Renewable energy

Tidal Power

Tidal power utilises the twice daily variation in sea level caused primarily by the gravitational effect of the Moon and, to a lesser extent the Sun on the world's oceans. The Earth's rotation is also a factor in the production of tides. Tidal power is not a new concept and has been used since at least the 11th Century in Britain and France for the milling of grains.

Tidal Physics

An understanding of the principles which give rise to tides is essential to explain tidal power.

Whilst a thorough understanding of the interactions involved is quite complex, the origin of tides can be explained in general terms by investigating the gravitational effects of the Moon and the Sun on the ocean and the effect of centrifugal forces.

Gravitational Effects and the Centrifugal Force

The interaction of the Moon and the Earth results in the oceans bulging out towards the Moon, whilst on the opposite side the gravitational effect is partly shielded by the Earth resulting in a slightly smaller interaction and the oceans on that side bulge out away from the Moon, due to centrifugal forces. This is known as the Lunar Tide. This is complicated by the gravitational interaction of the Sun which results in the same effect of bulging towards and away from the Sun on facing and opposing sides of the Earth. This is known as the Solar Tide.

As the Sun and Moon are not in fixed positions in the celestial sphere, but change position with respect to each other, their influence on the tidal range (difference between low and high tide) is also effected. For example, when the Moon and the Sun are in the same plane as the Earth, the tidal range is the superposition of the range due to the lunar and solar tides. This results in the maximum tidal range (spring tides). Alternatively when they are at right angles to each other, lower tidal differences are experienced (figure 1) resulting in neap tides.

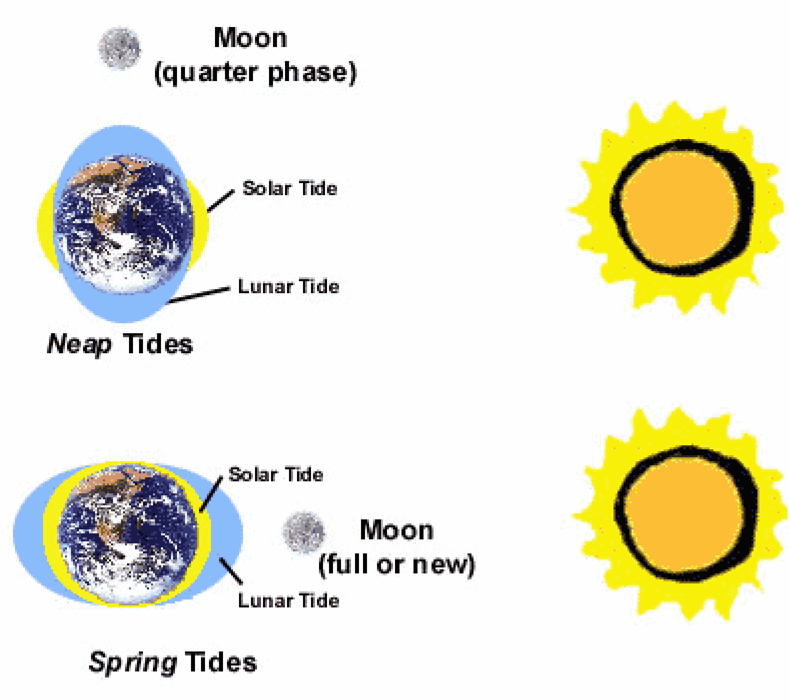

Figure 1 Gravitational effect of the Sun and the Moon on tidal range
(Adapted from Boyle, 1996)

Generating Electricity from the Tide

The generation of electricity from tides is very similar to hydroelectric generation, except that water is able to flow in both directions and this must be taken into account in the development of the generators.

The simplest generating system for tidal plants, known as an ebb generating system, involves a dam, known as a barrage across an estuary. Sluice gates on the barrage allow the tidal basin to fill on the incoming high tides and to exit through the turbine system on the outgoing tide (known as the ebb tide). Alternatively, flood generating systems which generate power from the incoming tide are possible, but are less favoured than ebb generating systems.

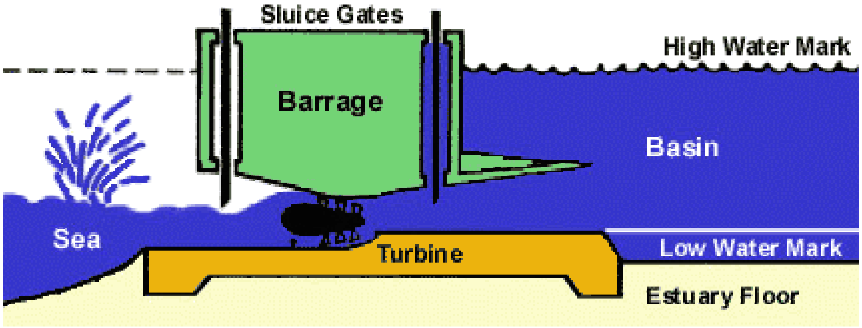

Figure 2 Ebb generating system with a bulb turbine
(Adapted from Energy Authority of NSW Tidal Power Fact Sheet)

Two way generation systems, which generate electricity on both the incoming and ebb tides are also possible.
Turbines Used in Tidal Power Stations

Several different turbine configurations are possible. For example, the La Rance tidal plant near St Malo on the Brittany coast in France uses a bulb turbine (figure 3). In systems with a bulb turbine, water flows around the turbine, making access for maintenance difficult, as the water must be prevented from flowing past the turbine. Rim turbines (figure 4), such as the Straflo turbine used at Annapolis Royal in Nova Scotia, reduce these problems as the generator is mounted in the barrage, at right angles to the turbine blades. Unfortunately, it is difficult to regulate the performance of these turbines and it is unsuitable for use in pumping. Tubular turbines have been proposed for use in the Severn tidal project in the United Kingdom. In this configuration (figure 5), the blades are connected to a long shaft and orientated at an angle so that the generator is sitting on top of the barrage.

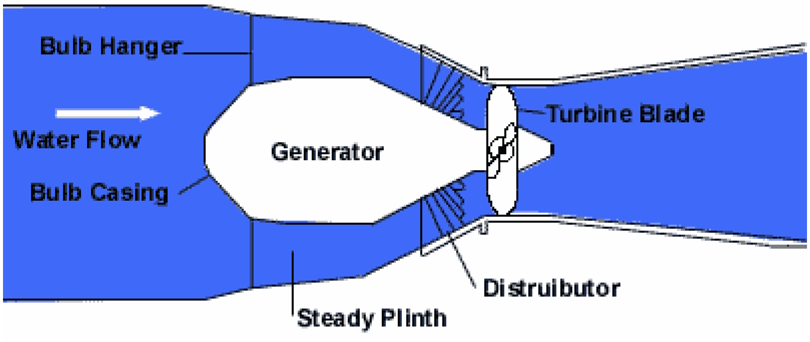

Figure 3 Bulb Turbine
(Copyright Boyle, 1996)

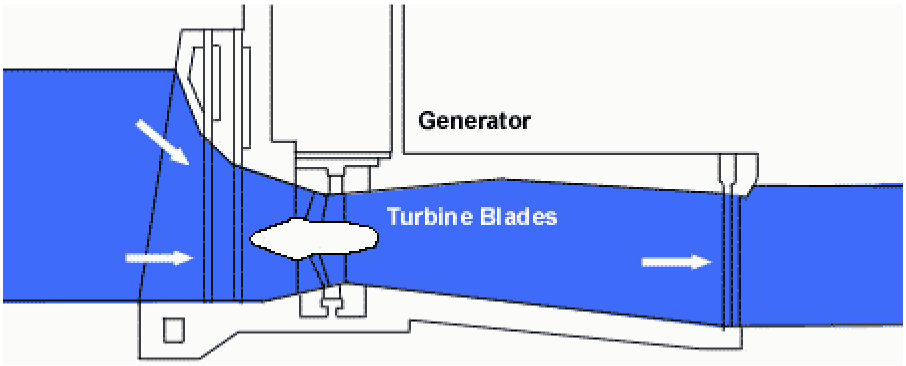

Figure 4 Rim Turbine
(Copyright Boyle, 1996)

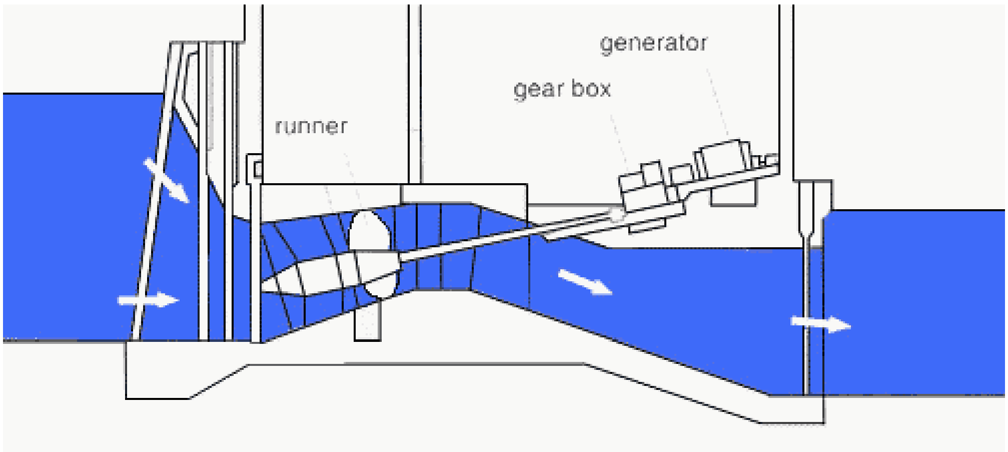

Figure 5 Tubular Turbine
(Copyright Boyle, 1996)

Tidal Fences

Tidal fences can be thought of as giant turn styles which completely block a channel, forcing all of the water through them as shown in figure 6.

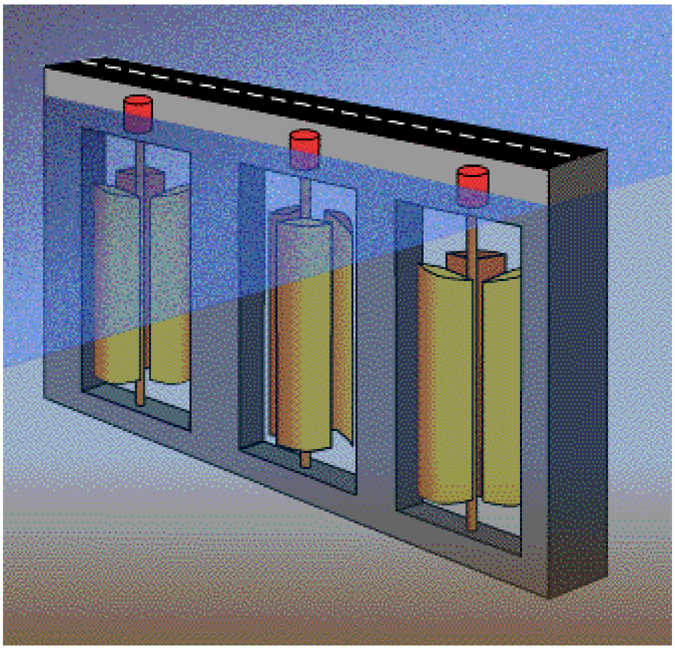

Figure 6 Artists impression of a tidal fence in operation.

Unlike barrage tidal plants, tidal fences can be used in unconfined basins, such as in the channel between the mainland and a nearby off shore island, or between two islands.

A 55MWp tidal fence using the Davis turbine, are being planned for the San Bernadino Strait.

Tidal Turbines

Proposed shortly after the oil crisis of the 1970s, tidal turbines have only become reality in the last five years, when a 15kW proof of concept turbine was operated on Loch Linnhe. Resembling a wind turbine, tidal turbines offer significant advantages over barrage and fence tidal systems, including reduced environmental effects.

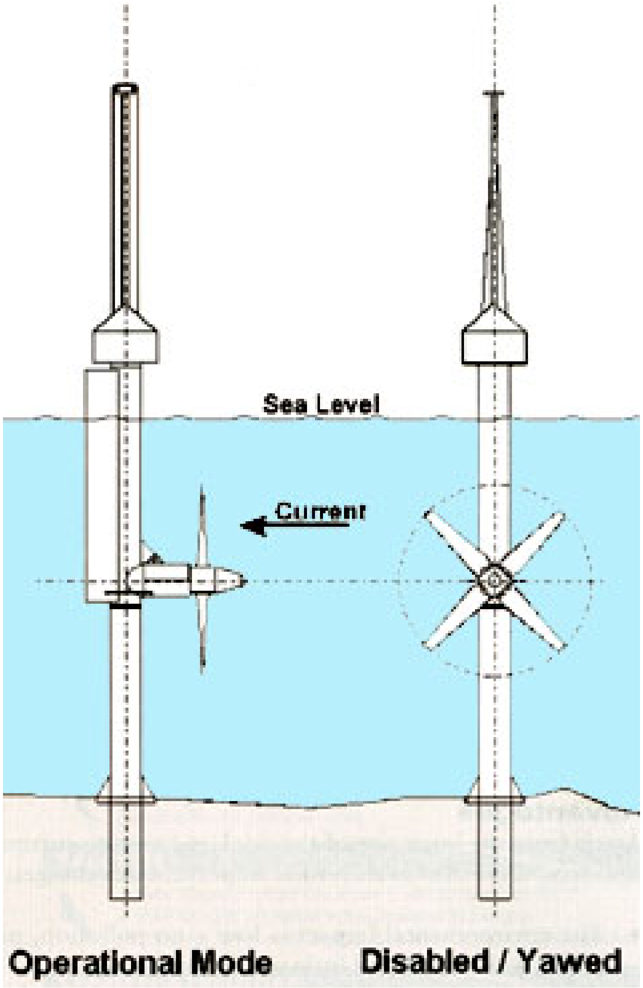

Figure 7 Schematic of an axial flow, seabed mounted marine current turbine
(Copyright IT Power Ltd)

Tidal turbines utilise tidal currents which are moving with velocities of between 2 and 3 m/s (4 to 6 knots) to generate between 4 and 13 kW/m2. Fast moving current (>3 m/s) can cause undue stress on the blades in a similar way that very strong gale force winds can damage traditional wind turbine generators, whilst lower velocities are uneconomic.

Constraints to Tidal Power Generation

Whilst tidal power generation can offer some advantages, including improved transportation due to the development of traffic or rail bridges across estuaries and reduced greenhouse gas emissions by utilising non polluting tidal power in place of fossil fuels, there are also some significant environmental disadvantages which make tidal power less attractive.

Tidal Changes

The construction of a tidal barrage in an estuary will change the tidal level in the basin. This change is difficult to predict, and can result in a lowering or raising of the tidal level. This change will also have a marked effect on the sedimentation and turbidity of the water within the basin. In addition, navigation and recreation can be affected as a result of a sea depth change due to increased sedimentation within the basin. A raising of the tidal level could result in the flooding of the shoreline, which could have an effect on the local marine food chain.

Ecological Changes

Potentially the largest disadvantage of tidal power is the effect a tidal station has on the plants and animals which live within the estuary. As very few tidal barrages have been built, very little is understood about the full impact of tidal power systems on the local environment. What has been concluded is that the effect due to a tidal barrage is highly dependent upon the local geography and marine ecosystem.

Tidal Power in Australia

Tidal power has been proposed in the Kimberley region of Western Australia since the 1960s, when a study of the Derby region identified a tidal resource of over 3000 MW. In recent years a proposal to construct a 50 MW tidal plant in the Derby region has been developed Derby Hydro Power. This project has received a $ 1 million grant through the Australian Greenhouse Office's Renewable Energy Commercialisation Program to further develop the project.

ST.-MALO, FRANCE–A $78 million renovation is under way on France's most visited industrial site, the La Rance tidal power plant.

Considered an engineering marvel, the 31-year-old power plant consists of a nearly half-mile-long dam that also serves as a highway bridge linking St.-Malo and Dinard. At high tide, the dam traps Atlantic waters in the bay. At low tide, the water flows back to the sea. En route, it passes through 24 turbines connected to generators that produce enough electricity for a city of 300,000.

The project includes installing turbines that can spin on both the incoming and outgoing tides. Since the turbines are located inside the dam, most of the work will be invisible to the 400,000 tourists who visit La Rance each year.

Those who depend on the plant's power–it furnishes 90% of Brittany's electricity–shouldn't notice much of a change either. To keep the current flowing, turbines will be upgraded one by one over 10 years.

Today, solar power and lunar power. The University of Houston's College of Engineering presents this series about the machines that make our civilization run, and the people whose ingenuity created them.

Renewable energy is a term worth looking at. We can use direct solar energy to heat water or our homes. We can focus solar energy to supply steam boilers. We can build engines to take energy from the warm surface of the ocean and discharge it into the cold water below. We use solar cells to convert solar energy to electricity. Nature often does the work of converting heat into usable power for us, by moving water and wind around the planet. Thus windmills and hydroelectric plants deliver solar power.

We call such energy renewable only because the sun replaces what we use. No energy is truly renewable. Sooner or later, every source runs down, even the sun. It's just in comparison with our brief human lives, that it might as well be inexhaustible.

TIDAL POWER: How it Works

A large amount of energy is stored in the tides. The tides go in and out, and we can capture energy from this with tidal power stations. Tidal power stations can stretch over a delta, estuaries, beaches or other places that are affected by the tides. A barrage is first set across a beach or river. When high tide comes in, water flows through a turbine to create electricity. Now some of the water is up behind the barrage. A gate is lowered from the barrage, capturing the water above it. When low tide comes, the gate is raised and the water flows out, first transferring its energy through turbines. This way, electricity is created with a two-way turbine. Some tidal power stations can produce 320 megawatts of electricity.

TIDAL POWER: History and Sites

Tidal mills were invented in the early 1900's. They didn't have two-way turbines then, so they could only use one tidal direction. They chose to capture the tides as they were receding, because there was the most possible outcome from there. When the tide came in, the floodgate lowered, trapping the water above it. When low tide came, the gate was lifted up, and the water turned a water wheel.

Tidal power stations are already being used in Canada, France, Russia and China. The station that generates the most electricity is on the Rance River, in France. It generates 320 megawatts of electricity. A possible site for a tidal power station is at the Bay of Fundy, between New Brunswick and Nova Scotia. The tidal head difference there is 50 feet.

TIDAL POWER: Design Issues and Problems

Tidal power stations are very expensive to build and they often create electricity when it isn't needed as much. The tides are always changing, but the need for electricity much smaller at night then in the day.

Tidal power stations also have environmental problems. Many fish like salmon swim up these estuaries where the barrages are and have already been killed by the turbines. The barrage also destroys homes to many birds, fish and other animals.

Tidal power operates by building a barrier across a river estuary. The tidal flow drives turbines to produce electricity. Europe's only tidal power station is at Rance in Northern France. A number of sites in the U.K could be developed to provide tidal power. The drawback is that these schemes affect the habitat of seabirds and fish because they alter the tidal currents. Also, barrage will only provide power for about 10 hours per day. Power for the other 14 hours must be provided by other means.

Waves possess great energy. Experiments with various different designs of generator have proved that waves can provide electricity. However, there are problems in developing and building wave powered generators which are both cheap and efficient, as they must be strong enough to cope with storms while being light enough to work with small waves. The drawback is that these schemes affect the habitat of birds and fish because they alter the tidal currents.

If every reasonable project in the UK were to be exploited for tidal power the yield could be over 50 kwh a year representing 20 per cent of the electricity demand in Britain. About 90 per cent of this potential is at eight large estuaries including Servern, Dee, Morecambe bay, Solway, Humber and Wash

A Severn barrage from Bread Down in Somerset to Lavernock point in Glamorgan 16 kilometres long with 216 large turbines, could generate as much as 8640 megawatts and supply up to 7% of electricity for England and wales. It would be a very large project costing over 8000 million. It would take seven years to close the barrage to produce first electricity, with full power output being reached two years later.

SOCIAL IMPACT

Tidal electricity generation would not require waste disposal nor would it result in acidic emissions (the greenhouse effect) by 17 million tonnes per year . Work on environmental and regional issues has identified possible benefits that would accrue with the barrage in operation . These include protection of a large length of coastline against storm surge tides (as with the Thames barrier), a road crossing ,opportunities for water-based recreation and amenity ,increased land values and substantial creation of employment.

The only major tidal power scheme operating anywhere in the world is in the Rance estuary between Dinard and Saint Malo in France , where a barrage with 240 MW of turbines was completed in 1966, as a pilot scheme for a prospective larger barrage across the Mont Saint Michel bay. After some commissioning difficulties with the turbines the Rance scheme has operated regularly and reliably or 24 years. however, the French have so far not proceeded with the large scheme, preferring to invest instead in nuclear power plants.

Views are divided on the environmental impact of a large tidal barrage. Some say it will do irreparable damage to the ecosystem of the estuary while others maintain that it will create an exciting new reserve for water birds, fish and vegetation.

Conclusion.

The drawbacks of TIDAL and WAVE power are that the alter of the tidal currents affect the habitat of the seabirds in the area also the fish are affected by the change in the tidal currents. Also the tidal and wave power stations can only produce ten hours of power in one day of twenty-four hours so they would have to generate the other fourteen hours of power another way which may be quite expensive. But there are also good points about tidal and wave power. One good point is that the power produced is cheap. Also, making the power does not pollute the environment in the same ways that fossil fuels do.

Tidal Power Development in
Estuarine and Marine Environments

Production of electricity by harnessing the power of ocean tides is being examined with renewed interest by many industrialized nations. Tidal power has become economically feasible as a result of the continuous rise in price of fossil fuels, and a number of nations already possess working tidally driven electric generating facilities. A tidal power plant is similar in principle to hydropower generation facilities in rivers. A barrage (dam) with a powerhouse and turbines is constructed across an estuary or embayment to form a basin (headpond) of sufficient size to allow production of electricity over a reasonable period. For the simplest design, the basin is allowed to fill during flood tide through floodgates and powerhouse, with turbines spinning freely. Power is produced on ebb tide.

Environmental concerns at issue with tidal power include alterations of primary and secondary productivity, fish mortality, changes in the tidal regime, local weather patterns, and local and regional socioeconomic structure. Tidal hydropower developments may encompass large embayments and affect wide geographic areas. Removing energy from the tide and reducing volume of seawater exchange across the barrage site, will alter water circulation patterns and tidal regimes both behind and seaward of the barrage. Seaward of the barrage tidal amplitudes may increase as far as 500 km from the barrage site, inundating narrow but substantial portions of nearby coasts and raising long-term storm damage potential. Within the headpond tidal range will be reduced but mean water level will rise causing increased stratification, producing greater extremes in surface temperatures and more ice cover in temperate climes. In some headponds turbidity will decrease and sedimentation will increase. Reduced storm surges and extreme tides could diminish flooding and erosion, but changes in tidal amplitude may alter groundwater drainage and cause changes in local climate conditions. Effluent disposal and assimilation problems in headpond areas could also develop because of reduced flushing time.

Changes in turbidity and sedimentation would alter biotic conditions in the headpond areas, shifting invertebrate species composition and thus altering the food chain. Fisheries impacts would be greatest in those areas where fish are abundant and fish passage is repeated by the same population many population many times over the year. Introducing hydraulic turbines into an estuarine environment will create the problems inherent to fish passage associated with riverine power installations, with several important exceptions: the estuarine environment contains larger fish populations, larger fish species, and marine mammals. Impacts may include altered migration routes and changes in the availability of food organisms.

The AFS policy regarding tidal power development in estuarine and marine environments is to:

1. Promote compilation and synthesis of information regarding pre- and post-construction of existing tidal power sites so it can be used to estimate, at least on a gross scale, the potential effects of proposed projects.

2. Encourage all relevant international, national, state, and provincial agencies to become involved and consider preparing policy statements on tidal power, regardless of their regulatory jurisdiction over the project. One of the specialized organizations of the United Nations could serve as a coordinating body.

3. Encourage development of management-oriented programs and decisions based on scientific evidence while being cautious of alarmist reactions or emotional response to proposed projects.

4. Encourage long-term, multi-source funding of regional studies to determine ecosystem effects of tidal power both before and after construction. Such studies should follow the conceptual approach outlined by the Ocean Sciences Board of the National Academy of Sciences.

5. Encourage response to tidal power projects similar to that of other large-scale construction projects, including: (a) preparation of appropriate environmental impact statements and long-term pre- and post-operational studies and (b) involvement of resource researchers and managers at all stages of tidal power development.

6. Encourage better cross-discipline discussion on the effects of tidal power projects among engineers and fishery biologists.

7. Encourage the holding of appropriate symposia in conjunction with other suitable international meetings to develop consensus on research priorities for assessing tidal power impacts, and minimum information needs for adequate long-term monitoring.

TIDAL ENERGY

In coastal areas with large tides, flowing tidal waters contain large amounts of potential energy. The principal of harnessing the energy of the tides dates back to eleventh century England when tides were used to turn waterwheels, producing mechanical power. More recently, rising and falling tides have been used to generate electricity, in much the same manner as hydroelectric power plants.

Tides originate from the motions of the earth, moon and sun. Although ocean tides contain extremely large amounts of energy, it is only practical to generate electricity at sites with exceptionally high tides such as the Bay of Fundy in Atlantic Canada which, at up to 17 metres, has the highest tides in the world. Tidal energy is an essentially renewable resource which has none of the typical environmental impacts of other traditional sources of electricity such as fossil fuels or nuclear power. Changing the tidal flow in a coastal region could, however, result in a wide variety of impacts on aquatic life, most of which are poorly understood.

Tides: Gravitational Energy

Tides, the daily rise and fall of ocean levels relative to coastlines, are a result of the gravitational force of the moon and sun as well as the revolution of the earth. The moon and the sun both exert a gravitational force of attraction on the earth. The magnitude of the gravitational attraction of an object is dependant upon the mass of an object and its distance. The moon exerts a larger gravitational force on the earth because, although it is much smaller in mass, it is a great deal closer than the sun. This force of attraction causes the oceans, which make up 71% of the earth's surface, to bulge along an axis pointing towards the moon (Figure 1). Tides are produced by the rotation of the earth beneath this bulge in its watery coating, resulting in the rhythmic rise and fall of coastal ocean levels.

FIGURE 1: The moon's gravitational force is the main influence in creating tidal bulges on the earth. In this diagram the arrow indicates the direction of the earth's rotation (126K).

The gravitational attraction of the sun also affects the tides in a similar manner as the moon, but to a lesser degree. As well as bulging towards the moon, the oceans also bulge slightly towards the sun. When the earth, moon and sun are positioned in a straight line (a full or new moon), the gravitational attractions are combined, resulting in very large "spring" tides. At half moon, the sun and moon are at right angles, resulting in lower tides called "neap" tides. Coastal areas experience two high and two low tides over a period of slightly greater than 24 hours. The friction of the bulging oceans acting on the spinning earth results in a very gradual slowing down of the earth's rotation. This will not have any significant effect for billions of years. Therefore, for human purposes, tidal energy can be considered a sustainable and renewable source of energy.

Certain coastal regions experience higher tides than others. This is a result of the amplification of tides caused by local geographical features such as bays and inlets. In order to produce practical amounts of power (electricity), a difference between high and low tides of at least five metres is required. There are about 40 sites around the world with this magnitude of tidal range. In Canada, the only practical site for exploiting tidal energy is the Bay of Fundy between New Brunswick and Nova Scotia (Figure 2). The higher the tides, the more electricity can be generated from a given site, and the lower the cost of electricity produced. Worldwide, approximately 3000 gigawatts (1 gigawatt = 1 GW = 1 billion watts) of energy is continuously available from the action of tides. Due to the constraints outlined above, it has been estimated that only 2% or 60 GW can potentially be recovered for electricity generation.

FIGURE 2: The principal of tidal power generation (183K).

Exploiting the Resource:

The technology required to convert tidal energy into electricity is very similar to the technology used in traditional hydroelectric power plants. The first requirement is a dam or "barrage" across a tidal bay or estuary. Building dams is an expensive process. Therefore, the best tidal sites are those where a bay has a narrow opening, thus reducing the length of dam which is required. At certain points along the dam, gates and turbines are installed. When there is an adequate difference in the elevation of the water on the different sides of the barrage, the gates are opened. This "hydrostatic head" that is created, causes water to flow through the turbines, turning an electric generator to produce electricity (Figure 2).

Electricity can be generated by water flowing both into and out of a bay. As there are two high and two low tides each day, electrical generation from tidal power plants is characterized by periods of maximum generation every twelve hours, with no electricity generation at the six hour mark in between (Figure 3). Alternatively, the turbines can be used as pumps to pump extra water into the basin behind the barrage during periods of low electricity demand. This water can then be released when demand on the system its greatest, thus allowing the tidal plant to function with some of the characteristics of a "pumped storage" hydroelectric facility.

FIGURE 3: Near optimum ebb generation over 14 tide spring-neap cycle (131K).

The demand for electricity on an electrical grid varies with the time of day. The supply of electricity from a tidal power plant will never match the demand on a system. But tidal power, although variable, is reliable and predictable and can make a valuable contribution to an electrical system which has a variety of sources. Tidal electricity can be used to displace electricity which would otherwise be generated by fossil fuel (coal, oil, natural gas) fired power plants, thus reducing emissions of greenhouse and acid gasses.

Currently, although the technology required to harness tidal energy is well established, tidal power is expensive, and there is only one major tidal generating station in operation. This is a 240 megawatt (1 megawatt = 1 MW = 1 million watts) at the mouth of the La Rance river estuary on the northern coast of France (a large coal or nuclear power plant generates about 1,000 MW of electricity). The La Rance generating station has been in operation since 1966 and has been a very reliable source of electricity for France. La Rance was supposed to be one of many tidal power plants in France, until their nuclear program was greatly expanded in the late 1960's. Elsewhere there is a 20 MW experimental facility at Annapolis Royal in Nova Scotia, and a 0.4 MW tidal power plant near Murmansk in Russia.

Studies have been undertaken to examine the potential of several other tidal power sites worldwide. It has been estimated that a barrage across the Severn River in western England could supply as much as 10% of the country's electricity needs (12 GW). Similarly, several sites in the Bay of Fundy, Cook Inlet in Alaska, and the White Sea in Russia have been found to have the potential to generate large amounts of electricity.

The Economics of Tidal Energy

One of the main barriers to the increased use of tidal energy is the cost of building tidal generating stations. For example, it has been estimated that the construction of the proposed facility on the Severn River in England would have a construction cost of $15 billion. Operating and maintenance costs of tidal power plants are very low because the "fuel", sea-water, is free; but the overall cost of electricity generated is still very high.

The major factors in determining the cost effectiveness of a tidal power site are the size (length and height) of the barrage required, and the difference in height between high and low tide. These factors can be expressed in what is called a site's "Gibrat" ratio. The Gibrat ratio is the ratio of the length of the barrage in metres to the annual energy production in kilowatt hours (1 kilowatt hour = 1 KWH = 1000 watts used for 1 hour). The smaller the Gibrat site ratio, the more desireable the site. Examples of Gibrat ratios are La Rance at 0.36, Severn at 0.87 and Passamaquoddy in the Bay of Fundy at 0.92.

Environmental Impacts

Tidal energy is a renewable source of electricity which does not result in the emission of gases responsible for global warming or acid rain associated with fossil fuel generated electricity. Use of tidal energy could also decrease the need for nuclear power, with its associated radiation risks. Changing tidal flows by damming a bay or estuary could, however, result in negative impacts on aquatic and shoreline ecosystems, as well as navigation and recreation.

The few studies that have been undertaken to date to identify the environmental impacts of a tidal power scheme have determined that each specific site is different and the impacts depend greatly upon local geography. Local tides changed only slightly due to the La Rance barrage, and the environmental impact has been negligible, but this may not be the case for all other sites. It has been estimated that in the Bay of Fundy, tidal power plants could decrease local tides by 15 cm. This does not seem like much when one considers that natural variations such as winds can change the level of the tides by several metres.

Very little is understood about how altering the tides can affect incredibly complex aquatic and shoreline ecosystems. One fear is that enhanced mixing of water could be caused by tidal barrages in the Bay of Fundy, potentially stimulating thegrowth of the "red tide" organism, Gonyalaux excavata, which causes paralysis in shellfish. Unfortunately, one of the only methods of increasing our knowledge about how tidal barrages affect ecosystems may be the study of the effects after such facilities have been built.

Conclusions

Tidal power has the potential to generate significant amounts of electricity at certain sites around the world. Although our entire electricity needs could never be met by tidal power alone, it can be a valuable source of renewable energy to an electrical system. The negative environmental impacts of tidal barrages are probably much smaller than those of other sources of electricity, but are not well understood at this time. The technology required for tidal power is well developed, and the main barrier to increased use of the tides is that of construction costs. The future costs of other sources of electricity, and concern over their environmental impacts, will ultimately determine whether humankind extensively harnesses the gravitational power of the moon.

Methods of Power Generation

Ebb generation

This system has the same outgoing flow direction during power generation as the ebb tide. For maximum power generation the turbines do not start to release the water until well after the sea has started to ebb, approximately 3 hours after.

Flood Generation

Flood Generation is essentially the opposite to ebb generation. In this case the power generation is during the flood tide and hence the turbines discharge the water into the basin.

Ebb generation plus Pumping at high tide

This is simply a variation on the ebb generation. During or very soon after high tide, the sluice gate are closed and the turbines are reversed in order to act as a pump, this forces more water into the basin. The pumping stops when sea has fallen to a level where it is no longer economical to pump the required head. The sea level falls further below after the pumps are stopped however since there is more water stored in the basin than there is in a simple ebb generation system the power generation can be started earlier. The additional water pumped into the basin is released through the turbines at a much greater head than what they were pumped therefore a net gain in energy results.

Often turbine blades are curved for maximum efficiency in the direction of generating power and so when they are used in reverse as a pump the efficiency is significantly reduced. This must be taken into account when determining at what point should the turbines stop pumping to enable maximum energy gain. A solution would be turbines that have variable blades to improve efficiency while pumping however these would be more expensive and require greater maintenance.

Two-way Power Generation

In a two-way generation system the power is generated from both the ebb and flood tides. The ebb generation starts at a basin level that is less than for single cycle generation. Towards the end of the generating cycle the sluice gates are opened to allow flow from the basin to the sea and hence drop the water level in the basin. This is necessary to achieve a sufficient difference in water height during the flood generation phase. At low tide the sea and basin levels become equal and the gates are closed. Once the sea has risen to the optimum height generation begins by operating the turbines in the opposite direction. Part way through this generation the sluice gates are opened to allow the basin level to rise and result in sufficient head for the next ebb generation cycle.

Because of the lower heads during each generation phase compared to one-way systems, the wasted water by opening the sluice gates part way through the generation cycles and the lower efficiency in operating the turbines in reverse, two-way generation does not produce any more energy than one-way ebb generation. However, the maximum power output lower and the two generation phases per tide mean the output of two-way generation is easier to absorb in the grid system.

Two-basin Generation

This system involves two basins formed adjacent to each other, both equipped with sluice gates. The simplest configuration is to have the turbines in the dividing wall between basin A and basin B. Basin A is the high level basin, filled through its sluices at high tide and emptied through the turbines into basin B. Basin B is the low level basin filled through the turbines from basin A and emptied through its sluice gates at low tide. The storage available in each basin generally allows the turbines to operate longer than the case of a single basin. In some cases it is possible for the turbines to run continuously.