Marine Energy

Chris Gardam, Deborah Lay & Sue Smith

Wave & Tidal Energy is not new….

- A tide mill is a water mill driven by tidal rise & fall
- The earliest dates back to Roman times – on the River Fleet, London
- A local example is the Woodbridge Tide Mill, dating from 1170 and reconstructed in 1792
- At one time there were 750 tide mills along the shores of the Atlantic - 300 in America, 200 in Britain and 100 in France
- Use of tide mills had dramatically declined by mid 20th century

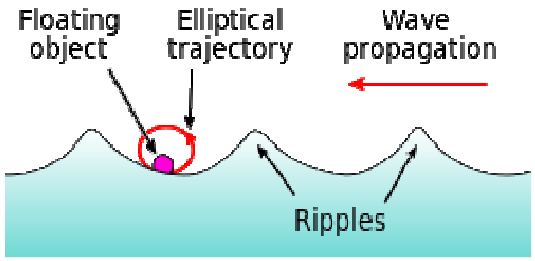
Four Different Types of Marine Power

- Wave energy from the motion of the waves
- Tidal energy from tidal height differences in tidal lagoons & tidal barrages
- Tidal current (stream) energy from natural horizontal flow of water in seas & oceans
- Ocean thermal energy conversion using the temperature difference between cooler deep and warmer shallow ocean water

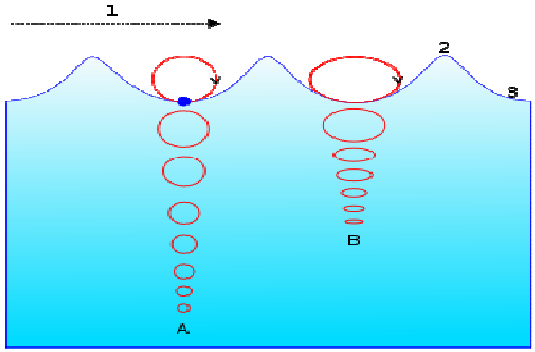
How does Wave Energy Work?

- Wave energy is the transport of energy by ocean surface waves and the capture of that energy to do useful work
- Not a currently widely used technology
- Attempts to use it since 1890
- In 2008, the first experimental wave farm opened in Portugal at the Agucadoura Wave Park
- Offshore wind power is its major competitor

The Technical Bit….



When an object bobs up and down on a ripple in a pond, it experiences an elliptical trajectory.



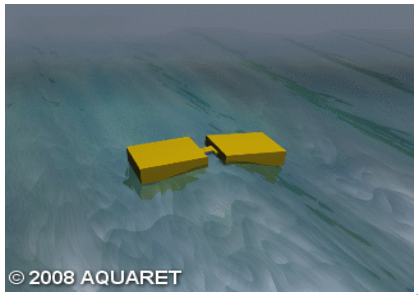
Motion of a particle in an ocean wave.
A = At deep water. The orbital motion of fluid particles decreases rapidly with increasing depth below the surface.
B = At shallow water (ocean floor is now at B). The elliptical movement of a fluid particle flattens with decreasing depth.
1 = Propagation direction.
2 = Wave crest.
3 = Wave trough.

What do they look like?

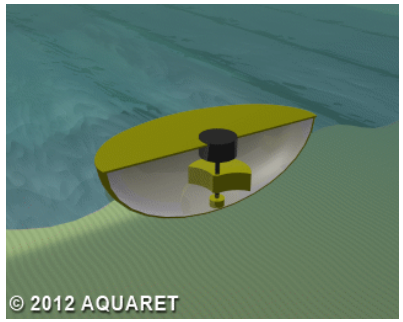
Wave Drag

Wave Roller

Wave Attenuator



Gyroscope



How does Tidal Energy Work?

- Tidal power has potential for future electricity generation
- More predictable than wind energy or solar power
- Traditionally had relatively high cost and limited availability of sites with sufficient tidal movement
- Recent technology improvements bringing costs down to competitive level

The Tidal Barrage

- Barrages are essentially dams across the full width of a tidal estuary
- They make use of the potential energy in the height difference between high & low tides
- Strategic placement of specialised dams
- When sea level rises, the temporary increase in tidal power is channelled into a large basin behind the dam
- When the tide recedes, this energy is converted into mechanical energy as the water is released through large turbines

The Rance Tidal Barrage in Brittany, France

- The first and also the second biggest tidal power station world-wide
- Opened on 26th November 1966
- Operated by EDF
- Peak rating of 240 megawatts generated by 24 turbines
- Supplies 0.012% of power demand in France
- Annual output is 540 gigawatts
- Barrage is 750m long and tidal basin measures 9 sq miles

Rance Tidal Barrage, Brittany, France

Location

Photograph

Underwater Tidal Stream Energy

- Fast sea currents often magnified by topographical features
- Devices are broadly similar to wind turbines and are used to exploit the kinetic energy in tidal currents
- Water is denser than air
- Higher density = smaller, slower turbine blades but which still deliver a significant amount of power

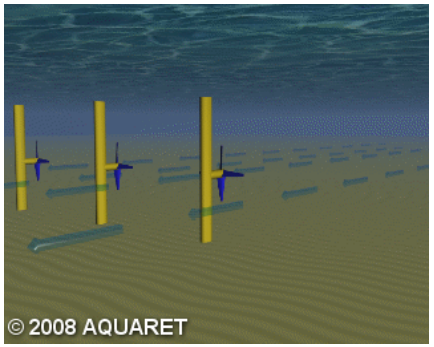
Tidal Stream Energy

- In 2007, Strangford Lough in Northern Ireland became the world's first commercial-scale and grid-connected tidal stream generator

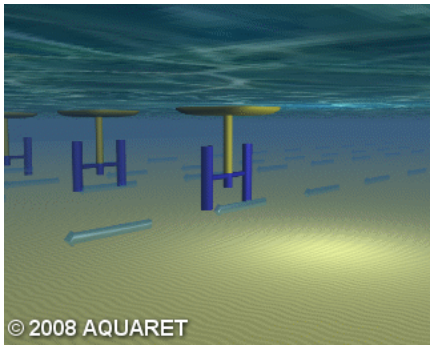
- The 1.2 megawatt underwater tidal electricity generator can power up to 1,000 homes
- The turbine has minimal environmental impact

What do they look like?

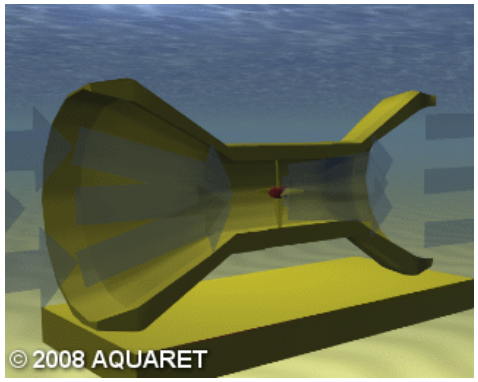
A Horizaxis Device



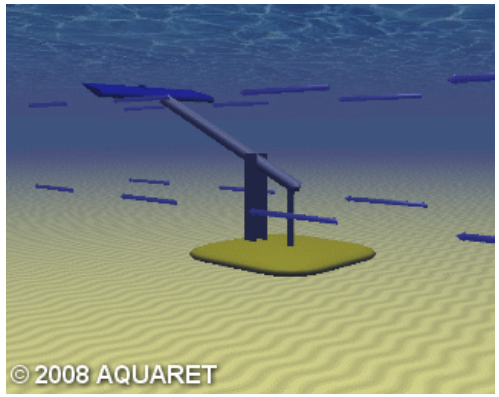
A Vertaxis Device



A Venturi Effect Device



A Reciprocating Hydrofoil Device



Operational Tidal Power Stations (2010)

Station	megawatts	Country	Comm
Annapolis Royal Generating Station	20	Canada	1984
Jiangxia Tidal Power Station	3.2	China	1980
Kislaa Guba Tidal Power Station	1.7	Russia	1968
Rance Tidal Power Station	240	France	1966
Sihwa Lake Tidal Power Station	254	South Korea	2011
Stangford Lough Tidal Power Station	1.2	United Kingdom	2008
Uldolmok Tidal Power Station	1.5	South Korea	2009

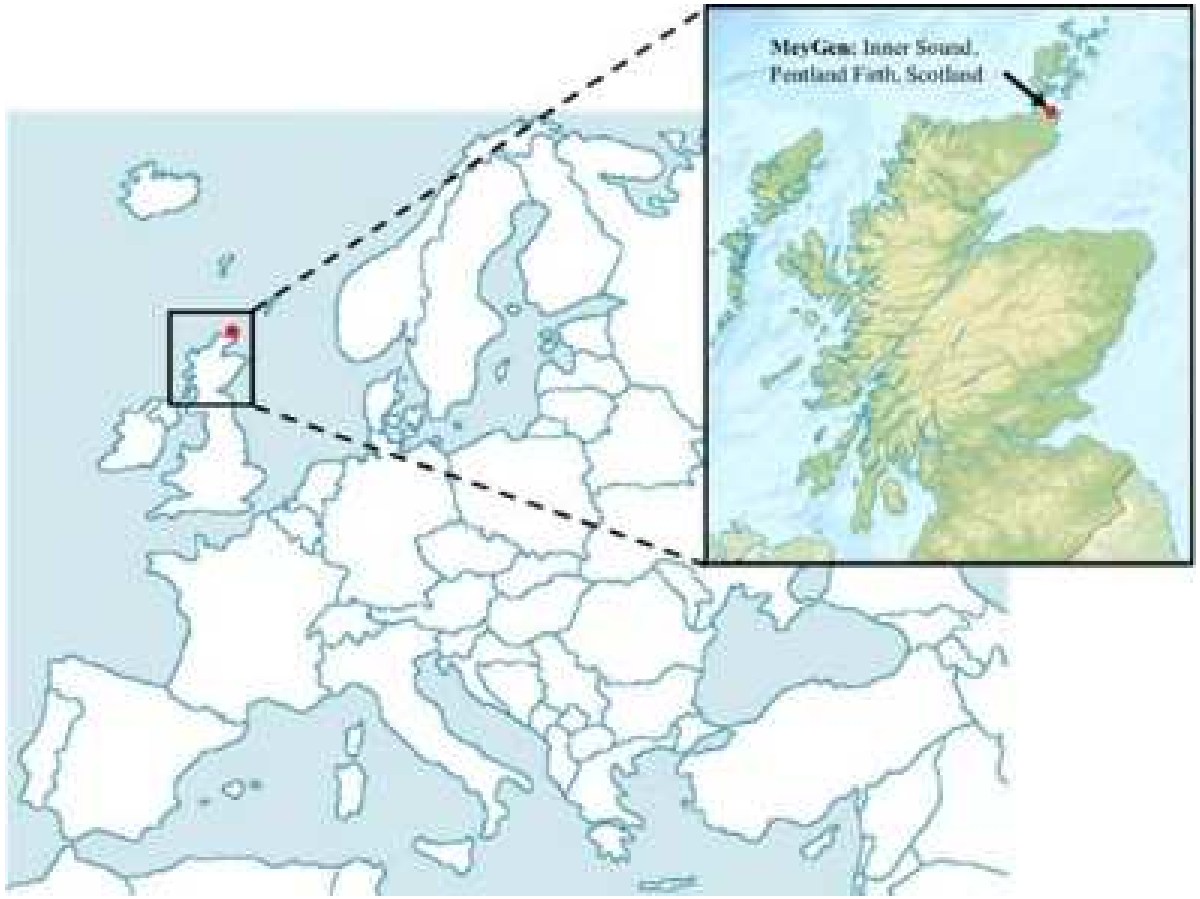
Tidal Power Station Under Construction

- The Incheon Tidal Power Station in South Korea is due for completion in 2017
- Its capacity could be up to 1,320 megawatts

Proposed Tidal Power Stations

Station	Capacity MW	Country
Garorim Bay Tidal Power Station	520	South Korea
Severn Barrage	8,640	United Kingdom
Tugurskaya Tidal Power Station	3,640	Russia
Mezenskaya Tidal Power Station	12,000-8,000	Russia
Penzhinskaya Tidal Power Station	87,100	Russia
Skerries Tidal Farm	10.5	United Kingdom
Swansea Tidal Bay Lagoon	300	United Kingdom
Dalupiri Blue Energy Project	2,200	Philippines
Gulf of Kutch Project	50	India

The Pentland Firth Project



The Pentland Firth Project

- Fast-moving waters off Scotland's northern coasts and islands seen as among the most valuable in the world for tidal and wave power
- Scottish ministers have approved first phase of the Pentland Firth Project by MeyGen (Morgan Stanley + International Power + Atlantis Resources Corporation)
- Initially six squat turbines which look like underwater propellers will be installed on the seabed off Caithness
- First phase will generate up to 9MW
- More than 50 turbines are planned for 86MW by 2020

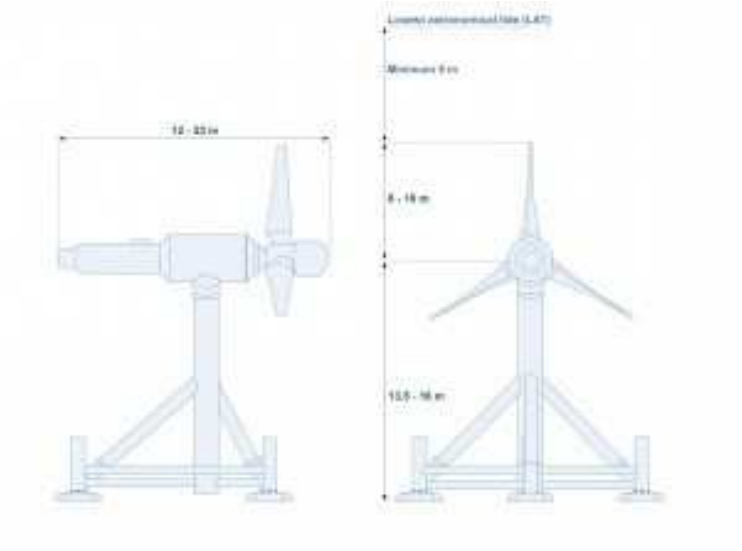
The Pentland Firth Project

Turbine Photo

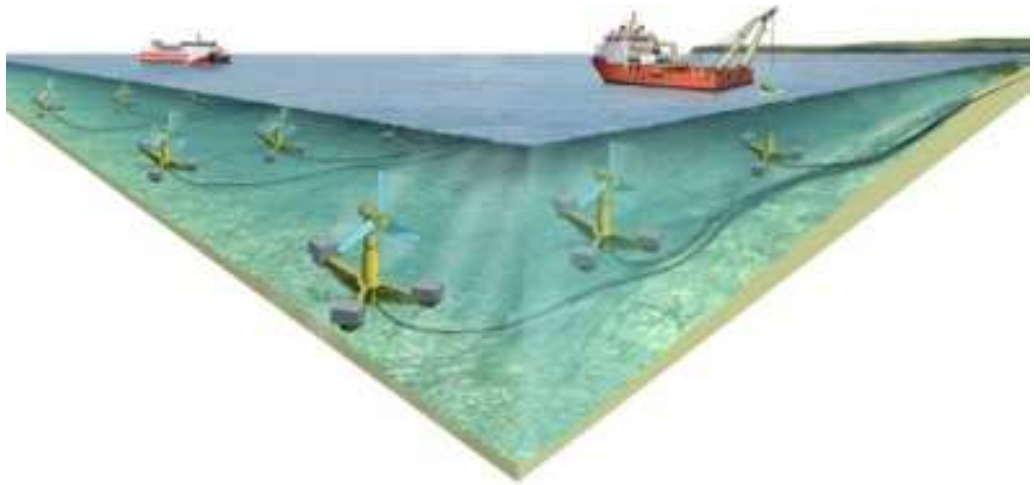
Turbine Photo

The Pentland Firth Project

Technical Drawing



Turbine on Seabed



How is the Electricity Generated?

- The turbines capture the kinetic energy of the ocean current
- The turbines and generators produce electrical energy
- Power cables from each device are connected to an underwater cable
- Grid synchronisation occurs via a variable speed and step-up transformer to a suitable voltage level
- Electrical energy transferred to consumers through the transmission grid

Ocean Thermal Energy Conversion (OTEC)

- OTEC uses the temperature difference between cooler deep and warmer shallow or surface ocean water (must be > 38F)
- Systems may be closed-cycle or open-cycle
- Closed-cycle engines use refrigerants such as ammonia
- Open-cycle engines use vapour from the seawater
- Allows for electricity production on a constant basis
- The temperature differential is small, therefore impacting economic viability

Ocean Thermal Energy Conversion (OTEC)

- Demonstration plants first constructed in 1880s
- Only operating OTEC is in Japan, overseen by Saga University
- Demonstration projects in Hawaii
- OTEC can supply cold water as by-product and can be used in air conditioning

Main Advantages of Marine Power

- Energy produced is clean and non-polluting
- No greenhouse gases produced
- As a renewable energy it will help reduce reliance on burning fossil fuels
- Tidal energy happens twice a day
- Electricity supply is therefore constant and efficient
- Not expensive to maintain

Main Disadvantages of Marine Power

- Dams and Barrages
  - Holding back tide allows silt build-up on river bed
  - May interfere with shipping
  - Salinity changes may damage ecosystems and mammals
- Tidal Power eg The Pentland Firth Project
  - Damage to seabed habitat of shellfish and other fish species
  - Disturbance of normal movement of seals, whales and dolphins
  - Disturbance of seashore habitat of otters and birds
  - Disturbance of existing shipping lanes