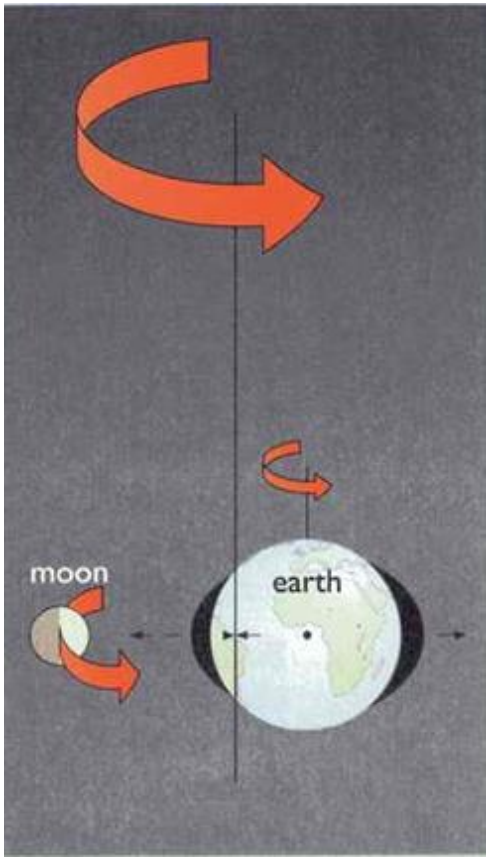
Energy Resources

Dr. Fahad Noor
Assosciate Professor
f.noor@uet.edu.pk

Engr. Adnan Qamar
Lecturer
adnan@uet.edu.pk

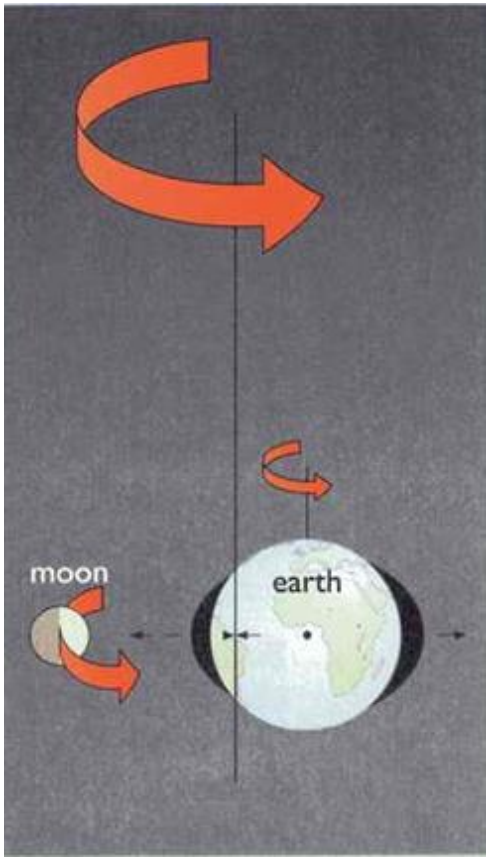
Tidal Energy

Definition: Tidal energy comes from the gravitational forces of the Sun and the Moon on the Earth's bodies of water, creating periodic shifts in these bodies of water. These shifts are called tides.



Tidal Energy

Tidal power facilities harness the energy from the rise and fall of tides.



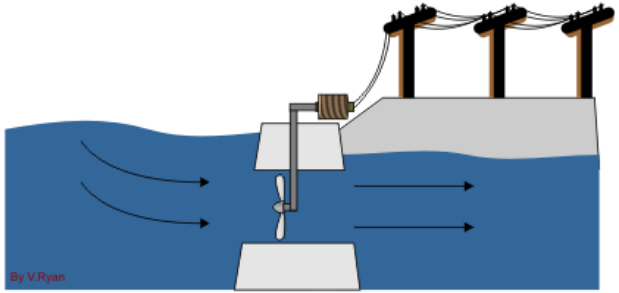
Tidal Energy

Millions of gallons of water flow onto shore during tidal flows and away from shore during ebb tide periods.

The larger the tidal influence, the greater the displacement of water and therefore the more potential energy that can be harvested during power generation.

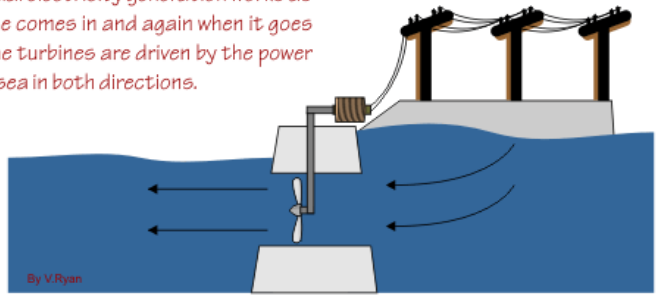
The tides are perfectly predictable, regular, and the US contains miles of coastline for energy exploitation.

Tidal Energy



TIDE COMING IN

This tidal electricity generation works as the tide comes in and again when it goes out. The turbines are driven by the power of the sea in both directions.



TIDE GOING OUT

Tidal Energy

Tidal energy is one of many forms of hydropower generation. Tidal power has many advantages as compared to other forms of renewable energy.

- It is predictable
- Global Climate Change should only increase its generating capacity due to higher ocean levels.
- It is completely carbon neutral like wind or hydro energy.

Tidal Energy

Its main drawbacks include: higher cost of installation, limited availability for ideal siting, environmental impacts on local area, including flooding and ecological changes, and the inflexible generation schedule (not timed to peak consumption).

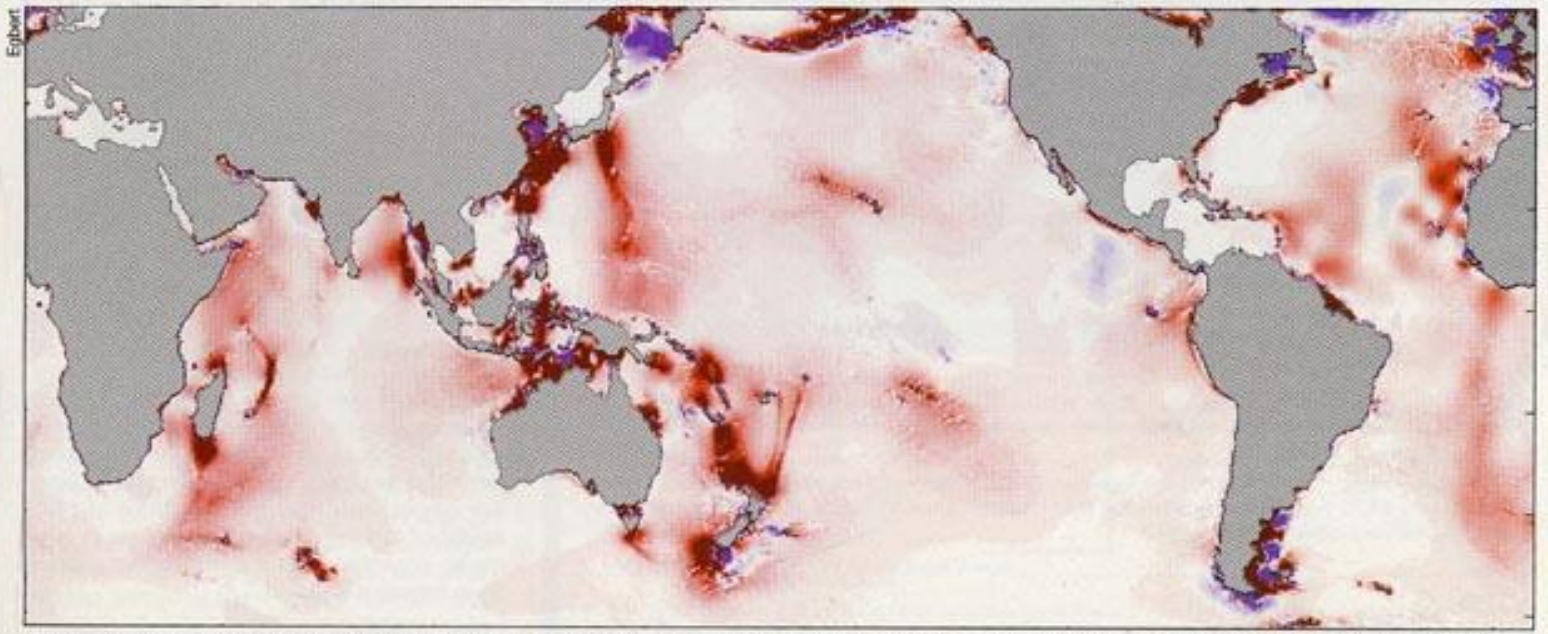
The Current Situation

- Tidal Energy is sustainable, clean, reliable, widely distributed, and can offer significant benefits to many marine nations.
- Tidal Energy can be captured in an efficient and cost-effective way.
- Tidal Energy is not yet recognized by the United Nations as an energy resource that should receive support and funding for its development.

The Current Situation

Tidal Energy is a clean, renewable source of energy--such as solar, wind, biofuels, and low-head hydro--and deserves official international support and funding for its development.

The Worldwide Distribution of Tidal Energy



Based on TOPEX/Poseidon satellite data, a color map estimates tidal energy dissipation in the ocean between 66°S and 66° N. Red areas show tides losing energy. Blue areas reflect noise in the data.

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Red areas show most intense tidal energy

Developing Nations that could receive significant benefits from Tidal Energy

Indian Ocean: Comoros, Madagascar, Maldives, Seychelles.

Asia: China, India, Indonesia, Korea, Philippines, Vietnam.

Pacific Ocean: Fiji, Kiribati, Micronesia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor, Tuvalu, Vanuatu.

Central and South America: Argentina, Brazil, Ecuador, Guyana, Panama, Surinam.

Atlantic Ocean: Cape Verde.

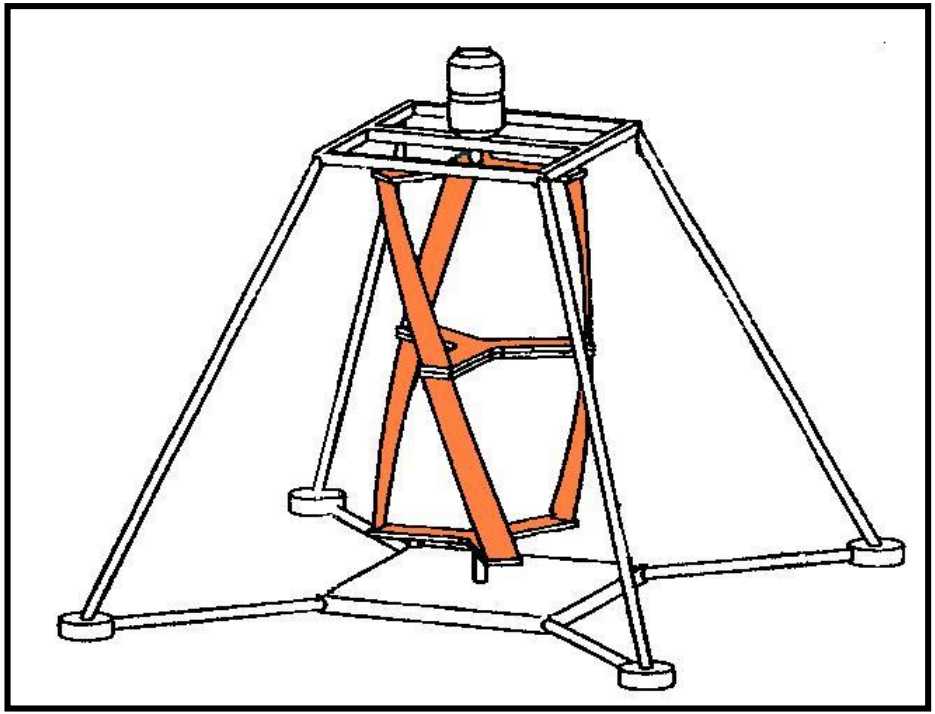
All coastal nations with tidal passes between coral reefs or offshore islands.

Significant benefits from using Tidal Energy include:

- Electrification of isolated communities
- Generation for the grid
- Regrowth of coral reefs using mineral accretion technology
- Substitution of imported petroleum used to generate electricity

Significant benefits from using Tidal Energy include:

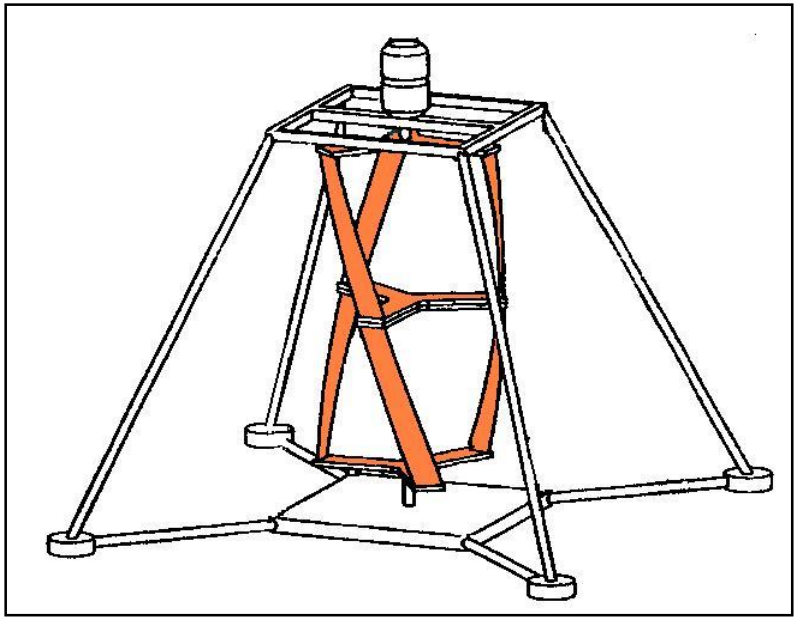
Schematic view of the helical turbine mounted in a frame.



Features of the Helical Turbine:

Basic Concept

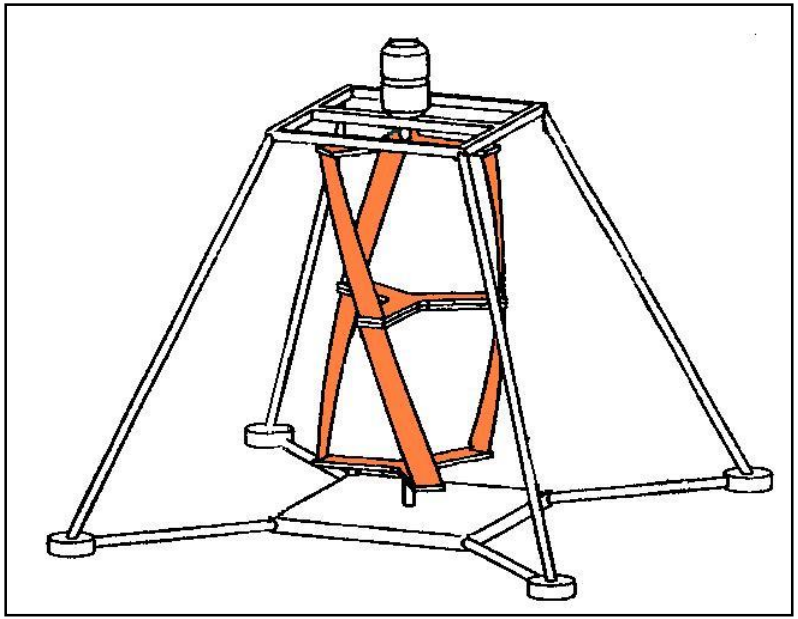
- designed for hydroelectric applications in free-flowing water
- operates in ocean, tidal, and river currents
- does not require expensive dams that can harm the environment



Features of the Helical Turbine:

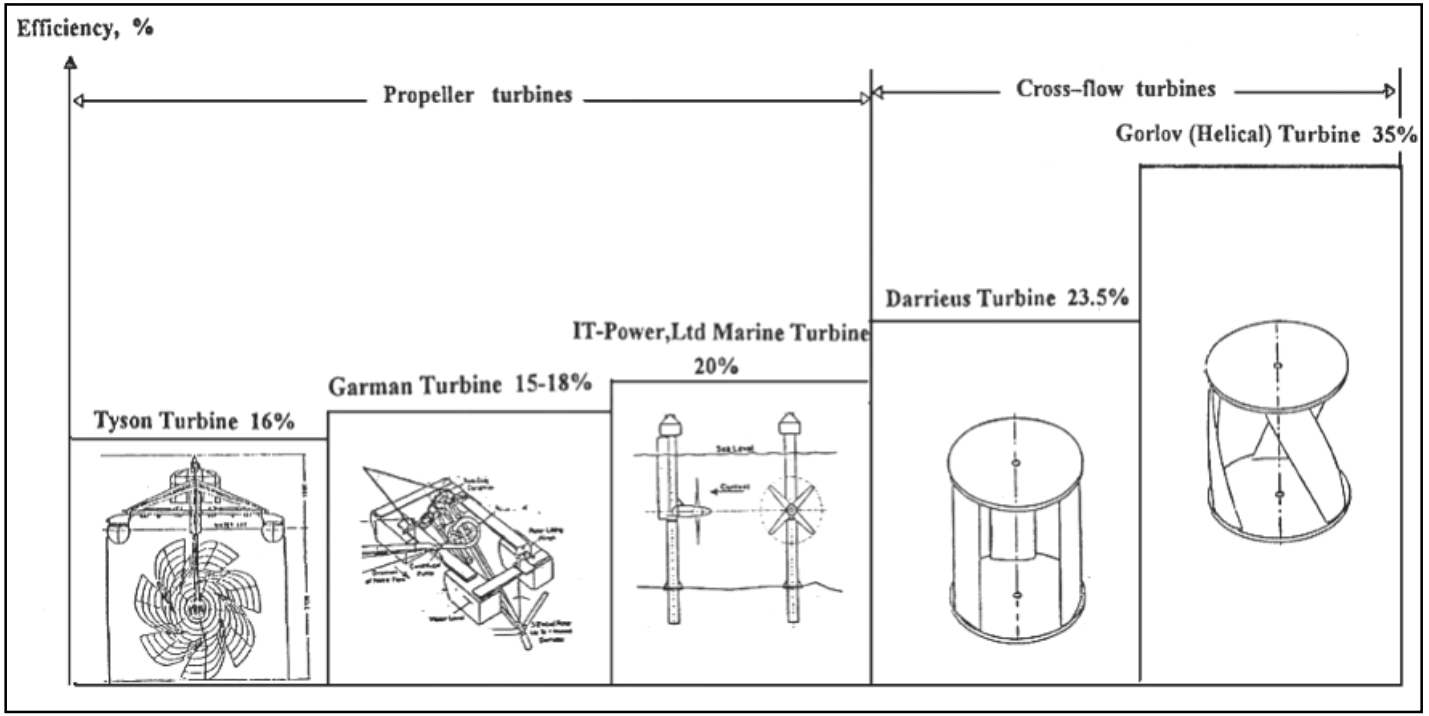
Operation

- self-starting with flow as low as 0.6 m/s
- smooth-running
- rotates in same direction regardless of the direction of flow, making it ideal for tidal applications



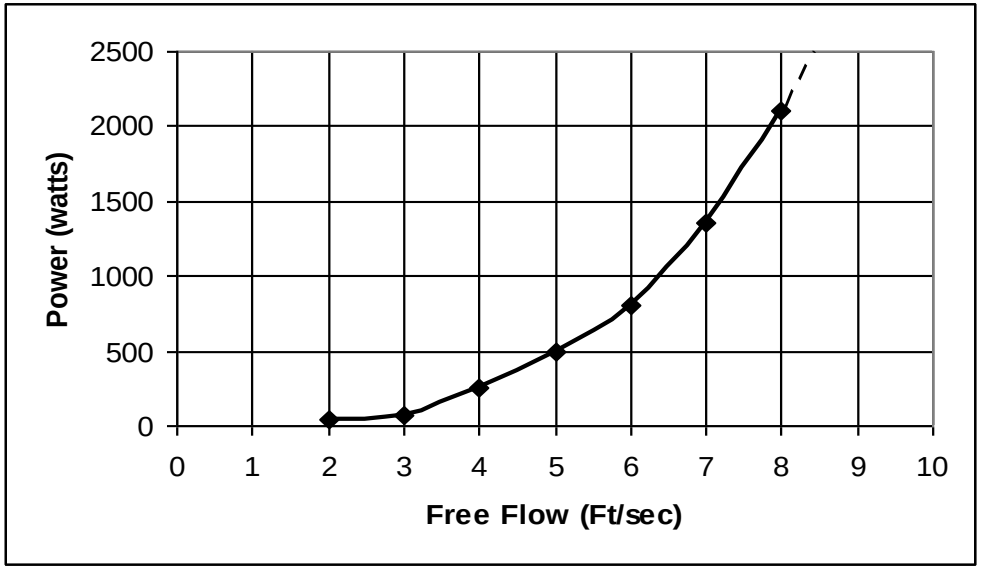
Features of the Helical Turbine:

35% Efficiency



Features of the Helical Turbine:

Power increases 8 times when velocity doubles

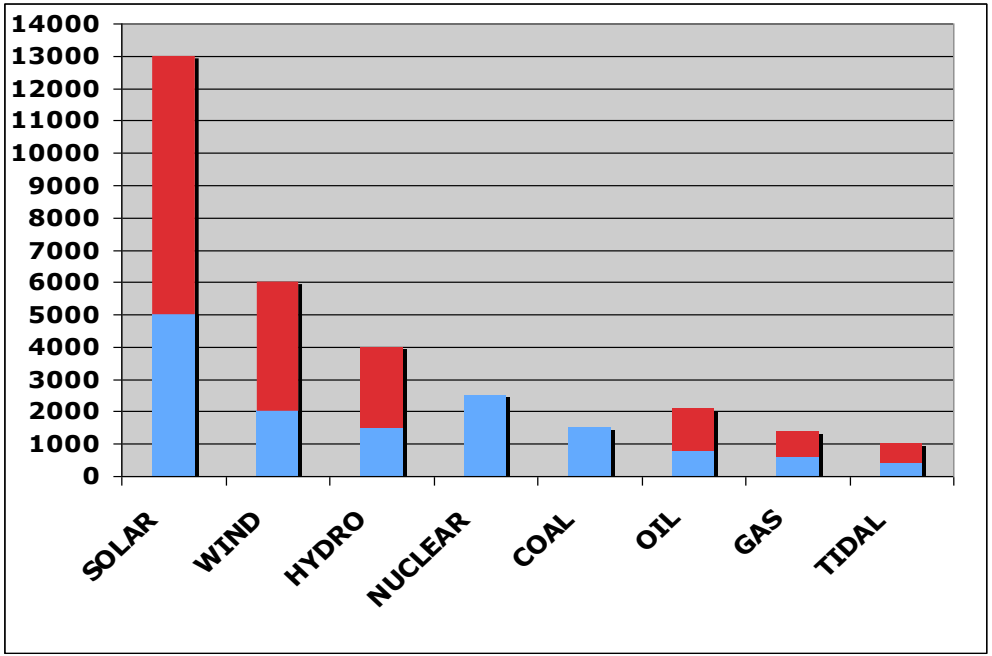


I Knot =
1.69 ft/sec

I M/sec =
3.28 ft/sec

Features of the Helical Turbine:

Installation Cost: dollars/kw



Different Types of Tidal Plants

Tidal Barrages

These involve the creation of mammoth concrete dams with sluices to create grander scale operations than the 12th century tide mills.

Tidal Stream Generators

Very similar to the principles in wind power generation – water flows across blades which turn a turbine much like how wind turns blades for wind power turbines.

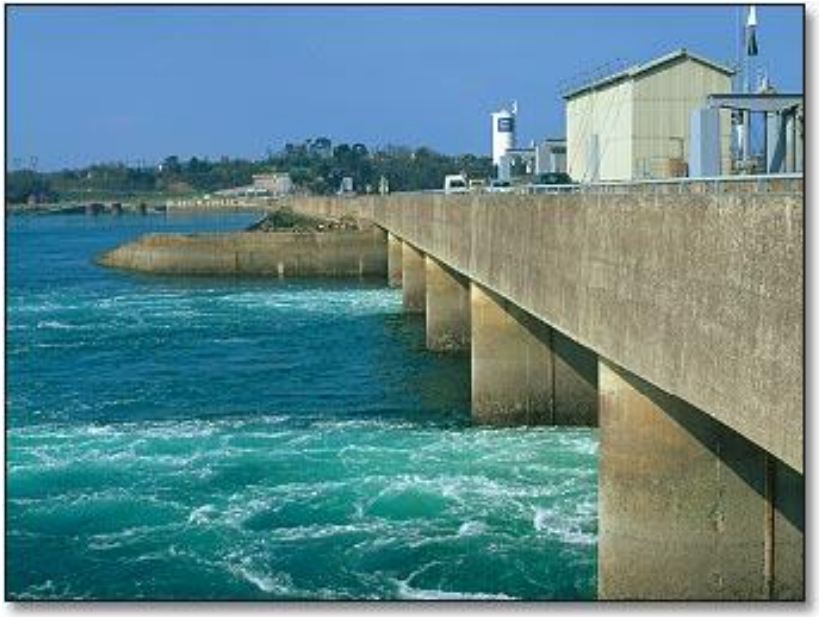
Different Types of Tidal Plants

Dynamic Tidal Power

This is a technology that is not currently commercial viable, but in which the UK, Korea, and China invested heavily to research. It involves a partial dam which raises the tidal height and several hydropower generators. The differences in height between the head of the dam and the low tide coast force water through the generator, much like a traditional hydropower dam.

Tidal Barrage

- The first commercial tidal power plant in the world since the middle ages is the La Rance Tidal Barrage in France.
- The barrage was constructed in 1960 and consists of a 330m long dam with a 22km^2 basin. The effective tidal range is 8m.
- The work was completed in 1967 when 24 5.4m diameter bulb turbines, rated at 10MW each, were connected to the French power network with a 225kV transmission line.
- The French authorities decided on a bulb turbine with axial power generation because it suited the style of a tidal barrage as it flows from the head of the dam to the basin through the turbine.



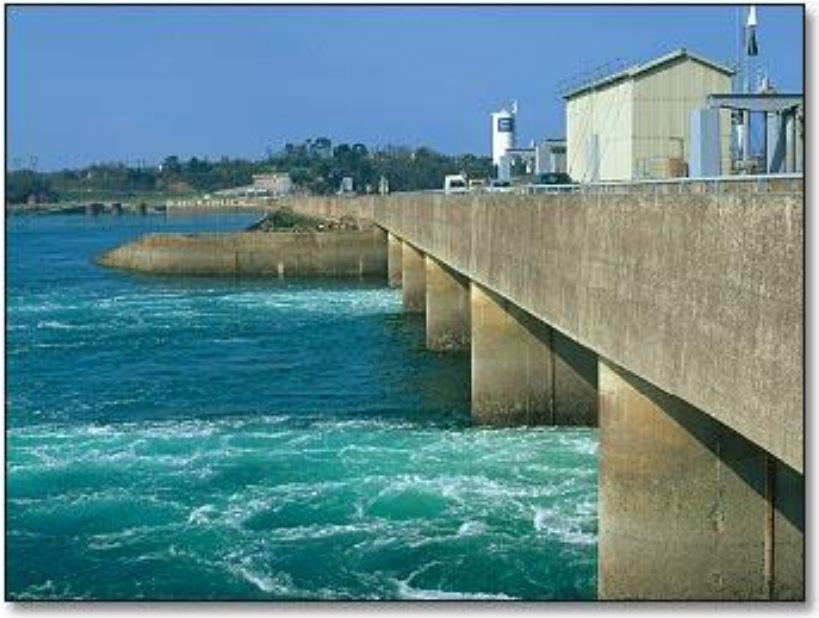
Tidal Barrage

Calculating the total energy production of the La Rance plant is easy if you know some key facts:

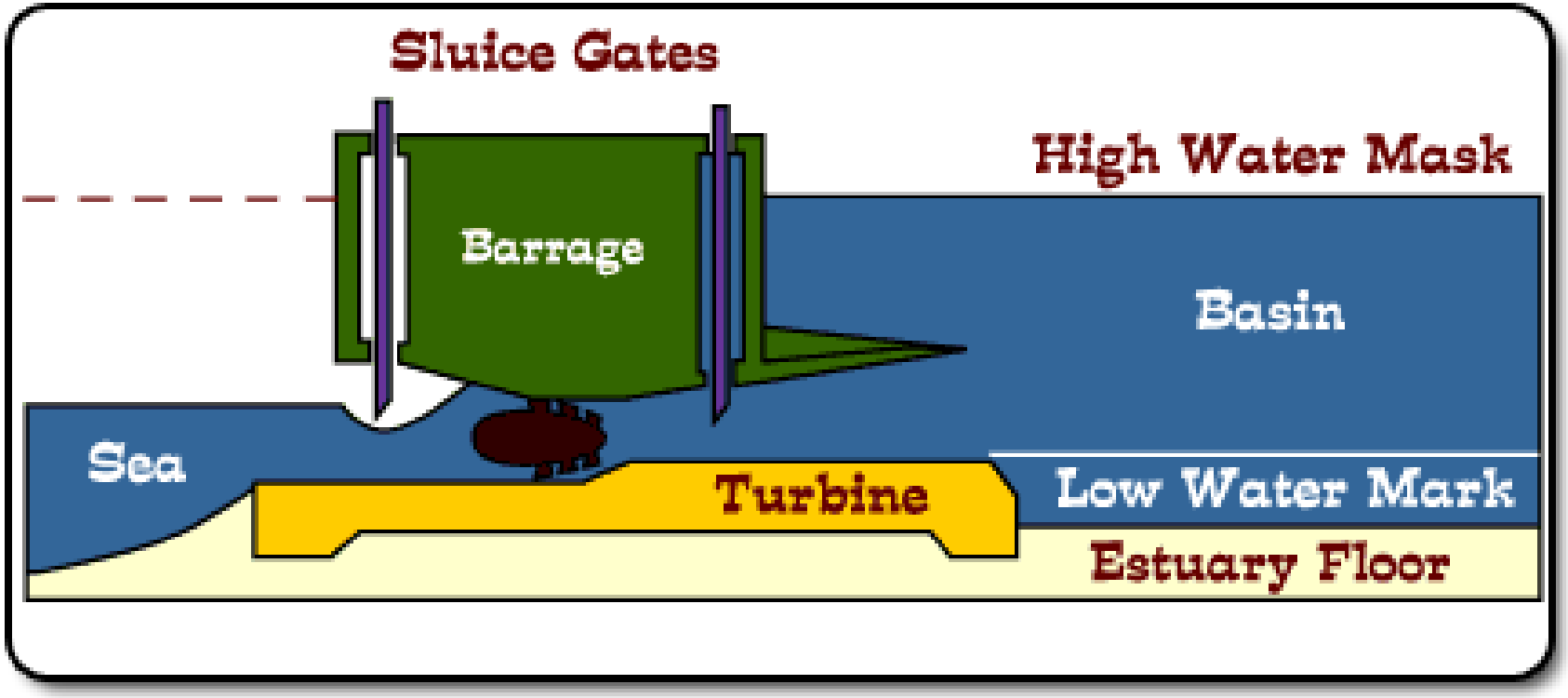
- The La Rance plant has 24 generators with a 10MW capacity:
- The equation is as follows:

Maximum Electricity generated per annum (kWh) = Generator capacity * time + Cf (capacity factor)

The particular generator used in this plant had a Cf of 40%, resulting in 3504MWh per year per generator.



How Tidal Barrages Work



Tidal Barrage Drawbacks

There are notable complications with tidal barrage energy generation. While they generate comparable power to hydropower plants, they also have economic and environmental issues;

- The necessary infrastructure to build a tidal barrage is cost prohibitive.
- Tidal barrages negatively affect the turbidity, water levels, and ecology of the separated areas.

Tidal Barrage Drawbacks

- Benthic habitats may change due to the bottom stress from modified waves and currents.
- Migratory fish may be impeded although fish passes can be constructed to facilitate migrations.
- Fish and marine mammals may suffer injuries and death when colliding with the barrage/turbines.
- Estuaries that are currently providing breeding spaces for fish, may not be suitable for this purpose after construction.

Effects on Turbidity

- Because the tides are being captured, the turbidity of the La Rance estuary more closely resembles lower tidal basins.
- The high turbidity regions have shrunk, affecting the preferences of wildlife who lived in the pre-barrage La Rance estuary.
- UK government reports made while preparing to evaluate the suitability of barrage style tidal power plants in the UK contain observations of the barrages have on the environment, including forecasted effects on UK tidal estuary systems.

Other Ecological Effects

- The increasing sea exchange (due to pumping to increase water head, and therefore generating capacity) has increased the invertebrate breeding capacity.
- The outer estuary is now being fed by the inner estuary, which is a role reversal due solely to the barrage's effect on the ecology and hydrology of the region.

Other Ecological Effects

- Shorebird prevalence has increased, but this is a nationwide trend across France.
- The primary attributing force for the increased shorebird populations are the increasing invertebrate life which is the primary source of food for shorebirds.
- Like shorebirds, fish diversity and biomass have increased due to the greater availability of invertebrate life that sustains these fish stocks.

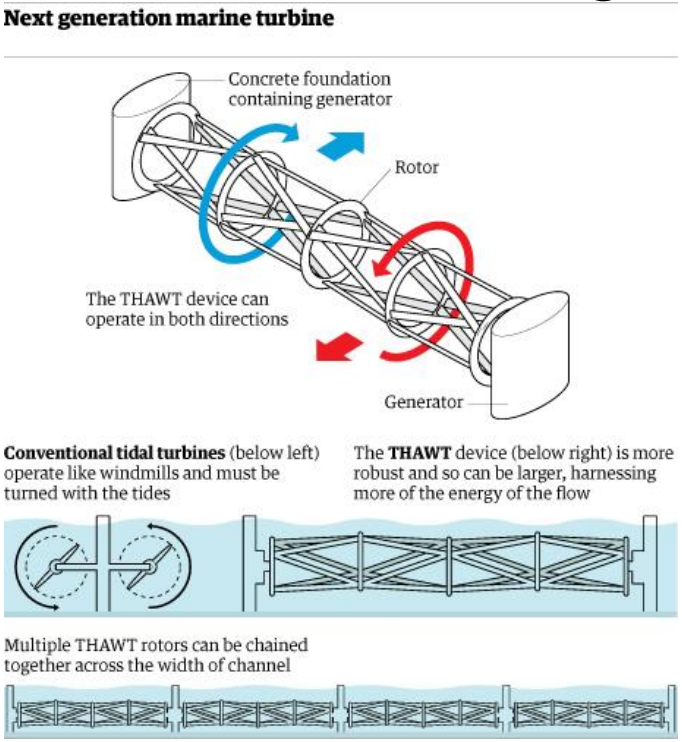
Other Ecological Effects

- However, some fish species cannot traverse through the barrage and these species are no longer present.
- The new types of fish have displaced these original fish stocks and have thrived.
- Due to the dual flow nature of tidal barrages, fish mortality from turbine blades is nearly twice that of other hydropower.

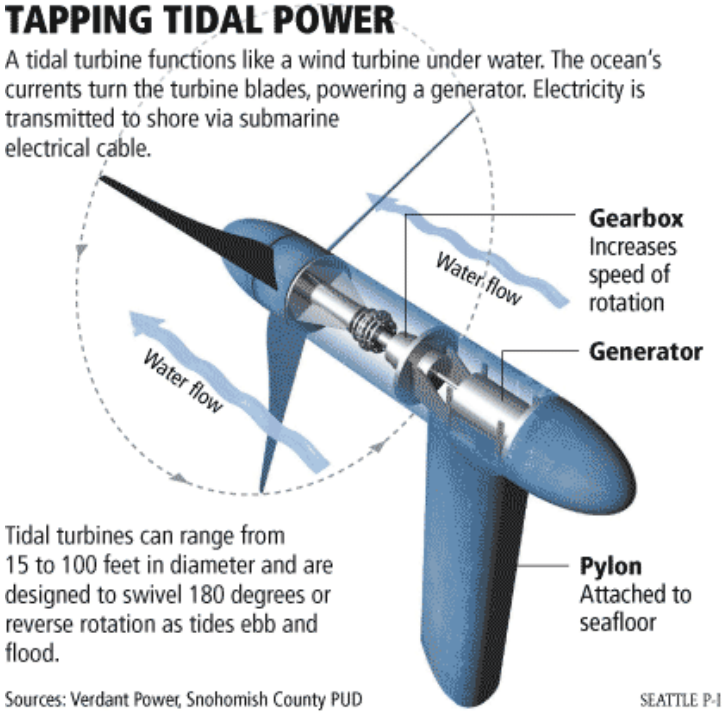
Economic Issues

- The capital costs of a barrage like La Rance are tremendous because of the sheer scope of a project and the few sites around the world that are suitable for tidal power generation.
- The company that administers the La Rance power plant now claims that the capital investments in the barrage have been paid off and currently the power plant generates cheaper electricity than a nuclear power plant. (1.6 cents per kWh vs. 2.5 cents per kWh for a nuclear plant).

The Future of Tidal Barrages

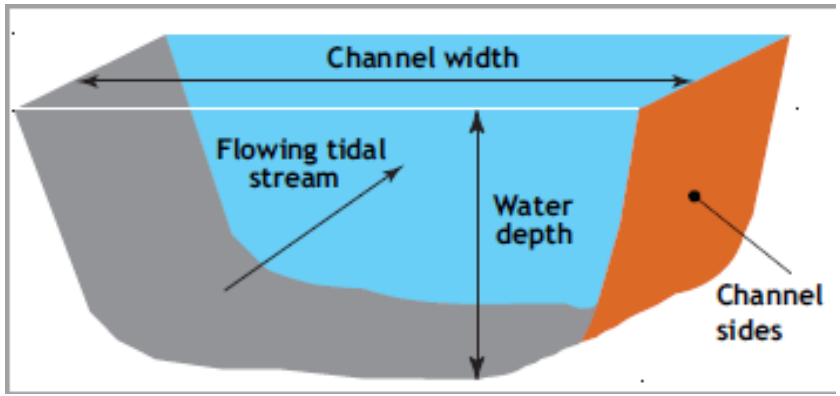


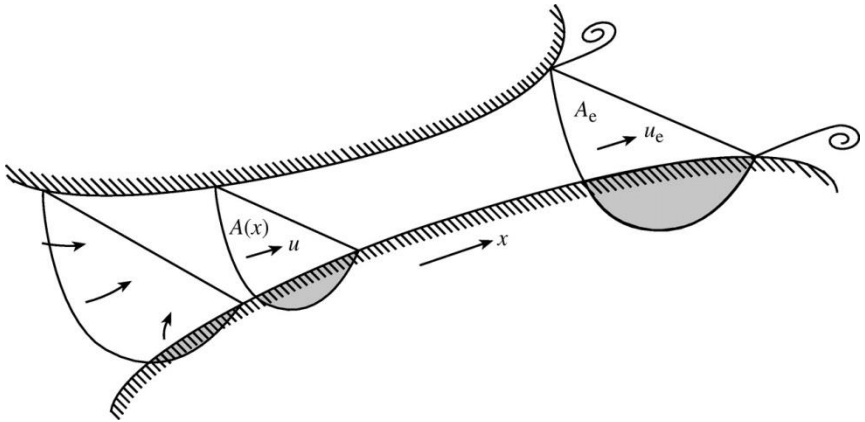
Tidal Stream Generators



What are Tidal Streams?

A channel connects two basins with different tidal elevations.

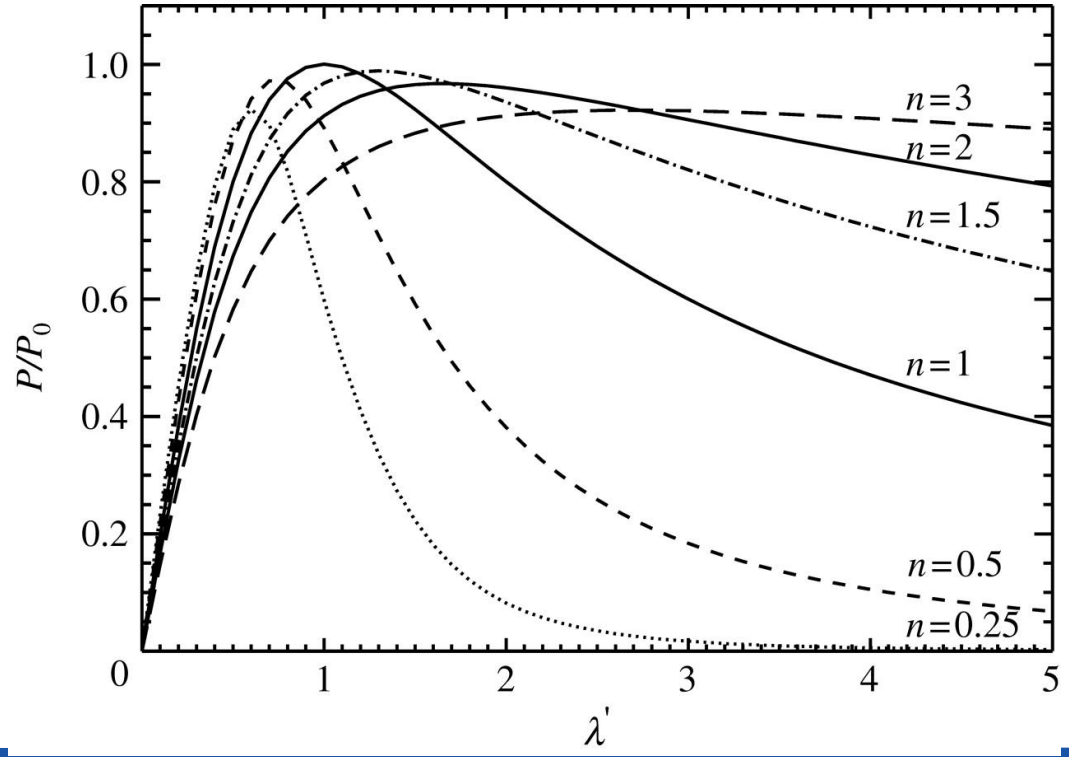




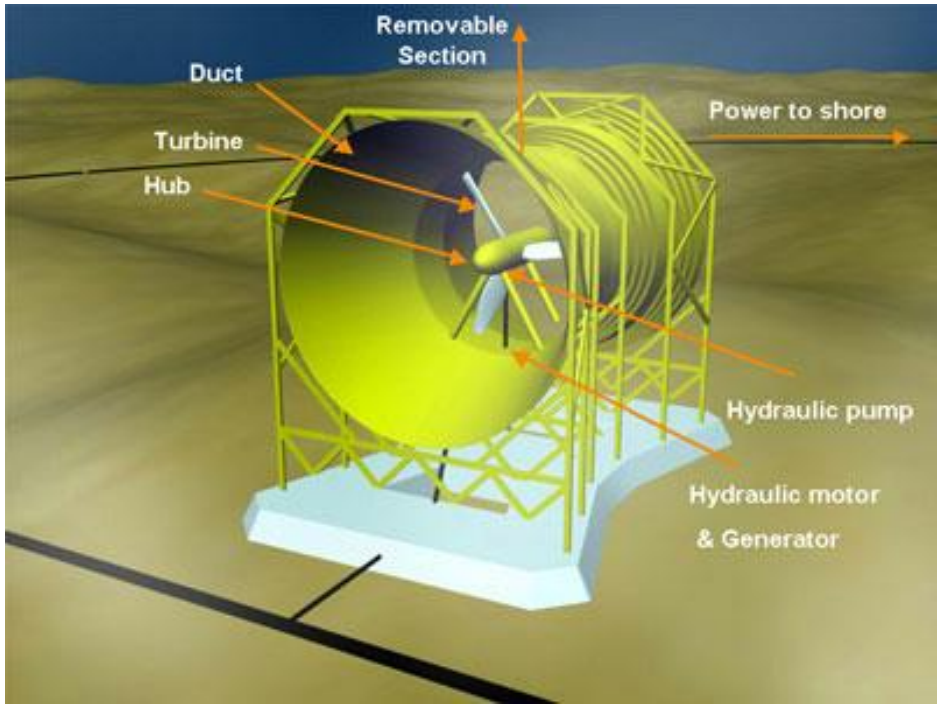
What are Tidal Streams?

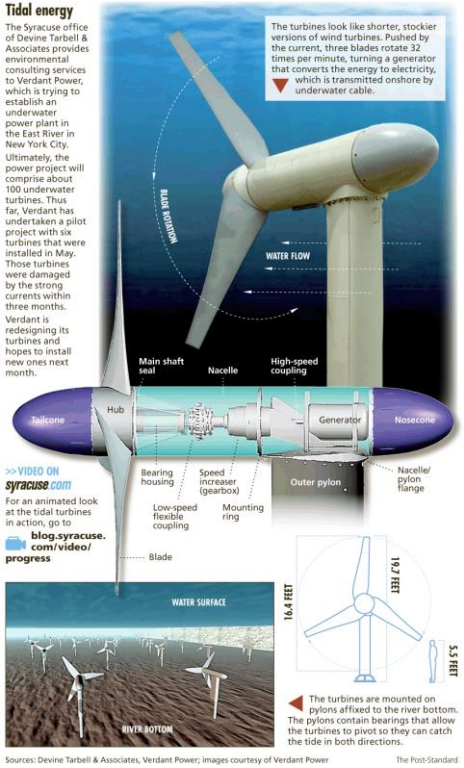
The scaled maximum power as a function of a parameter λ′, representing the frictional drag associated with the turbines, for various values of n where the turbine drag is assumed proportional to the nth power of the current speed.

What are Tidal Streams?

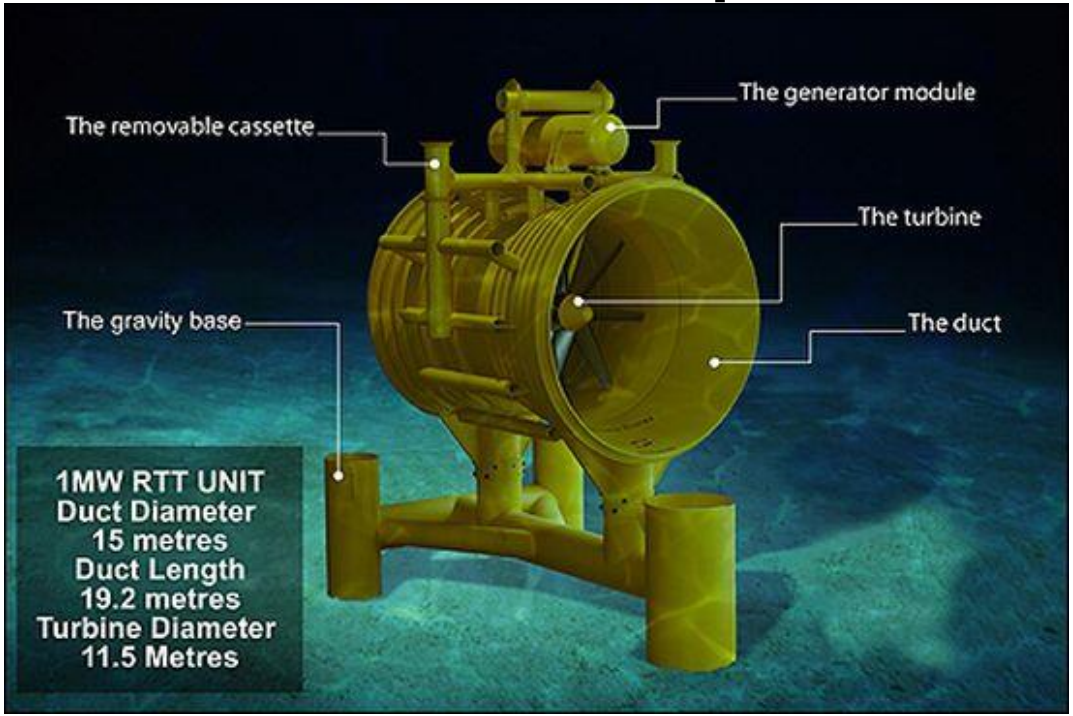


Tidal Stream Generators





Tidal Stream Generator Specifics



Tidal Stream Generators

- The world's only operational commercial-scale tidal turbine, SeaGen, was installed in Strangford Narrows in Northern Ireland in 2008.
- The prototype SeaGen turbine produces 1.2MW with currents of 2.4m/s or more. The capacity factor exceeds 60%.
- The facility is an accredited UK power station, and can contribute up to 6,000MWh annually to the UK grid, the equivalent of approximately 1500 homes.

Room to Grow

- Plans are underway to install a tidal farm in Kyle Rhea, a strait of water between the Isle of Skye and the Scottish mainland
- The project will have the capacity to generate electricity for up to 4,000 homes in the Scottish Highlands & Islands by harnessing the power of the fast tidal currents that pass through Kyle Rhea 14 hours a day.
- The parent company, Marine Current Turbines (MCT), estimates that the cost of the 5MW Kyle Rhea scheme, consisting of four SeaGen tidal units, will be £35million.

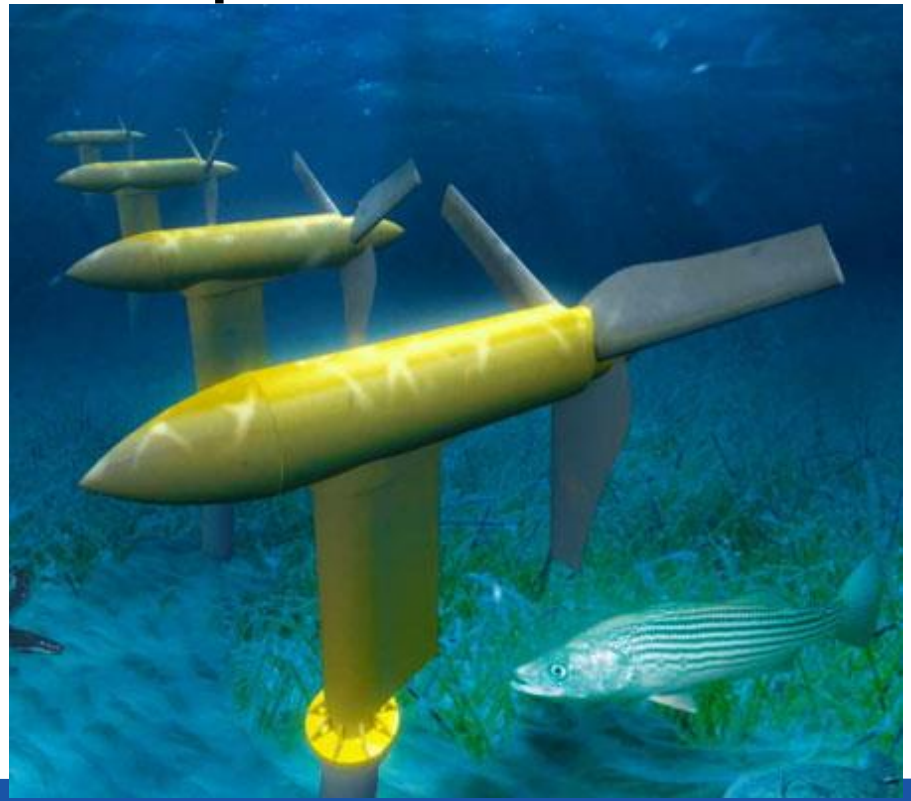
Drawbacks of Tidal Stream Generators

- High start-up and construction costs: due to limited experience of installing, operating and maintaining plants, contractors' perceptions of risk are likely to be reflected in higher costs.
- Like the wind, waves and tidal streams are variable renewable energy sources. Their intermittent generation has implications for large scale grid integration.
- Because the amount of energy tidal streams naturally varies over time, the power output of wave energy converters and tidal stream energy generators will also vary. This has implications for grid integration, particularly balancing supply and demand.

Economic Issues

- Although the capital costs of tidal stream generators can be quite high, there is preliminary evidence that the installation of these facilities gives support to local economies because local firms can expect to participate in the tidal farm's installation, operation and maintenance.
- The company that administers MCT's project in Northern Ireland notes that a number of local companies such as marine support vessels, engineering and electrical contractors, civil engineers, environmental scientists and divers as well as local hotels, pubs and restaurants have benefited from the Strangford Lough project. It is estimated that the project has contributed more than £4million into the Northern Irish economy over the past three years

Environmental Impacts of Tidal Stream Generation



Environmental Effects

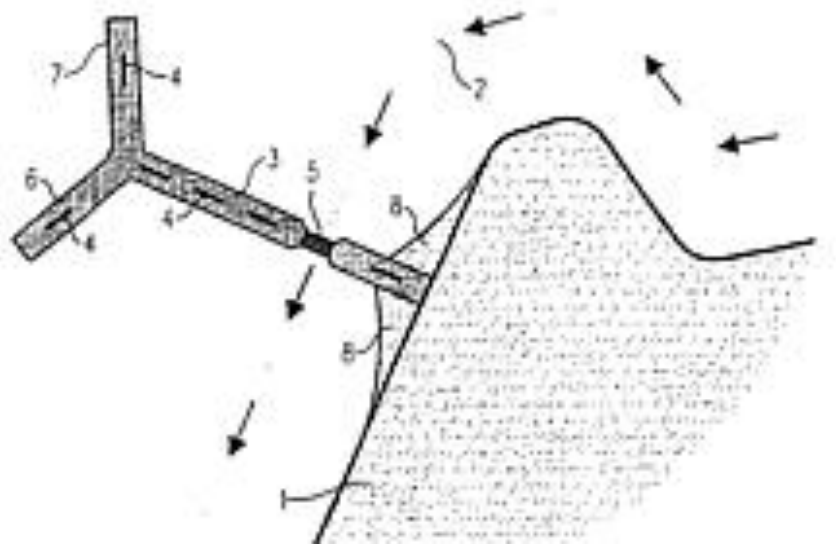
- Studies to date suggest that local environmental impacts are likely to be minor, but further research is required into device-environment interactions, particularly the impact of tidal stream energy generators on flow momentum.
- Although the generators create no noise audible to humans, they do create “modest” noise underwater. Manufacturers maintain that this is important to help marine wild-life have an awareness of the presence of the turbine.

Environmental Effects

- MCT's information for the project in Northern Ireland notes that, "rigorous and detailed environmental impact studies, carried out by independent consultants, suggest that the technology is most unlikely to pose a threat to fish or marine mammals, or the marine environment in which they live. A major monitoring programme is already under way for the SeaGen device installed in Strangford Narrows which will build upon this work."

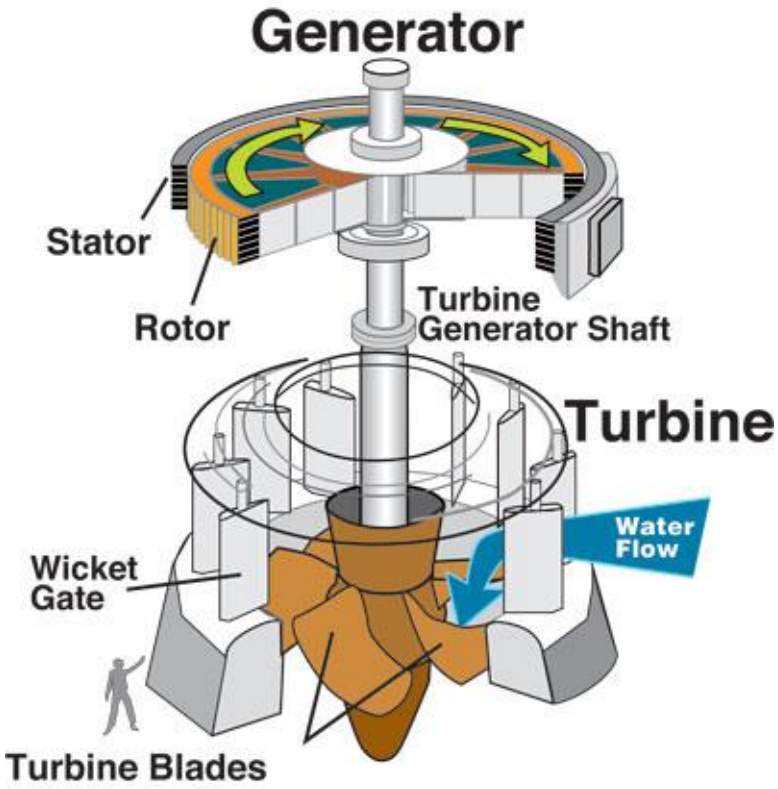
Dynamic Tidal Power

- Similar to tidal barrage method with similar advantages and disadvantages.
- Capital intensive and has a large, dominant footprint.
- With DTP the dam does not fully separate the sea from the tidal estuary.
- This minimizes some environmental effects but also slightly diminishes the tidal energy captured as a result of each ebb and flow.
- No commercial implementation, purely theoretical at this time.

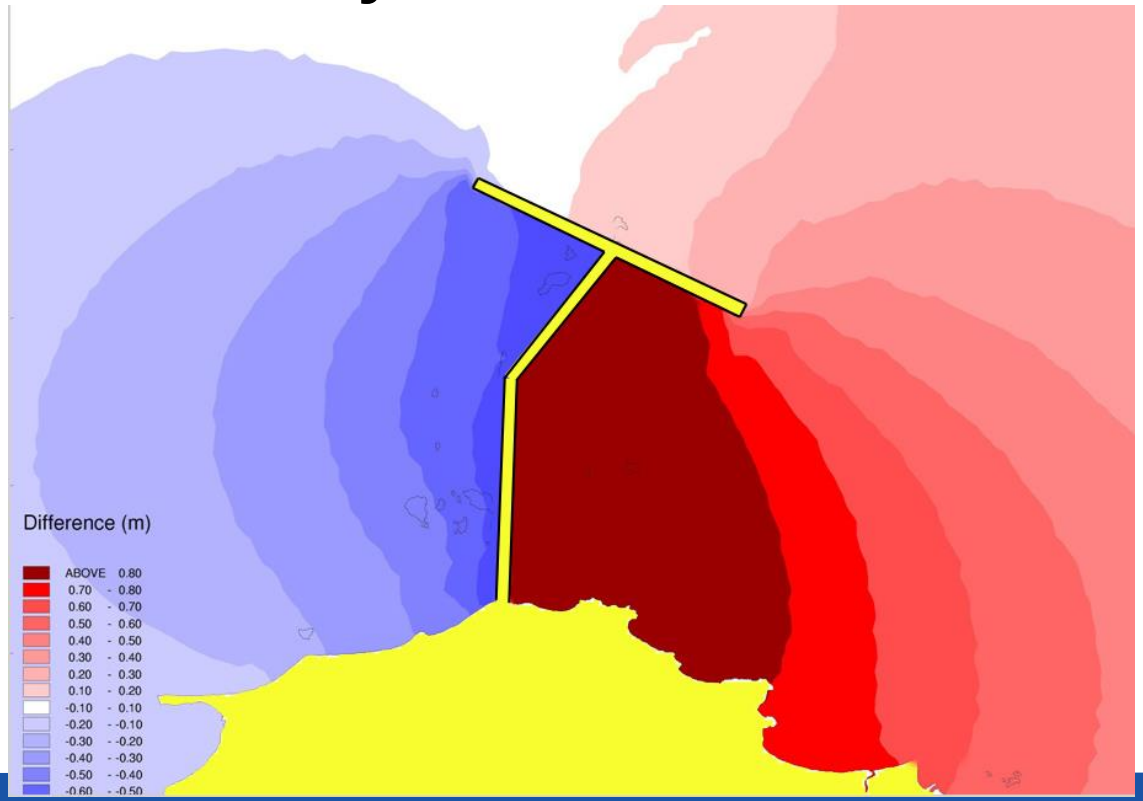


Dynamic Tidal Power

- Utilizes a special type of turbine that should increase the efficiency of the tidal energy capture.



How Tidal Dynamic Power Works



Practical Steps Regarding Tidal Energy

- The EISA of 2007, Title II, has specific provisions for hydrokinetic energy sources.
- It provides in Subtitle C, Section 621 et seq.:
  - Research and development
  - A lack of specific mandates or priority on federal land.
  - Coastal management with state lands (CMZA).
- Energy Policy Act of 2005, §931 directs the Secretary of Energy to conduct research and development (R&D) programs for ocean energy, including wave energy and kinetic hydrogeneration projects, and §388 amends §8 of the Outer Continental Shelf Lands Act (43 U.S.C. §1337) to grant authority to the Secretary of the Interior to grant leases on the Outer Continental Shelf (OCS) for the production of energy from sources other than oil and natural gas.

Steps for Permit

- File for a preliminary permit subject to 4(f) of the Federal Power Act to preserve priority of permit status while:
- Conduct studies to determine the feasibility of the proposed project.
- Design specs are reviewed
- Preliminary permit does not grant title to land, but instead sparks the public comment process per APA regulations.

Steps for Permit

- Licensing provisions are fashioned from the consideration of the studies on feasibility and environmental and social impacts and the public comment process.
- Commission decides whether to grant preliminary permit and whether to grant a license.
- Similar to other proceedings under FPA and procedures under the APA.

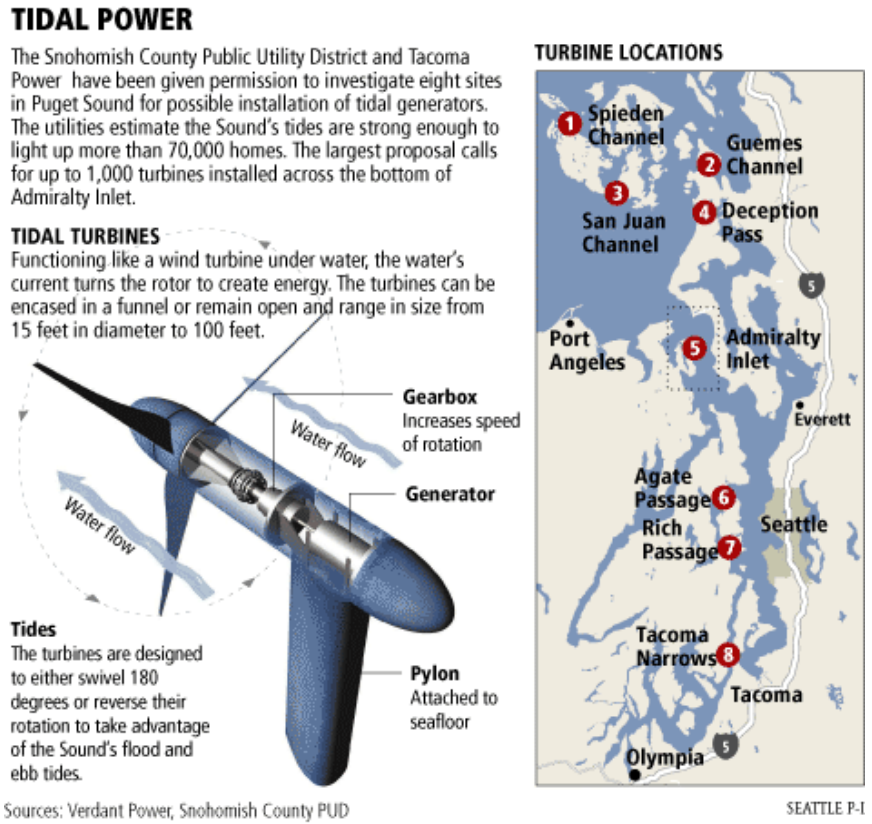
Current Legal Issues Regarding Proposed Tidal Plants in the US

- Section 4(e) of the FPA directs the Commission to give equal consideration to the purposes of power and development, energy conservation, fish and wildlife, recreational opportunities, and preservation of environmental quality "in deciding whether to issue a *license*." (*National Wildlife Federation)*.

Current Legal Issues Regarding Proposed Tidal Plants in the US

- Similarly, sections 10(a) and 10(j) are prefaced with the direction that “all *licenses* issued under this subchapter” shall include the conditions required by sections 10(a) and 10(j).

Conclusion


TIDAL POWER
The Snohomish County Public Utility District and Tacoma Power have been given permission to investigate eight sites in Puget Sound for possible installation of tidal generators. The utilities estimate the Sound's tides are strong enough to light up more than 70,000 homes. The largest proposal calls for up to 1,000 turbines installed across the bottom of Admiralty Inlet.
TIDAL TURBINES
Functioning like a wind turbine under water, the water's current turns the rotor to create energy. The turbines can be encased in a funnel or remain open and range in size from 15 feet in diameter to 100 feet.
Gearbox
Increases speed of rotation
Water flow
Water flow
Generator
Pylon
Attached to seafloor
Tides
The turbines are designed to either swivel 180 degrees or reverse their rotation to take advantage of the Sound's flood and ebb tides.
Sources: Verdant Power, Snohomish County PUD
TURBINE LOCATIONS
1 Spieden Channel
2 Guemes Channel
3 San Juan Channel
4 Deception Pass
5 Admiralty Inlet
Port Angeles
Everett
Agate Passage 6
Rich Passage 7
Seattle
Tacoma Narrows 8
Tacoma
Olympia
5
SEATTLE P-I

Thank You