>
<td>Minor impacts may result from baseline environmental surveys, e.g., localised loss of substrates and plants and animals on the estuary floor through coring, boring and grab sampling, disruption to mammals from seismic and other vessel-based surveys.</td>
<td>Potential harm to fish species</td>
<td>Local contractors and scientific experts can be employed to conduct and support baseline surveys for example, vessel operators, consultants and divers etc.</td>
<td>No key interactions anticipated</td>
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<td>Site preparation</td>
<td>Noise disturbance through increased vessel activity and sonar / seismic surveying</td>
<td>No key interactions anticipated</td>
<td>Disruption of marine mammal behaviour</td>
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<td>Foundation construction</td>
<td>Disruption to seabed and water column</td>
<td>Resuspension of existing sediments into the water column during marine construction works and introduction of additional particulate matter from building materials</td>
<td>Smothering/crashing of plants and animals on the estuary floor during construction</td>
<td>Protracted migratory fish species and associated predatory bird species may be affected.</td>
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<td>Disruption to seabed and water column</td>
<td></td>
<td>Disruption to feeding and breeding patterns of fish, birds and mammals from marine obstacles, temporary works and increased levels of activity in the area.</td>
<td></td>
<td>Large short-term employment opportunities.</td>
<td>Downstream and other nearby fisheries may be affected.</td>
</tr>
<tr>
<td>Completion of lagoon</td>
<td>Changes in water flow around and within installation</td>
<td>Scouring may occur around the installation; further affecting the seabed around the installation and local sedimentary processes. Water flow around the installation may be affected leading to changes in sediment settlement patterns and distribution.</td>
<td>Smothering may occur around the installation as a result of altered sedimentary processes. Opportunistic species may replace those previously established.</td>
<td>No key interactions anticipated.</td>
<td>Permanent structure introduced into the local landscape.</td>
<td></td>
</tr>
<tr>
<td>Commissioning, operation and management</td>
<td>Energy extraction</td>
<td>Introduction of moving manmade structure into the environment altering water flow and sediment transport</td>
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<td>Protracted species foraging and migrating within the water column may be harmed/disrupted</td>
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<td>Reduction of greenhouse gas and exhaust emissions from fossil fuel combustion</td>
<td>Reduction in air pollution and atmospheric anthropogenic greenhouse gases</td>
<td>Ecological effects resulting from greenhouse gas emissions and air pollution will be reduced</td>
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<td>Additional hazard to navigation, disruption of fishing grounds</td>
<td></td>
</tr>
<tr>
<td>Pollution of surface waters and shorelines from floating debris</td>
<td>No significant impact</td>
<td>Disruption to shoreline habitats through smothering and harm to species through ingestion/entanglement</td>
<td></td>
<td></td>
<td>Loss of amenity value, disruption to intertidal fisheries</td>
<td></td>
</tr>
<tr>
<td>Decommissioning</td>
<td>The extent to which tidal lagoon systems will be decommissioned is uncertain. However, if completely removed, due to the relatively low impact on local ecosystem structures, hydrology and water chemistry, it is quite probable that preinstallation environmental conditions would become re-established after an extended period of time.</td>
<td></td>
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</tr>
</tbody>
</table>
2.7. Future Potential

Tidal power availability is site specific; however, there are a number of potential sites for barrage and lagoon schemes around the world. The main potential for tidal impoundment power generation is from a small number of large schemes; however, there are also many potentially suitable sites for small-to-medium-scale projects. Several potential sites for large-scale tidal barrage and lagoon schemes have been identified in the UK and France.

Of six identified potential sites within the UK with mean tidal ranges of 5.2-7.0 m, feasibility studies have been completed for two large schemes: the Severn estuary (8640MW) and the Mersey estuary (700MW) and for smaller schemes on the estuaries of the Duddon (100MW), Wyre (64MW), Conwy (33 MW) and Loughor (5MW) (World Energy Council, 2007). These tidal impoundment power plants could, in the future, play an important role in energy generation, and in reducing the greenhouse gas emissions of these countries. In the UK, for example, the proposed 8.64GW Cardiff-Weston barrage scheme on the Severn Estuary would potentially provide about 5% of UK electrical power.

2.7.1. Level 2

Despite the benefits a new tidal impoundment power plant would bring, such as boosting regional economies with the creation of temporary and permanent jobs, several previous proposals for the construction of new plants have not been viable because of cost and environmental concerns, even though they have been technologically feasible. A major obstacle to development is the impact on sensitive estuarine ecosystems, and the protected habitats and species characteristic of these areas.

According to its developers, tidal lagoons may be a cheaper alternative to barrages, operate at higher load factors, and may also potentially cause less damage to sensitive ecosystems and therefore prove more environmentally attractive.

Tidal barrages are a proven, but highly capital-intensive, option that would require government support. In respect to tidal lagoons, a lack of evidence means the priority should be on filling information gaps through practical, on-the-ground experience so that long-term viability can be assessed (Sustainable Development Commission, 2007).

2.8. Case Studies

There are two commercial scale tidal impoundment power plants in operation: a tidal barrage plant at the Rance estuary, Brittany, France and a tidal barrage plant at Annapolis Royal, Nova Scotia, Canada. To date, there are no tidal lagoon power plants.

The two tidal barrage projects are detailed below, as well as a case study of a proposed multi-pool 60MW Tidal Lagoon for Swansea Bay in Wales, UK.
Case Study: La Rance Barrage

<table>
<thead>
<tr>
<th>Project Name</th>
<th>La Rance Barrage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>The Rance estuary in Brittany, France</td>
</tr>
<tr>
<td>Installed capacity</td>
<td>240MW</td>
</tr>
<tr>
<td>Technology Type</td>
<td>Tidal impoundment barrage</td>
</tr>
<tr>
<td>Project Type/Phase</td>
<td>Full scale experimental power plant</td>
</tr>
<tr>
<td>Year</td>
<td>Operational since 1967</td>
</tr>
</tbody>
</table>

Project Description
The Rance tidal power plant is located on the estuary of the Rance River, in Brittany, France (Figure 1).

Following twenty-five years of research and six years of construction work, the 240MW La Rance Barrage became the first commercial-scale tidal power plant in the world. It was built as a large scale demonstration project for low-head hydro technology. The construction of the tidal power plant started in 1961, and was completed in 1967.

The Rance estuary has one of the highest tidal ranges in the world (an average of 8 meters, reaching up to 13.5 metres during equinoctial spring tides) which makes it an attractive site for tidal impoundment power generation. The complete barrage is 750m long and 13m high with a reservoir of 22km² capable of impounding 180 million cubic meters.

The structure includes a dam 330m long in which the turbines are housed, a lock to allow the passage of small craft, a rock-fill dam 165m long and a mobile weir with six gates. Before construction of the tidal barrage, two temporary dams were built across the estuary in order to create a dry construction site; an effort which took two years. In July 1963, the Rance was cut off from the ocean and construction of the tidal barrage commenced. This took another three years. A road across the barrage connects the towns of Dinard and Saint-Malo. Boats can pass the barrage via a canal lock at the west side and there is also a drawbridge which can be raised to allow larger vessels to pass.

In 1996, after 30 years of operation, Électricité de France (EDF) carried out a general and preventive overhaul of all equipment. This refurbishment programme was spread out over ten years. The plant is now operating successfully and generates on average 600 million kWh of electricity per year.

Technology
The plant uses 24 10-megawatt low-head bulb-type turbine generator sets. The new bulb-type turbines, developed by EDF, were designed to generate energy on either the incoming
(flood) or outgoing (ebb) tide, and to pump in both directions to raise (high tide) or lower (low tide) the basin level to add to the energy potential of the subsequent generating phase.

The barrage was originally planned for two-way generation, using the new bulb-type turbines, but the turbines were less efficient in reverse. Pumping extra water into the impounded area during high tide (when the height difference is small) gives extra volume to drive the turbines when the height difference is large. It is therefore predominantly operated on ebb-tide generation with flood pumping. This helps to minimise progressive disruption of the intertidal zone that would eventually lead to the silting up of the head pond.

![Figure 1: Location of the La Rance Tidal Barrage.](image)

**Project Partners**

The plant is owned and operated by *Électricité de France*.

**Cost and Financing**

The total cost of the barrage was 620 million Francs (94.5 million Euros).
References

4. La Rance Tidal Power Plant. http://www.reuk.co.uk/la-rance-tidal-power-plant.htm
Case Study - Annapolis Royal

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Annapolis Royal Tidal Generating Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Annapolis River, Nova Scotia</td>
</tr>
<tr>
<td>Installed capacity</td>
<td>20MW</td>
</tr>
<tr>
<td>Technology Type</td>
<td>Tidal Impoundment Barrage</td>
</tr>
<tr>
<td>Project Type/Phase</td>
<td>Full scale experimental power plant</td>
</tr>
<tr>
<td>Year</td>
<td>Operational since 1984</td>
</tr>
</tbody>
</table>

Project Description

The Annapolis Royal Tidal Generating Station is located on a small island at the mouth of the Annapolis River which feeds into the Annapolis Basin, a sub-basin of the Bay of Fundy (Figure 1). The Bay of Fundy is notable as the vertical tidal range at its eastern extremity is one of highest in the world at 16 meters\(^1\). The site at Annapolis Royal was chosen because the estuary had already been closed off by a causeway in order to restrict tidal flow further up the river\(^2\). Construction began on the Annapolis Tidal Generation Station in 1980 and was completed four years later in 1984. The barrage encloses an area of water of 15 km\(^2\) with a mean tidal range of 6.4 m\(^2\).

![Figure 1: Location of the Annapolis Royal Tidal Barrage.](image)
Technology
The Annapolis Tidal generation plant was designed as a demonstration project to test a large Straflo turbine generator\(^3\). The plant operates in ebb generation only\(^4\), has a maximum rated capacity of 20MW\(^5\) and produces 30 GWh\(^5\) of electrical energy annually.

Project Partners
The plant is owned and operated by Nova Scotia Power.

Cost and Financing
No information is yet available to the public domain.

References

Further Information
For more information on Nova Scotia Power see:

http://www.nspower.ca/environment/green_power/tidal/index.shtml

For more information on tidal energy see:

Sheth, S.; Shahidehpour, M., Tidal energy in electric power systems. Power Engineering Society General Meeting, 2005. 630 - 635
2.9. Test Your Knowledge

**Learning Outcomes – Tidal Impoundment**

<table>
<thead>
<tr>
<th>Level</th>
<th>Tidal Impoundment</th>
</tr>
</thead>
</table>
| **Basic** | On successful completion of this module you will be able to:  
  • Understand the physical processes that result in tides and tidal flows  
  • Recognise that the movement of water associated with tides is a renewable resource  
  • Recognise that tidal energy resources are widely but not evenly distributed across Europe and that local topography affects tidal range  
  • Recall the two broad technologies (tidal barrages and tidal lagoons) that could be used for tidal impoundment  
  • Identify the operational regimes used for tidal impoundment plants such as ebb generation, flood generation and two-way generation  
  • Identify the different project phases such as Design and Planning, Construction and Installation, Operation and Management, and Decommissioning  
  • Understand that the surrounding environment includes physical processes, wildlife and habitats, conservation interests, communities and social features, as well as commerce and economic activities  
  • Explain how energy extraction leads to a number of possible interactions (both negative and positive) with the surrounding environment  
  • Understand that the surrounding environment includes physical processes, wildlife and habitats, conservation interests, communities and social features, as well as commerce and economic activities  
  • Outline how these negative impacts can be minimised  
  • Name specific examples where tidal energy is being extracted |
| **Intermediate** | On successful completion of this module you will be able to:  
  • Describe the key development in the use of tidal energy  
  • Describe in general terms the periodicity of tidal cycles  
  • Outline the topological factors which affect tidal range  
  • Describe the different operational regimes used for tidal impoundment plants (ebb generation, flood generation and two-way generation)  
  • Outline the basic steps involved in energy conversion by a tidal energy converter  
  • Outline the important factors of each phase of a project  
  • Outline the key types of environmental interactions associated with aquatic renewable technologies  
  • Explain how environmental interactions may change through a project lifecycle, in different locations and at different times  
  • Outline some of the factors which influence the overall cost of the project for the different technologies  
  • Describe specific examples where tidal energy is being extracted |

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1 **Basic** – Equivalent to EQF (European Qualification Framework) Level 1 and Bloom’s Taxonomy “Knowledge” category. This level requires the student to have basic general knowledge of the subject, be able to recall important information.

**Intermediate** – Equivalent to EQF level 2 and Bloom’s Taxonomy “Comprehension” category. This level requires the student to be able to explain basic factual knowledge.
2.9.1 Quiz

Answers are given in the footnote²

Q1 Tidal impoundment technologies use the following as an energy source:
   a) Kinetic energy in the wind caused by the uneven heating of the earth's surface by the sun
   b) The rise and fall of the tides caused by the gravitational pull of the moon and the sun on the seas
   c) Kinetic energy in the waves caused winds blowing over the surface of the sea
   d) Solar energy from the sun

Q2 Tidal ranges are at their maximum when the sun, earth and moon are in alignment. These are called spring tides. Spring tides occur every:
   a) 12 and a half hours
   b) 7 days
   c) 14 days
   d) 18 years

Q3 The highest tides in the world occur in
   a) The Bay of Fundy in Canada
   b) The Rance Estuary in France
   c) The Severn Estuary in the UK
   d) The Gulf of Finland in the Baltic Sea

Q4 Tidal impoundment plants can be built to operate in:
   a) Ebb generation only
   b) Flood generation only
   c) Both ebb and flood generation
   d) Neither

² 1b, 2c, 3a, 4c, 5a, 6a, 7c, 8a
Q5  Flood and ebb pumping are normally used to raise or lower the basin level in order to
a)  Increase the energy potential of the subsequent generation cycle
b)  Maintain the water level in the basin during the tidal cycle
c)  Prevent water entering the tidal impoundment
d)  Prevent coastal erosion

Q6  In flood pumping mode extra water is pumped into the impounded area to give extra volume to drive the turbines during:
   a)  Ebb tide generation
   b)  Flood tide generation
   c)  Both
   d)  The entire tidal cycle

Q7  The following is an example of where energy from tidal impoundment is being extracted:
   a)  Anatoliki, Greece using a 700kW “Pelton-2” turbine
   b)  Aguçadoura, Northern Portugal device using a 3 x 750kW Floating articulated attenuators
   c)  La Rance Estuary, France using 24 x 10MW low-head bulb type turbines
   d)  Scroby Sands, England using 30 x 2MW horizontal axis turbines

Q8  The following is an impact associated with extraction of energy by tidal impoundment:
   a)  Reduced tidal range leading to potential decrease in number of intertidal species
   b)  Reduced wave action leading to potential changes in intertidal and sublittoral habitats
   c)  Changes in river flow patterns leading to potential disruption to protected migratory fish routes
   d)  Risk of bird collisions with moving turbine blades
2.10. Further Information

Referenced in website text

Sustainable Development Commission, October 2007. Turning the Tide - Tidal Power in the UK
Available online at: http://www.sd-commission.org.uk/publications.php?id=607. A major study carried
out by the Sustainable Development Commission, examining the harnessing of tidal power in the UK.
Locations and technologies are considered; results are also useful for locations outside the UK.


A useful summary of tidal energy developments and future plans for a number of countries are

Further reading

Sustainable Development Commission, October 2007. Turning the Tide - Tidal Power in the UK

A major study carried out by the Sustainable Development Commission (SDC), examining the
harnessing of tidal power in the UK. Locations and technologies are considered; results are also
useful for locations outside the UK.

As part of the study, five research reports were commissioned by the SDC. These are available
online at: http://www.sd-commission.org.uk/pages/tidal.html

- Research Report 1 - UK tidal resource assessment
- Research Report 2 - Tidal technologies overview
- Research Report 3 - Severn barrage proposals
- Research Report 4 - Severn non-barrage options
- Research Report 5 - UK case studies

Survey of Energy Resources 2007
A useful summary of tidal energy developments and future plans for a number of countries are

Tidal Impoundment Projects

La Rance - The 240MW experimenta’l La Rance tidal power project in Brittany, France was
completed in 1967. This plant (operated by Electricite de France) is equipped with 24 bulb-
type turbine generators rated at 10MW.

Electricite de France - The Rance tidal power plant, power from the ocean.

Bay of Fundy - The Annapolis pilot tidal power plant in Canada’s Bay of Fundy on the
Atlantic coast in the province of Nova Scotia was completed in 1984. It features a Straflo
turbine and a generator with a 20MW capacity. It is owned and operated by Nova Scotia Power.


**Tidal Lagoons**

To date, there are no tidal lagoon plants; however Tidal Electric, a US based company developing tidal lagoon technology, plans to test the concept in Swansea Bay, in Wales, UK with a 60MW output plant. [http://www.tidalelectric.com](http://www.tidalelectric.com)

**Tidal Electric**
The US based company developing tidal lagoon technology. The company proposes to install the world’s first tidal lagoon in Swansea Bay in the UK. [http://www.tidalelectric.com](http://www.tidalelectric.com)


**Severn barrage**

Bryant, P., 2004. A report on current technology that may affect Severn Estuary barrage proposals. Available online at: [www.r-energy.co.uk/index.shtml](http://www.r-energy.co.uk/index.shtml)


The objective of this definition study was to examine whether a reappraisal of the Severn Barrage Project is justified since the tripartite studies reported in Energy Paper 57 in 1989.


This report sets out why Friends of the Earth Cymru maintains its opposition to the construction of a Severn Barrage after reviewing recent calls for a new appraisal of the scheme.


### Resource


Sustainable Energy Ireland, Tidal & Current Energy Resources in Ireland

### How Tides are Created


Tides and Currents [http://tidesandcurrents.noaa.gov/education.html](http://tidesandcurrents.noaa.gov/education.html)

### Books


### Other

Tide Mills of Western Europe [http://www.moinhosdemare-europa.org/](http://www.moinhosdemare-europa.org/)

*Tide mills of western Europe project, available in English, Portuguese, French and Spanish*