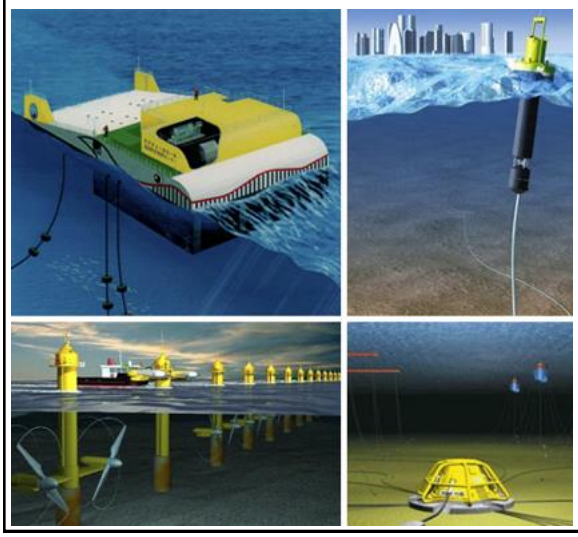
Renewable Energy Systems (12210588)

14. Hydropower III: Tides and wave energy

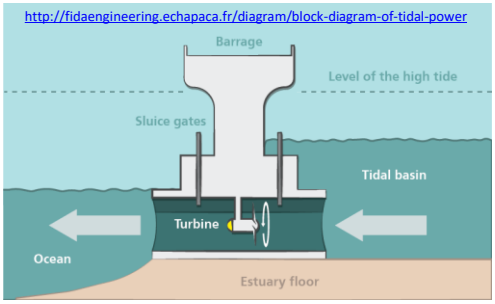


Fathi Anayah, PhD

Lecture 14

Water power 2: Tidal power

- **Tidal** power involves building a **dam** across a river estuary.
- Water can only flow in and out of the estuary through **turbines** in the dam, which harness the tidal energy.



- Tidal power is able to provide a lot of **electricity**, however building a tidal **barrage** is very expensive.
- When a tidal **barrage** is built, it results in some of the estuary being flooded. This can mean the **loss** of important habits for wading birds.

http://bioblocks.weebly.com/uploads/8/7/0/6/8706802/notes_-_renewable_energy.pdf

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Effective use of tidal power

- **Tidal** power provides a regular source of **electricity**. Exactly when this electricity will be produced is governed by the **tides**, which depend on the **Moon**.
- **Monthly variations** in the tidal range will also affect how much electricity can be produced.
- The passage of **ships** past the tidal barrier and the effect on **wildlife** also complicate the **construction** of tidal barrage schemes.

https://www.audubon.org/news/how-read-tides-shorebird-photography

http://bioblocks.weebly.com/uploads/8/7/0/6/8706802/notes_-_renewable_energy.pdf

How Tides Work?

- As you all know, when the **tide** comes in at the ocean, the water **level** appears to **rise** (and can do so significantly), while at **low tide**, the water **level** appears to **drop**.

http://scienceblogs.com/startswithabang/2010/02/24/how-tides-work/

- This goes in a **cycle twice per day**, with the ocean level reaching its **highest** point **twice** daily (**high tide**), having the water recede over a period of **six hours** until it reaches its **lowest** level (**low tide**), and then having the water level rise again over a period of another six hours until it reaches the next high tide.

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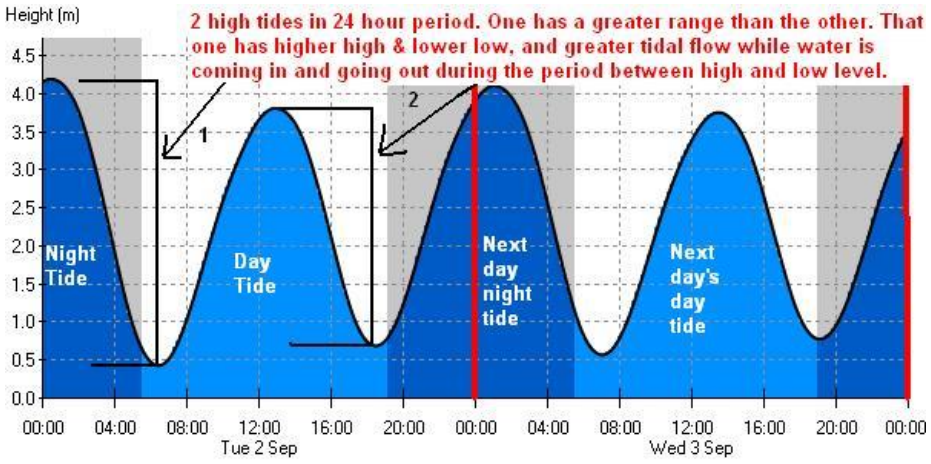
- **Variations** in the height of the water level are typically on the order of **three** meters (maybe ten feet) each **day**, depending on a couple of **factors**.



http://scienceblogs.com/startswithabang/2010/02/24/how-tides-work/

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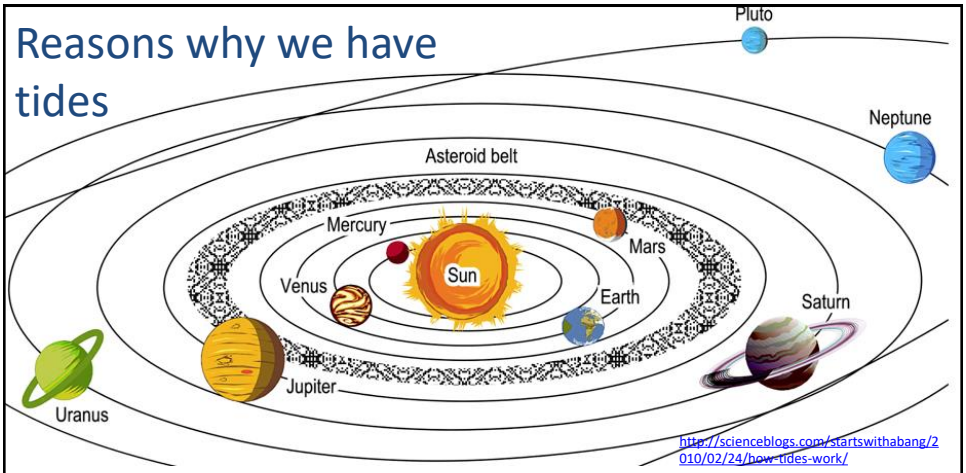
Reasons why we have tides



http://scienceblogs.com/startswithabang/2010/02/24/how-tides-work/

- The **Earth** is pretty big and **gravity** cares how far away you are.
- The **farther** away you are from something, the **weaker** gravity's pull is on you.
- The **force** of gravity from the **Sun** on the **Earth** would be an **astounding 1,600** times **weaker** than it is today, as Pluto is **40** times as **far** away as Earth is from the Sun!

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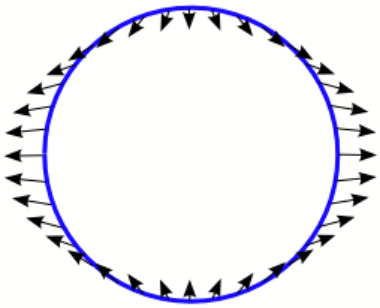
- If you were to look at everything in our **Solar System** and ask what affects the **Earth** the most, **gravitationally**, you'd think to look at two things: the **Moon**, because it's **massive** and it's very, very **close** to us, and the **Sun**, because it's **extremely massive**, even though it's quite **far** away.
- The **tidal** forces from the **Sun** are **weaker** than those from the **Moon**, but are still quite strong, causing tides that are about **30%** as strong as the Moon's.
- The **Earth** is quite **far** from the **Moon**, at an average distance of **384,400** km. The force of **gravity** of the **Moon** on the **far** side of the Earth is about **3.2% weaker** than it is at the **center** of the Earth.



http://scienceblogs.com/startswithabang/2010/02/24/how-tides-work/

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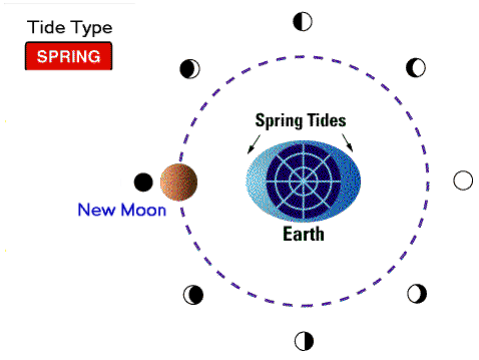
Tide Cycle

There are **two high tides** and **two low tides** around the Earth at any instant. One **high** tide is on the **longitude closest** to the **Moon** and the other on the **longitude furthest** from the **Moon**. The **low tides** are on the **longitudes** at **90**◦ to the longitudes where the high tides are situated.



On any given longitude the **interval** between **high** tides is approximately **12** hours **25** minutes. The **difference** in **height** between a **high** tide and a **low** tide is called the **tidal range**.

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Tidal potential of some large tidal range sites

Country	Site	Mean tidal range (m)	Basin area (km^2)	Capacity (GW)
Argentina	Golfo Nuevo	3.7	2376	6.6
Canada	Cobequid	12.4	240	5.3
India	Gulf of Khambat	7.0	1970	7.0
Russia	Mezen	6.7	2640	15.0
Russia	Penzhinsk	11.4	20530	87.4
UK	Severn	7	520	8.6

Generating Power Methods

a. Tidal barrage
b. Tidal stream generator
c. Dynamic tidal power

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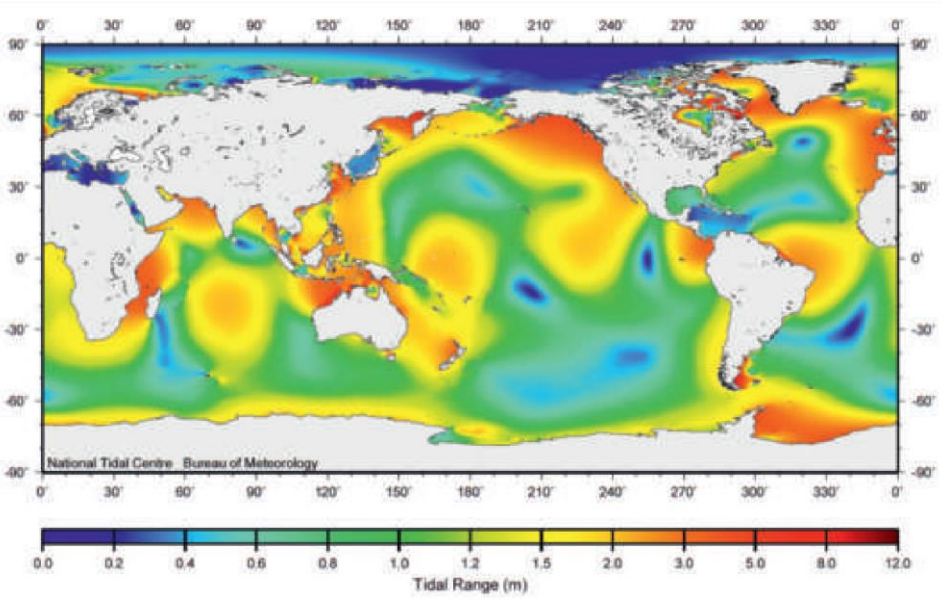
Tidal range resources worldwide



https://irena.org/-/media/Files/IRENA/Agency/Publication/2014/Tidal_Energy_V4_WEB.pdf

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a. Tidal barrage

The Rance Tidal Power Station, a tidal barrage in France (1966)

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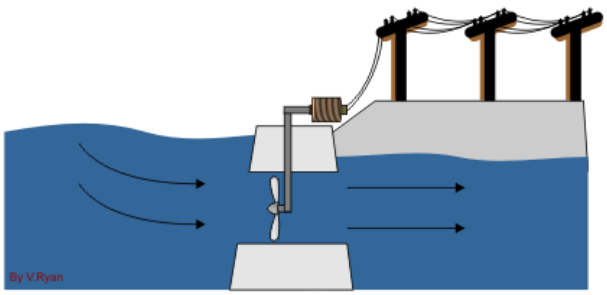
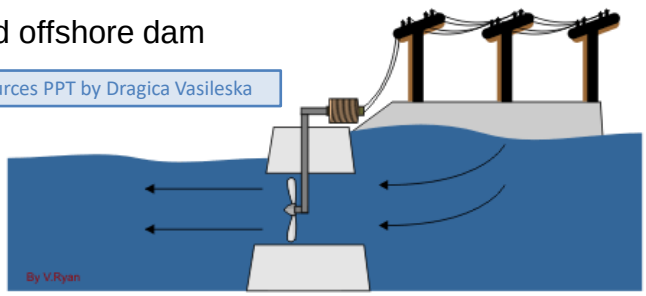
Tidal Power



TIDE COMING IN

1. In areas of large tides
2. Anywhere – build offshore dam

Source: Renewable Energy Sources PPT by Dragica Vasileska

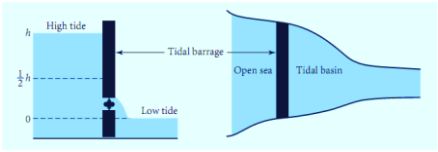


TIDE GOING OUT

Tidal barrage

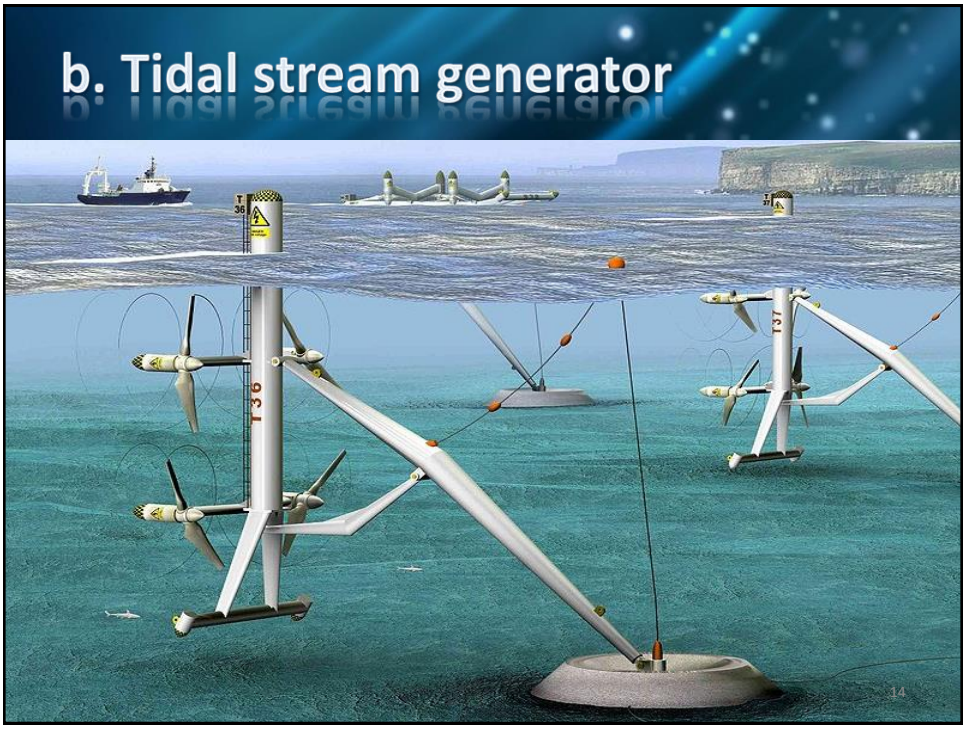
A rough estimate of the **average power output** from a tidal barrage can be obtained from a **simple energy balance** model. Consider a tidal basin of area A. The **total mass** of **water** in the tidal basin above the **low** water level is $\mathrm{m} = \rho \mathrm{Ah}$, where h is the **tidal range**. The **height** of the center of gravity is $\frac{1}{2}h$, so the **work** done in raising the water $mg\left(\frac{1}{2}h\right) = \frac{1}{2}\rho g A h^2$. Hence the **average power output** is

$$P_{\text{ave}} = \frac{\rho g A h^2}{2T}$$



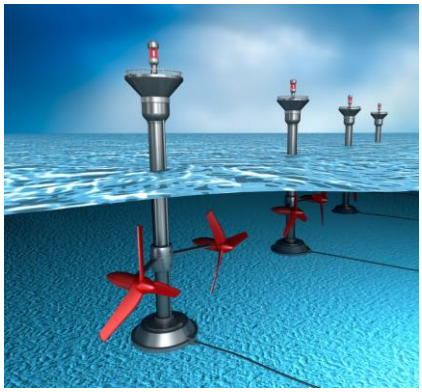
where T is the **time interval** between **tides**, i.e. the **tidal period**. In practice, the power varies with time according to the difference in water levels across the barrage and the volume of water

John Andrews, Nicholas Alfred Jelley, Nick Jelley (2007). Energy. Science: Principles, Technologies, and Impacts. OUP Oxford, U.K.



Tidal stream generator

Tidal stream generators draw **energy** from **water** currents in much the same way as **wind turbines** draw **energy** from **air** currents. However, the **potential** for power generation by an individual tidal turbine can be **greater** than that of similarly rated wind energy **turbine**.



The higher density of water relative to air (water is about 800 times the density of air) means that a **single generator** can provide **significant power** at **low tidal flow velocities** compared with similar **wind speed**.

https://www.woodharbinger.com/tidal-energy-sustainable-resource/

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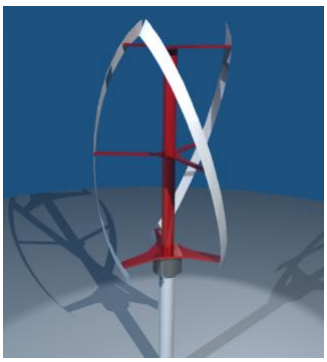
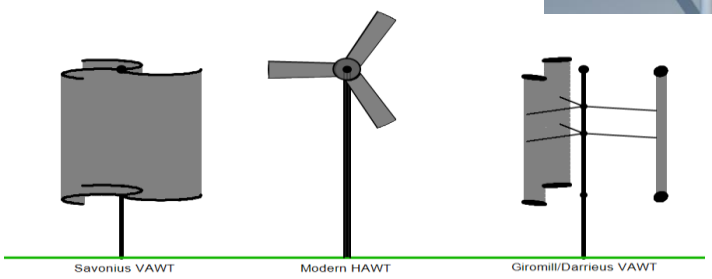
Types of Tidal stream generator

1) Axial turbines
2) Vertical turbines
3) Vertical and horizontal axis crossflow turbines





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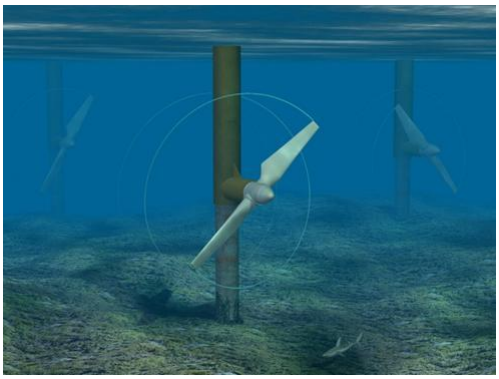
Tidal power anywhere

1. No dam – but a turbine.



Problems

1. Corrosion
2. Navigation
3. Appearance
4. Amount of energy available is low
5. Best tides are near poles – away from people.

Source: Renewable Energy Sources PPT by Dragica Vasileska

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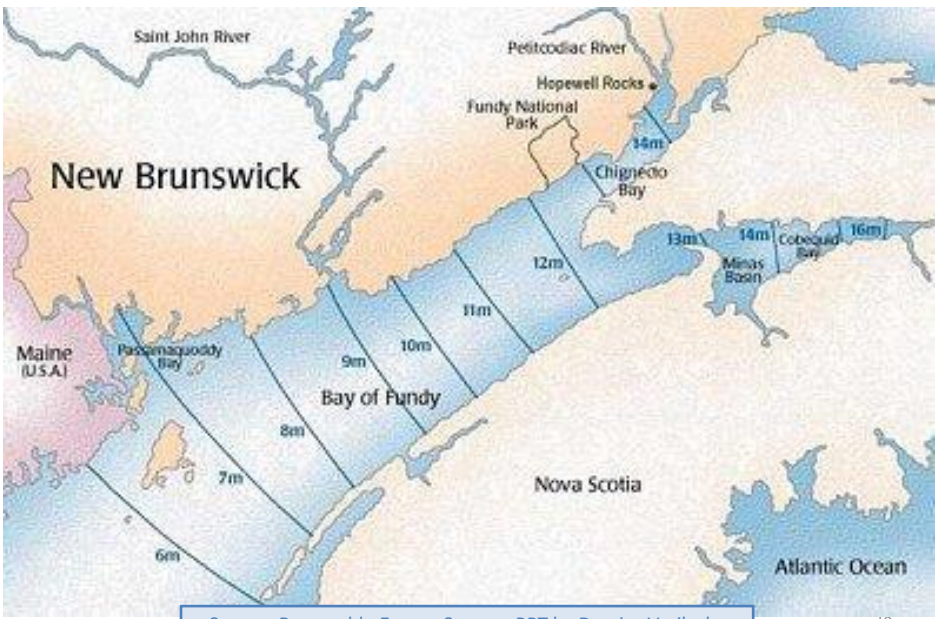
Highest tides in the world = Bay of Fundy 16 m = +48 ft!



Source: Renewable Energy Sources PPT by Dragica Vasileska

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Tidal turbines I

https://irena.org/-/media/Files/IRENA/Agency/Publication/2014/Tidal_Energy_V4_WEB.pdf

Tidal turbines II

https://irena.org/-/media/Files/IRENA/Agency/Publication/2014/Tidal_Energy_V4_WEB.pdf

Water power 3: wave power

The **rise** and **fall** of **waves** is a **renewable** source of energy. Effective sites for **harnessing** wave energy need to have **strong** waves **most** of the time, to ensure that enough **electricity** will be produced.

The "**Limpet**" (land-installed marine-powered energy transformer) on Islay, **Scotland**, is the world's **first** commercial wave energy device. Its **low profile** is designed so that it does **not** affect **coastal views**.

http://bioblocks.weebly.com/uploads/8/7/0/6/8706802/notes_-_renewable_energy.pdf

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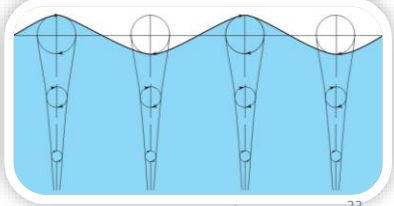
Wave power principle

Wave power is the transport of energy by **ocean** surface waves, and the capture of that energy to do useful **work** — for example, electricity generation, water desalination, or the pumping of water (into reservoirs). **Machinery** able to exploit wave power is generally known as a **wave energy converter** (WEC).

Wave power is **distinct** from the diurnal flux of **tidal power** and the steady gyre of ocean currents. **Wave-power** generation is **not** currently a **widely** employed commercial technology, although there have been attempts to use it since at least **1890**.

In **2008**, the **first** experimental **wave farm** was opened in **Portugal**, at the Aguçadoura Wave Park. The major **competitor** of wave power is **offshore wind power**.



https://www.wavewaterworks.com/wave-power-generation/

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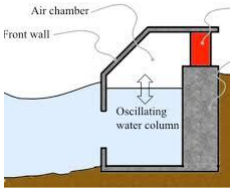
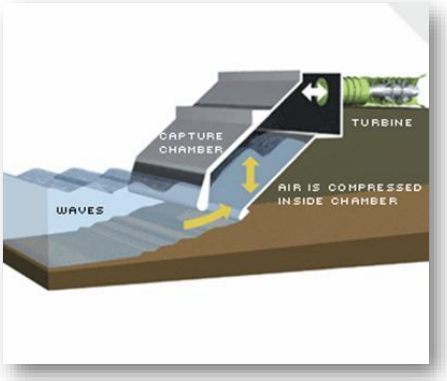
Application of Wave Power I

Oscillating Water Column (OWC):



This method of generating power from the **tide** works by using a **column** of water as a **piston** to pump air and drive a **turbine** to generate **power**. This type of device can be fixed to the seabed or installed on shore.

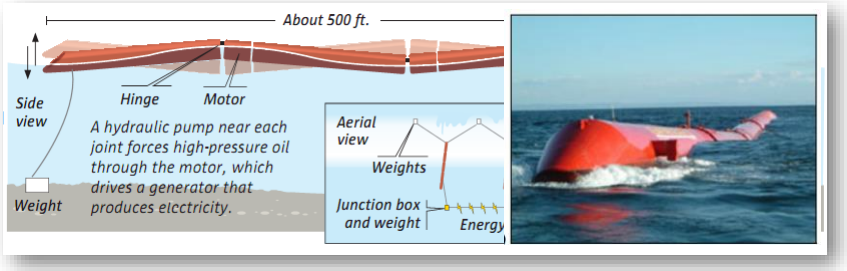


https://wavepoweralternativeenergy.weebly.com/oscillating-water-column.html

Application of Wave Power II

Hinged Contour Device (Pelamis):

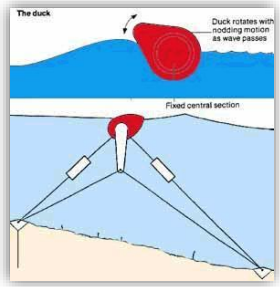
This **snake** like **power converter** generates **electricity** with three hydraulic **pumps** activated by hinged **pontoons** that move with passing waves. The **Pelamis** is loosely anchored so that most of the wave **motion** is **absorbed** by the device and **converted** to electricity.



http://www.esru.strath.ac.uk/EandE/Web_sites/14-15/Wave_Energy/attenuator.html

https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/CHC-TR-041.pdf

Application of Wave Power III



Buoyant moored device:

This type of device **floats** on the surface of the water or below it. It is **moored** to the **seabed** by either a taught or loose **mooring system** as shown in the figure.

Ducks work by independently **rotating** about a long linkage; this maintains its stability by out spanning wave crests. The front edge of the duck matches the wave particle motion. In moderate seas, the more **cylindrical** back portion creates no stern waves but when the weather is bad these parts shed energy through wave making to the rear.

The device requires a depth of at least **80** meters and uses a system of **weights** and **floats** to give almost constant **tension** in the mooring cables.

https://wavepoweralternativeenergy.weebly.com/buoyant-moored-device.html 25

LIMPET system, Scotland

Land Installed Marine Powered Energy Transformer on Islay, West Coast of Scotland.

LIMPET provides **500** kW of electricity for the National Grid

Three floating wave power stations at Lewis/**1** MW each

Source: Renewable Energy PPT by Garth Ratcliffe

https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/CHC-TR-041.pdf 26