Wave Energy Converters (WECs)

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1. Evaluation criteria

The feasibility of the devices discussed in this section will be evaluated in terms of the following criteria:

- Environmental impact
- Maintenance
- Manufacturability

Environmental impact

The environmental impact and the visual impact of both the device and its PTO will be evaluated according to the following criterion:

High: Excessive damage to the environment and a great visual impact.
Medium: It has an impact on the environment, but marine life will still be able to coexist with the device. The visual impact is less as for the previous category.
Low: The device has a neglect able impact on the environment.

Maintenance

The maintenance cost and the ease of maintenance will be assessed by means of the following criterion:

High: These devices will not only require regular maintenance, but the performing of the maintenance is also difficult. Thus the maintenance cost will be high.
Medium: The device will require scheduled. It will also be moderately easy to access.
Low: Regular maintenance is required. The performing of the maintenance will also be quite difficult, typically bottom mounted devices that's difficult to access.

Manufacturability

The manufacturability of each WEC will be assessed by evaluating the ease of producing a unit locally from local components and considering installation cost of the device.

Good: The WEC is made from readily available components and/or materials, for instance steel and concrete. It will also require minimal preparation of the desired installation site and should be easy to install.
Medium: These WECs will require some custom made components and may require some exotic materials. They will also be more difficult to install than the previous category.
Poor: Custom made components and/or exotic materials are necessary. These devices will also require are large structure that accompanied with great installation cost.

2. Description of WECs

2.1 Onshore Wave Absorber, S.D.E Energy Ltd., Israel

The SDE Limited device is based on a float connected to the shoreline or a breakwater via a hinge and hydraulic pistons. Incoming waves cause the float to pitch up and down, driving hydraulic fluid through the pistons and into a hydraulic motor and generator. SDE produced a series of eight test units, the largest of which produced up to 40kW during the 8-month test period. The company has received partial government funding and plans to build a 10MW plant in Ashdod, Israel within the next three years.

Classification:

- Shore based with hydraulic PTO.
- Development stage: test/early production
- Line absorber.

Key Statistics:

Generation capacity: 1MW up to 200MW (estimated cost $130 million).

Unit cost: $0.02/kWh.

Feasibility:

Environmental impact: Medium. Could be incorporated into a existing breakwater.

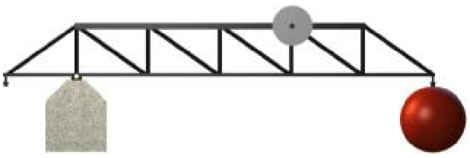
Maintenance: Low. Most of its components are outside of the water; therefore corrosion should be low assuring low maintenance. The most critical parts of the system are also easily accessible.

Manufacturability: Good. It can be premanufactured and then installed, therefore good manufacturability. The system also uses proven and readily available technology (hydraulics). The manufacturers further claim that the system will return its investment cost within 3 years.

Developed by: S.D.E Energy Ltd

Source: http://www.sde.co.il/ [2007, 25 February].

2.2 Wave Energy Machine



A float, at the end of a truss, is used to cause a “teeter-trotter” effect in the truss. The truss is allowed to pivot at the hinge point that’s situated at the base (the base is situated on the beach).

The motion of the structure is translated into mechanical energy by a cam system at the other end of the structure. The system uses a counter weight that can be moved forward and backwards in order to control the floating depth of the float.

Classification:

- Shore based WEC using a mechanical to electrical PTO system.
- Point absorber.
- Shore based.
- Development stage: concept.

Key Statistics:

- Unknown

Feasibility:

Environmental impact: Medium. It will impact the more sensitive beach. The biggest concern with this system is the large visual impact it will have.

Maintenance: Low. It has few components and all the critical components are outside of the water.

Manufacturability: Good. A simple structure combined with proven technology.

Developed by: Unknown.

Source: http://www.waveenergymachine.com/ [2007, 11 March].

2.3 Limpet, Wavegen, Scotland

The limpet is designed by Wavegen; a unit has been operational in Islay (an island off Scotland's west coast) where it supplied electricity to the national grid. The limpet operates on the owc (waves causes an air pocket, which is trapped behind a wall, to oscillate) principal and it uses a Wells turbo generator that drives an induction generator in order to convert the extracted energy into electricity.

The system can be designed to be an integral part of breakwater. This will result in a much lower installation cost.

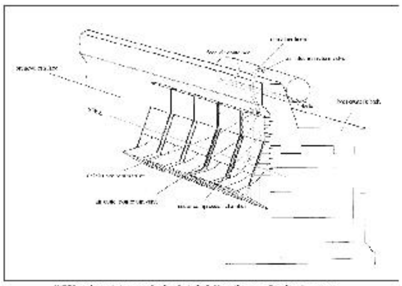
Classification:

- Shore based, preferable water depth is 15m, with OWC PTO.
- Development stage: production

Key Statistics:
Generation capacity: 500 kW

Feasibility:
Environmental impact: High. The system totally occupies the beach; therefore its use will probably be limited to breakwaters and other special places. However the system will have a small environmental impact if it is stalled in a breakwater.
Maintenance: Low. All the critical components will be housed outside of the water and also it's accessible from the beach.
Manufacturability: Medium. The system requires a solid structure which will increase installation costs, but the installation can be eased if the system is designed as an integral part of a breakwater.
Developed by: Wavegen
Source: http://www.wavegen.co.uk

2.4 WECA



WECA early prototypes: Design Details & Mounting on a Breakwater

The device consist of a steel structure that can be mounted on any rigid structure (shore based or off shore structures like oilrigs). It absorbs most of the energy in the waves by turning it into compressed air, thereby protecting the structure that it's mounted on.

It uses a specially shaped seafloor or a submerged surface in order to convert the kinetic energy into potential energy by utilizing the "Critical Momentum Wedge" effect. The potential energy will be absorbed by compressing air, the energy will then be extracted by a turbine which in turn will transfer the energy to a generator.

Classification:

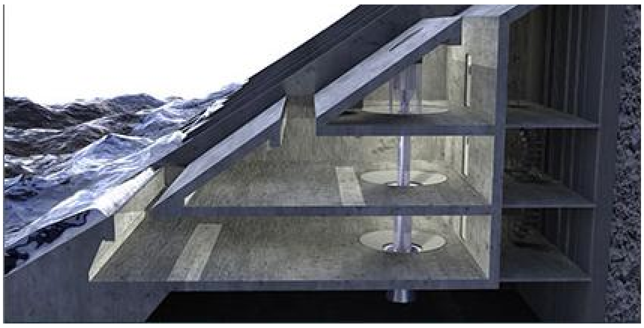
- Shore based with OWC type PTO.
- Development stage: Unknown

Key Statistics:

Feasibility:
Note: Too little information is available to properly evaluate the feasibility of the device.

Source:
http://www.daedalus.gr/DAEI/PRODUCTS/RET/General/RETWW1.html

2.5 *Seawave Slot-Cone Generator, Norway*



The SSG concept is based on the over topping principal. The system uses a total of three reservoirs placed on top of each other to capture the crest of the incoming wave and a specially designed multistage turbine to convert the head into mechanical energy (the system will operate very similar to a conventional hydropower station). The turbine will be connected to an electrical generating system in order to generate electricity for the grid, or to generate hydrogen.

The developers claim that the system will be very efficient and that it can also be mounted on offshore structures, for instance decommissioned oilrigs.

Classification:

- Shore based with an overtopping type PTO.
- Development stage: concept.

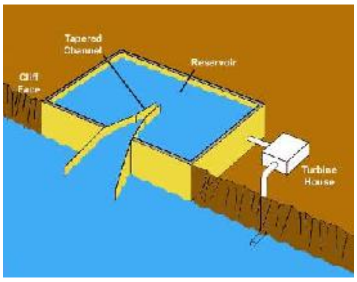
Key Statistics:

Investigating the feasibility of SSG in jetty reconstruction project at the Port ofGaribaldi, Oregon US.

Feasibility:

Environmental impact: High. If it is built on the shore, but low if it is built off shore (will completely occupy the beach it's installed on).
Maintenance: Low. It will use well proven hydro technology and all the components will be easily accessible.
Manufacturability: Medium to poor. It will require a large structure. The system is also limited to sites with steep beachfronts facing deep water.
Developed by: WaveEnergy
Source: http://www.waveenergy.no/ [2007, 25 February].

2.6 *Tapchan*



The system has a tapered channel that leads up to an elevated reservoir. The channel focuses the waves as it gets narrower, this effect allows the waves to flow into the elevated reservoir. The elevated water will be used to drive a conventional hydropower plant as it's allowed to flow back into the ocean.

It is a favorable system because it can deliver electricity on demand (it stores the water in the reservoir until needed), but its use is limited to coastlines with deep water near shore and high cliffs. It also requires a tidal range of less than 1m.

Classification:

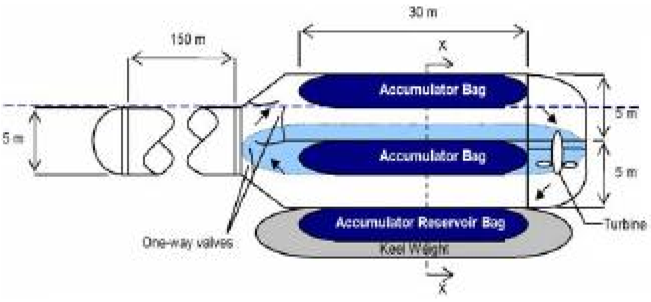
- Shore based WEC with an overtopping type PTO.
- Development stage: Unknown.

Key Statistics:

Feasibility:

Environmental impact: Medium. It is a rather large structure, but it will not have too a great affect on the suitable places where it can be installed.
Maintenance: Low. It uses well proven and readily available technology. All the critical components are protected from storms and also easily accessible.
Manufacturability: Medium. It requires a relatively large structure and it is limited to only a few suitable locations.
Source: http://www.oceanenergy.ie [2007, 11 June].

2.7 *Anaconda*



The Anaconda has a unique working principal. The device captures the wave energy in the form of a "bulge wave" that travels in the water that's trapped inside the device. A turbine is then used to extract the energy from the water and convert it into electricity (the turbine drives an electrical generator).

Rubber is used as the basic structural material. The front end is a 150m long rubber tube with a 5m diameter (the bulge wave is induced inside this section). The rear is larger than the front end (It is larger because it houses the turbine and it also needs to have a large inertia.) and it is also made from rubber.

Classification:

- Above waterline with an hydraulic PTO.
- Development stage: Scale model testing in wave tank.

Key Statistics:
Generation capacity: 1MW (expected).
Size: 150m long with a 7m diameter

Feasibility:
Environmental impact: Low. The floating device will have a low environmental impact since it does not have any components that pose a threat to marine life.
Maintenance: Medium to low. Rubber is very durable (the rubber casing will last the lifetime of the device according to the source). The turbine may be more of a problem, because it is not known how difficult it will be to reach.
Manufacturability: Medium. The device will use very little off the shelf components, but the manufacturing techniques for the concerned materials is common.
Source: Chaplin, J.R., Farley, F.J.M. & Prentice, M.E. & Rainey, R.C.T. & Rimmer, S.J. &Roach, A.T. 2007 *Development of the ANACONDA all-rubber WEC http://www.checkmateuk.com/seaenergy/*

2.8 *Energen Wave Generator*

There is very little information available on the exact working principal of the device, the author assumes that it's an attempt to protect the patent of the device.

It is a floating device that will be anchored in such a way that it will face the incoming wave direction. The device consists of a rectangular frame with several horizontal torque cylinders at the centre. It is these cylinders that will be used to absorb the wave energy (the waves will force them to move in the horizontal position) in order to drive a hydraulic system, the hydraulic system in turn will power a generator. The before mentioned PTO system will be housed inside the cylinders in order to protect it from the harsh ocean environment.

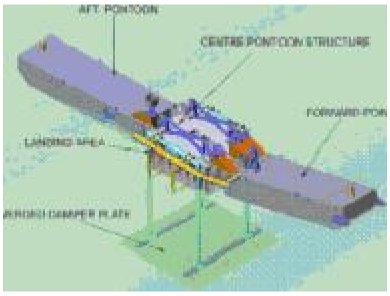
Classification:

- Above waterline WEC with hydraulic PTO.
- Development stage: 2D tests, 3D tests coming soon.

Key Statistics:
Rated power: 1-1.5MW expected for S.A wave climate.

Feasibility:
It's very difficult to evaluate the concept do to the little information that's given.
Environmental impact: Low. It a floating device that seemingly wouldn't need a large anchoring system.
Maintenance: Low. According to the inventors the PTOs will be housed in the cylinders. These cylinders should protect it. The PTOs will also be easily accessible since it's a floating whose PTOs are near the surface.
Manufacturability: Good. The inventors claim that off the shelve components will be used for the PTOs; therefore development cost should be low. The device can be premanufactured before it's tugged to the desired location.
Developed by: Energen International
Source: http://www.energeninternational.com/contact.html [2007, 10 October].

2.9 McCabe Wave Pump, Hydam Technologies, Ireland



The device consists of three steel pontoons that point into the wave direction. There is a damping plate attached underneath the central pontoon in order to increase its inertia, therefore it will stay relatively still.

The wave energy is converted by hydraulic pumps that are situated at the hinge points between the central pontoon and the two on its sides. The high pressure hydraulic fluid can drive a hydraulic motor that is coupled to an electric generator in order to generate electricity, or the pumps can pump high pressure seawater that can be desalinated in a reverse osmosis possess.

Classification:

- Above waterline WEC with hydraulic PTO.
- Development stage: Sea trails.

Feasibility:
Environmental impact: Low. The device will make use of a small anchoring system since the damping plate will absorb most of the force.
Maintenance: Low. All the critical components can be accessed from the surface and the device can be towed to a port if major maintenance needs to be performed.
Manufacturability: Good. The device makes use of common materials that can be used in well known manufacturing processes. It can be built in a shipyard and then towed to the desired site.

Key Statistics:
Rated power: 250-500 kW
Size: 40m long prototype.

Developed by: Hydam Technology
Source: http://www.worldenergy.org [2007, 1 July].

2.10 Pelamis

It is a semi submerged system that consists of several cylindrical sections (made out of steel) that are connected with hinged joints. Hydraulic pumps are used to utilize the bending motion inside the joints, which is caused by the passing waves. The high pressure oil is used to generate electricity in a hydraulic system.

The electricity generation system, as well as the rectifying circuit, is situated inside the structure. Several modules can be connected in parallel and the electricity will be fed into the grids using a single cable system.

It is possibly the furthest developed system up to date and the company is busy with negotiations in order to build several plants across the world (including South Africa).

Classification:

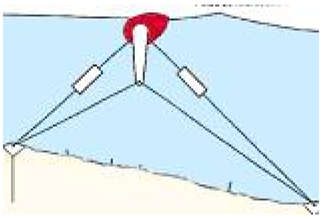
- Above waterline WEC with hydraulic PTO.
- Far off shore (5-10 km).
- Development stage: Currently busy to install the worlds first wave farm (Agucadura) with a capacity of 2.25MW.

Feasibility:
Environmental impact: Low. The unit itself will have a small impact and that of the anchor is also very small. The hydraulic system further uses biodegradable fluid.
Maintenance: Low. The system uses proven technology and all the critical components are easily accessible. If it's necessary the device can be towed to a nearby harbor to be serviced.
Manufacturability: Good. The structure is made from steel and it can be built in almost any shipyard using standard equipment and then towed to the desired site.

Key Statistics:
Generation capacity: 30 MW farm (square kilometer).
Device capacity: 750 kW.
Size: 150m long and 4.63m diameter.
Cost for a single device: $2 to $3 million (estimated in 2004)

Invented by: Ocean Power Delivery Ltd
Source: www.oceanpd.com [2007, 25 February].

2.11 Salter Duck



The passing waves cause the Duck to rotate in a nodding motion; this motion is used to pump hydraulic fluid or to compress air. If the hydraulic principal is utilized the fluid will drive a hydraulic motor which in turn drives an electrical generator in order to generate electricity, but if air is used the compressed air will drive a turbine.

It was designed in the 1980s, but development was stalled after calculations showed that its operating costs were too high. However a resent review showed that the operating cost is about 10 times lower than originally estimated.

Classification:

- Above waterline WEC with hydraulic PTO.
- Line absorber.
- Development stage: Early testing stage.

Key Statistics:

- Unknown

Feasibility:

Environmental impact: Low. It is a slow rotating structure with no sharp rotating parts that poses no threat to marine life.

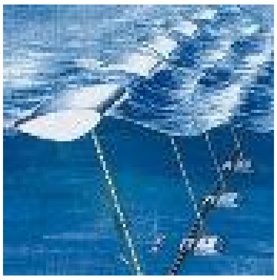
Maintenance: Medium. All the critical components are protected and are accessible from a boat, but It is a complicated system, but the critically component is not only protected by the structure but also easily accessible with a boat.

Manufacturability: Medium to poor. According to the source that was used, it will use a complicated hydraulic system.

Developed by: Prof Steven Salter

Source: http://www.oceanenergy.ie [2007, 11 June].

2.12 Wave Rider, SeaVolt Technologies, USA



A hydraulic system inside the specially shaped buoy converts the slow rolling action of the waves into high-pressure hydraulic fluid flow. The hydraulic circuit drives a small turbine which generates electricity.
The buoys can be connected in parallel and the electricity, if so, the electricity will be collected by a grid before its fed into the grid.

Classification:

- Above waterline WEC, hydraulic PTO.
- Line absorber.

Key Statistics:

Generation capacity: 10 to 400 MW farms.

Feasibility:

Environmental impact: Low since it will only occupy a small peace of the ocean floor to anchor it.

Maintenance: Medium, all the critical components are accessible from the ocean surface since it is all housed inside the buoy. It will require high maintenance due to its complex design.

Manufacturability: The system can be premanufactured before it's installed.

Developed by: SeaVolt Technologies

Source: http://www.seavolt.com/ [2007, 25 February].

2.13 Wave Star

The Wave Star consists has 20 partially submerged hemisphere-shaped floats that each drives a hydraulic pump. The approaching wave pushes the floats up in sequential order. The compressed oil (at about 200 bar) is collected from each pump and fed into a common accumulation system. The accumulator feeds the oil to a hydraulic motor which in turn drives an electrical generator.

The whole platform is bolted onto two steel pillars in such a way that it is positioned at right angles to the approaching waves. This makes it impossible for the system to align itself with waves from any other direction, thereby limiting it efficiency.

During rough weather the floats are pulled up and locket as a safety mechanism.

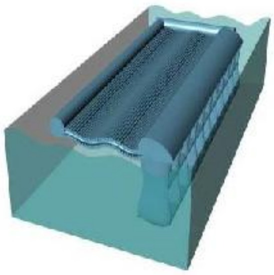
Classification:

- Above waterline WEC with hydraulic PTO.
- Multi point absorber.
- Development stage: early tests (1:10 scale model).(1:2 scale)

Key Statistics:
Generation capacity: 3 MW estimated.

Feasibility:
Environmental impact: Low. The stand will have a small impact on marine life.
Maintenance: Low. All the critical components will be above the waterline and inside a protected cover, protecting them from the harsh ocean environment. The whole system will be loosened from the base and tugged to shore when extensive maintenance needs to be performed.
Manufacturability: Medium. The whole system (except for the stand) will be premanufactured and the towed to the location and then bolted onto the stand.
Developed by: Wave Star Energy
Source: http://www.wavestarenergy.com/ [2007, 25 February].

2.14 WaveBlanket



Thin polymer films, that are filled with water, forms a blanket that floats on the surface. The motion of the waves causes the hydraulic chambers to compress or relax. The pressure difference between the chambers is utilized, in a closed loop system, to generate electricity.

The system uses its flexibility to withstand rough waves.

Classification:

- Above waterline WEC with hydraulic PTO.
- Development stage: concept.

Key Statistics:

- USA

Feasibility:
Environmental impact: Low. No open rotating parts, large mooring system or hazardous chemicals is used.
Maintenance: Medium. It will be easily accessible because it is on the surface, but the amount of maintenance required greatly depends on the durability of the material that is used.
Manufacturability: Good. The exact power takeoff is unknown (therefore its complexity can not be discussed), but polymers are generally easy to use during common manufacturing processes.
Invented by: Benjamin Gatti
Source: http://www.windwavesandsun.com/ [2007, 25 February].

2.15 WEC (FO3)

The system is very similar to the Manchester Bobber. The system consists of several egg-shaped buoys that are connected to a platform. The buoys use the up and down motion of the waves to drive hydraulic pumps. The high pressure oil is used to drive a hydraulic motor which in turn drives an electrical generator.

Classification:

- Above waterline WEC with hydraulic PTO.
- Multiple point absorber.
- Development stage: test (1:3 scale model).

Key Statistics:
Generation capacity: Estimated to produce 2.52 MW from 6 m waves.
Size: 36 m by 36 m.
Unit cost: 2.8 EUR/kWh.
Manufacturing cost: 3-4 million euros.

Feasibility:
Environmental impact: Medium. It will have very little interference on marine life.
Maintenance: Low. Al the critical components are above see level, hence they are easily accessible.
Manufacturability: Medium. The whole system will be premanufactured and then towed to the preferred location. On the down side, it will require a large structure which will make it expensive to build.
Developed by: Fred Olsen in conjunction with Marintek/Sintef laboratories in Trondheim. (University of Ghent, Belgium also involved)
Source: http://www.seewec.org/ [2008, 15 May].

2.16 DCEM

The system is developed by Trident Energy and it uses a buoy to capture the wave energy and a linear generator to covert the up and down motion of the buoy into electricity. The linear generator will be housed outside of the water where it will be protected from storms and high corrosion caused by the ocean. The whole system will be attached to a large structure.

If a storm approaches sensors will detect it and then the linear generators will act as linear motors in order to lift the buoys out of the water, thereby protecting the system from the storm.

The system should have a very high efficiency (the developers claims an efficiency of 80%), because there are only two conversion processes (the buoy is the first stage and the linear generator is the second) of the energy and not as many as in the most WECs.

Classification:

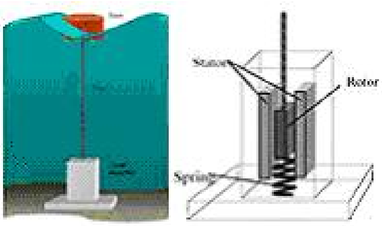
- Above waterline WEC using a linear generator as PTO.
- Point absorber.
- Development stage: scale model (1:5) testing.

Feasibility:
Environmental impact: Low. The system will float on the surface and it does not need a base.
Maintenance: Low. All the critical components are outside the water, thereby allowing easy access. The buoys can be serviced separately; this will result in minimal down time, because the rest of the buoys can still remain operational.
Manufacturability: Medium. The system uses a simple design and it can be build using well proven processes in almost any shipyard. The only disadvantage is the relatively large base that is required.

Key Statistics:
Total generation capacity: 100 MW farm occupying 5 hectares.
Generation capacity per unit: 100 kW
Unit cost: 6p per unit.

Invented by: Trident Energy
Source: http://www.tridentenergy.co.uk/ [2007, 11 March].

2.17 Seabased AB



The system uses a three-phase permanent magnet linear generator to generate electricity. The linear generator is mounted on the seabed and it is driven by a floating buoy.

The system will have high efficiency because it uses a direct drive conversion system. The designers of the system say that it will be able to utilize small low frequency waves and it will be economically viable to use generators as small as 10kW in 1 MW farms.

Classification:

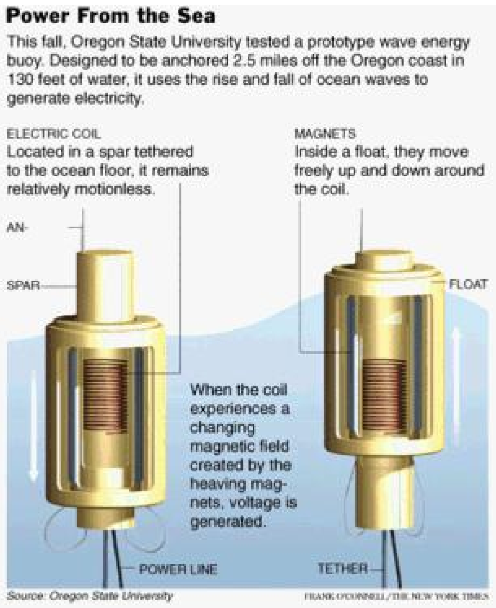
- Above waterline WEC with a linear generator PTO.
- Point absorber.
- Varying depth (more than 50m preferred).
- Development stage: concept.

Key Statistics:
Generation capacity: 1 MW farms.

Feasibility:
Environmental impact: Low. The base will have a small impact.
Maintenance: Medium. The most critical components are underneath the water, making it more complicated to service than floating concepts.
Manufacturability: Medium. The base is the most complicated component to install due the under water labor that's necessary.

Invented by: Seabased AB in cooperation with Uppsala University Sweden.
Source: http://www.seabased.com/ [2007, 11 March].

2.18 Wave Energy Buoy



The buoy has permanent linear magnets that are attached to the shaft. These magnets induce a current in the coil that's housed inside the buoy. This unregulated AC voltage (from the buoys) is fed via a cable to a junction box on the seabed where it is converted to 12000V DC. The DC voltage will be changed back into AC on the shore before it's fed into the grid.

Classification:

- Above waterline WEC using a linear generator as PTO.
- Point absorber.
- Medium depth (30m, 2 tot 3 km from shore).
- Development stage: concept.

Key Statistics:
Generation capacity: 100kW/buoy.

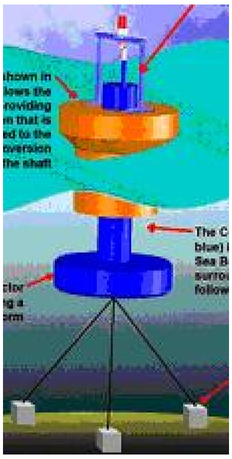
Feasibility:
Environmental impact: Low. The buoys will be 30m apart and it does not take up large space on the ocean bed, therefore it should have a very low impact.
Maintenance: Low. It has few moving parts and if it is made of durable materials, it shouldn't have high maintenance.
Manufacturability: Good. It can be premanufactured and then installed, therefore good manufacturability.

Developed by: Prof von Jouanna and prof Wallace (Oregon State University) in partnership with Columbia Power

Size: 3.6m height.

Technologies
Source: http://www.popularmechanics.co.za [2007, 25 February].
http://www.columbiapwr.com/ [2008, 19 August]

2.19 Aegir Dynamo



Classification:

- Above waterline WEC using a mechanical to electrical PTO system.
- Point absorbing device.

Key Statistics:
Unit cost: 1MWh at 2.8 cents (US) per kW at coastal applications.
Size: 4.5m diameter accelerator for a 25kw unit.
Expected life: 20+ years

The Aegir Dynamos' two major components are the buoyant base (that is anchored by three cables) and the float that moves up and down with the swell. The linear motion between the float and the base is converted into angular momentum (the details of this conversion process is unknown to the author). The angular motion is then used to drive the generator that is sealed inside the central column.

Feasibility:
Environmental impact: Low. The anchoring block will cause the only significant impact on the environment.
Maintenance: Medium. The company claims that inspections will only have top be performed every six months and maintenance only every two years.
Manufacturability: Unknown, too little information is available.
Developed by: Ocean Navitas
Source: http://oceannavitas.com/ [2007, 26 July].

2.20 AquaBouy

Classification:

- Above waterline WEC.
- Point absorber.
- Development stage: early production

The AquaBuoy uses a cylindrical buoy as a displacer within which the impulse turbine and generator is housed. The reactor is a water mass underneath the buoy which is enclosed by a long vertical cylinder. A large neutrally buoyant disk inside the cylinder is used to drive the house pump (A hose pump is a soft rubber tube with a spiral steel cord inside the tube wall, If the tube is stretched the cord contracts the tube, thereby decreasing it's inside volume.). As the passing waves causes the device to move up and down the disk stays relatively still, this cases the upper or lower pipe respectively to stretch (thereby decreasing its displacement volume) thereby pumping the water into a high pressure accumulator. The water is fed from the accumulator to a turbine that in turn drives a generator. The electricity will be fed to shore through a cable.

The efficiency of the device will be limited, because it cannot rapidly tune itself to the wave frequency.

Feasibility:
Environmental impact: Low. It will provide minimal obstruction for marine life. The material composition is in accordance with the Kyoto Protocol Standards; therefore the materials only environmentally friendly are used.
Maintenance: Low. All the critical components are housed inside

Key Statistics:
Rated power: 250kW per buoy.
Average output: 56kW
Total cost: $3million for 4 units.
Size: 6m diameter buoy.
Water depth: >50m

the buoy where they are protected and also easily accessible. The device can be towed to the nearest harbor if major maintenance needs to be performed.
Manufacturability: Good. The buoy can be premanufactured and there after towed to the desired location. The device can be built in a shipyard since it uses readily available materials like steel.
Developed by: Finerva Renewables
Source: http://www.finerva.com/ [2007, 15 February].

2.21 C-Wave, C-Wave Ltd, UK

Classification:

- Above waterline WEC using a mechanical to electrical PTO system.
- Far off shore (5-20 km).
- Development stage: concept.

Key Statistics:

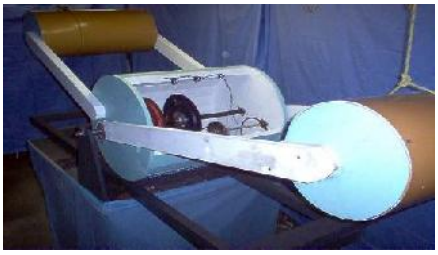
- Unknown

The system will have three neutrally buoyant walls that are connected to two hulls. The two outside walls will be positioned one wavelength apart. This will cause the two outside walls to move in opposite directions (the one will move forward while the other is moving backwards).

The relative motion between the two outside walls will be used to drive a generator.

Feasibility:
Environmental impact: Low. The system will have a small impact on the environment because it floats jus below the surface.
Maintenance: Medium. It has few moving parts and it is below the surface, limiting the impact of storms.
Manufacturability: Medium. It doesn't have a complex structure, but it will not have a high efficiency. Therefore it will require a lot of modules.
Invented by: C-Wave Ltd
Source: http://www.cwavepower.com/ [2007, 25 February].

2.22 Floating wave generator



Classification:

- Above waterline WEC using a mechanical to electrical PTO system.
- Development stage: concept/early scale model testing.

Key Statistics:

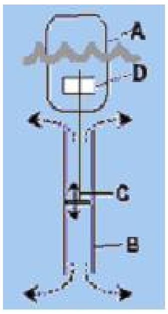
- Unknown

The system consists of three cylinders, the central cylinder houses the generation system and the two on the sides are empty cylinders that drive the generator. One of the outside pontoons will be connected rigidly to the central one while the other one will be connected to a shaft that runs through the main pontoon.

The primary shaft (which runs through the centre of the main pontoon) will be connected to a secondary shaft through belts or gears and one way clutches. This will allow the alternating primary shaft to drive the secondary shaft in one direction that in turn will drive the generator.

Feasibility:
Environmental impact: Low. The anchor will have a small impact on the seabed and the device will have an equally small environmental impact.
Maintenance: Low. The central cylinder protects all the critical components from the elements.
Manufacturability: Good. The system can be premanufactured and before installation. The components are readily available.
Developed by: Glen Edward Cook
Source: http://gedwardcook.com/wavegenerator.html
[2007, 11 March].

2.23 *IPS OWEC Buoy*



The buoy consists of three different parts: a buoy A, acceleration tube B and a piston C. The passing waves cause the acceleration tube to move relative to the water column inside it. The water (that is trapped inside the column) forces the piston to move relative to the acceleration tube. The up and down movement of the piston is converted to rotational energy by a mechanical system. This rotational energy is used to drive a turbine (no D).

Classification:

- Above waterline WEC using a mechanical to electrical PTO system.
- Point absorber.
- Medium depth, 50m to 100m.

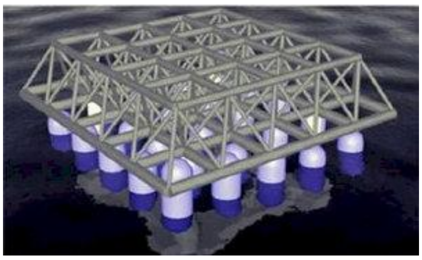
Key Statistics:

Generation capacity: 120-250kW/buoy.
Size: From 3-4m up to 10-12m diameter and 20m acceleration tube.

Feasibility:

Environmental impact: Low. It will provide minimal obstruction for marine life. The material composition is in accordance with the Kyoto Protocol Standards; therefore the materials only environmentally friendly are used.
Maintenance: Low. All the critical components are housed inside the buoy where they are protected and also easily accessible. The device can be towed to the nearest harbor if major maintenance needs to be performed.
Manufacturability: Good. The buoy can be premanufactured and there after towed to the desired location. The device can be built in a shipyard since it uses readily available materials like steel.
Developed by: Interproject Service AB (IPS) and Technocean (TO).
Source: http://www.ips-ab.com [2007, 20 April].

2.24 *Manchester Bobber*



The system consists of a series of bobbers that's attached underneath a platform. The bobbers will harness the up and down motion of the waves in order to generate electricity (the exact principal is unknown to the author). The rig will be allowed to float freely, allowing it to harness waves from any direction.

Classification:

- Above waterline WEC using a mechanical to electrical PTO system.
- Multiple point-absorber.
- Offshore.
- Development stage: second stage testing (1:10 scale model).

Key Statistics:

Generation capacity: 5 MW (estimated).

Feasibility:

Environmental impact: Low. It will float on the surface where it will have a minimal impact on the environment.
Maintenance: Low. Each buoy can be serviced separately and it is also very accessible since it floats.
Manufacturability: Medium. Decommissioned offshore rigs can be used as platforms, hence lowering manufacturing costs.
Developed by: University of Manchester.
Source: http://www.manchesterbobber.com [2007, 25 February].

2.25 OWEC

All three OWEC models have a very similar working principal. The whole structure is submerged, except for the buoy that is partially submerged. A damping plate is used to resist movement of the base, thereby allowing the buoy to move relative to the base.

The relative motion between the base and buoy is either directly converted into electricity by means of a linear generator, or by using an intermediate stage to convert the horizontal motion into rotational motion before it's used to drive a generator.

Classification:

- Above waterline WEC using a mechanical to electrical PTO system.
- Development stage: Unknown.

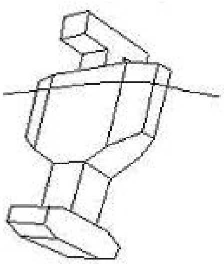
Key Statistics:

- Unknown.

Feasibility:

Environmental impact: Low. The system will need a relatively small anchor, because the damping plate will resist most of the force.
Maintenance: Unknown. There is not enough information to evaluate the maintenance.
Manufacturability: Unknown. It will depend on the size, material and complexity of the PTO.
Developed by: OWECO
Source: http://www.owec.com/developedment.html [2007, 5 July].

2.26 PS Frog



It is a specially shaped buoy (the shape of the device is still being fine tuned for optimum efficiency) that uses the rocking motion, caused by the waves, as driving force. The power takeoff system will consist of a sliding mass at the top of the device that runs on a set of runners. The device will also have ballast mass at the bottom in order to keep it stable.

Classification:

- Above waterline WEC using a mechanical to electrical PTO system.
- Point absorber.
- Development stage: concept/early testing.

Key Statistics:

- Unknown

Feasibility:

Environmental impact: Low. It is a slow moving device that does not interfere with the beach or seabed.
Maintenance: Low. All the critical components will be housed inside the device where they will be protected from the elements.
Manufacturability: Good. It's a relatively simple design that can be premanufactured before installation.
Developed by: Lancaster University
Source: http://www.engineering.lancs.ac.uk/REGROUPS/ LUREG/Wavw/Wave_Current_Research.htm [2007, 11 March].

2.27 *PowerBuoy*

The buoy like structure is been developed Ocean Power Technologies (an Australian company). The structure is loosely moored to the ocean floor hence allowing it to move freely up and down with the waves. The power takeoff, an electrical generator, a power electronics system and the control system are all sealed inside the device.

Each buoy houses a float (the float acts like a piston) that moves up and down as the waves passes, this motion of the float is used to drive the electrical generator. The electricity that is generated will be fed to shore through a cable.

Classification:

- Above waterline WEC using a mechanical to electrical PTO system.
- Point absorber.
- Medium depth, 30m to 60m.
- Development stage: Contract with US Navy to build a 2MW wave farm.

Key Statistics:
Generation capacity: Currently 40kW but the goal is 500kW.
Size: 40kW unit has a 3.7m diameter and is 15.8m long. The 500kW system will have a 12.8m diameter and will be 19m long.

Feasibility:
Environmental impact: Low. It doesn't have a lot of cables which sea animals can get entangled in and it also doesn't have any open moving parts.
Maintenance: Low. All the critical components are protected by the elements since they are housed inside the buoy.
Manufacturability: Medium. The fact that the system can be premanufactured is a plus point, but the current 40kW system is rather large for such a mall output therefore production cost will be quite high.
Developed by: Ocean Power Technologies
Source: http://www.oceanpowertechnologies.com/ [2007, 15 February].

2.28 *WET EnGen, Wave Energy Technology Inc., Canada*

The system's main feature is its "Smart Float", the float moves up and down a rigid spar which is at a 45° incline. The float is connected to a synthetic cable which drives a shaft via a capstan. The rotational energy of the shaft can be used to generate electricity through a generator or to drive a high pressure pump in order to desalinate water.

The spar is moored at a single point; this allows it to align itself with the incoming waves.

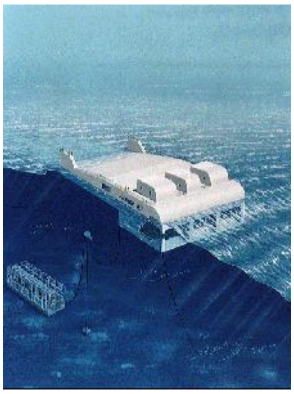
Classification:

- Above waterline WEC using a mechanical to electrical PTO system.
- Point absorber.
- Development stage: Early commercializing.

Key Statistics:
Unit cost: 0.08-0.15$/kWh.

Feasibility:
Environmental impact: Low. Marine life will not get entangled in it and it does not make use of a large anchoring system.
Maintenance: Medium to low. The synthetic cable and the joint at the bottom may cause problems due to fouling.
Manufacturability: Medium. It is a simple structure, but the vast majority of the components must be tailor made for the system.
Developed by: http://Wave Energy Technologies Inc

2.29 Mighty Whale



The Mighty Whale operates on the OWC (oscillating water colomn) principal. It has three chambers in the front which houses trapped air pockets. The waves forces the air to oscillate, it's this motion that's used to drive air turbines which in turn drive electrical generators.

The concept has been under development since the 1940's. The idea is to use a number of these machines in a line in order to create calm seas behind them and to generate electricity.

Classification:

- Above waterline WEC with an OWC PTO system.
- Development stage: sea trails.

Key Statistics:
Generation capacity: 110 kW (prototype).
Size: 50m (Length) x 30m (Breadth) and 12m (Depth)
Displacement: 4 400t

Feasibility:
Environmental impact: Low. It is not a major obstruction for marine life.
Maintenance: Low. It will be easy to perform maintenance since all the critical components are above the waterline. The whole structure can be towed to a nearby harbor when major maintenance needs to be performed or when a storm approaches.
Manufacturability: Medium. The structure is made out of steel and it can be built in almost any shipyard before it's towed to the appropriate location.
Developed by: JAMSTEC (Japan Agency for Marine-Earth Science Technology)
Source: http://www.mext.go.jp/nglish/news/1998/07/980704.htm [2007, 11 June].

2.30 MRC 1000

The device uses multiple oscillating water columns that are housed in tubes with different lengths. This gives the device a high efficiency over a wide range of frequencies, because the different diameter tubes have different resonant frequencies. It thereby overcomes the shortfall of the majority of the devices, namely that they lack the ability to tune in with the changing wave frequencies.

The PTO consists of three stages. During the first stage the oscillating air drives an impulse turbine. During the second stage the turbine drives a hydraulic circuit and in the last stage the high pressure oil drives an electrical generator.

Classification:

- Above waterline WEC with an OWC PTO.
- Point absorbing device.
- Depth: >50m

Key Statistics:
Generation capacity: 1 MW.
Size: 32m diameter.

Feasibility:
Environmental impact: Low. The device itself will have small impact. The anchoring weights eliminate the need to prepare the seabed.
Maintenance: Low. The device is designed to withstand the forces if large waves over tops it during a storm. All the critical components are housed inside the device where they are protected, but still easily accessible from the surface.
Manufacturability: Good. The devise will be built out of steel and it can be built in most shipyards and thereafter towed to the desired location. The devise is anchored by six weights on the ocean floor; this will result in a very low mooring cost. The three stage pto is the most complicated part of the device.
Developed by: Orecon
Source: Bedard, R. & Hagerman, G. 2004. *Offshore Wave Energy Conversion Devices.* EPRI E2I.

2.31 Oceanlinx

Classification:

- Above waterline WEC with an OWC PTO system.
- Development stage: sea trails.

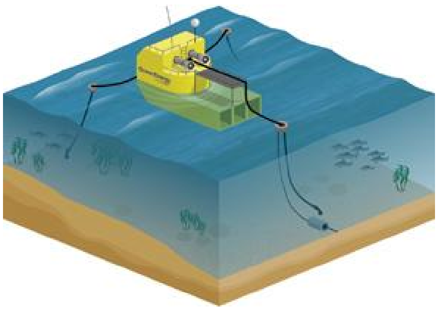
Key Statistics:
Generation capacity: 321 kW in 2m waves with 7 sec period.
Size: 20 m length, 40 m width, and a focal length of 5 m.

A parabolic wall is used to focus the waves on a point. A chamber is situated above the focal point of the parabola, this chamber extends deeper into the water than any through that will be encountered. This chamber is filled with air and it narrows to the top where there is a variable speed pitch blade air turbine. The turbine utilizes the oscillating air (the waves causes the air to oscillate) to drive a generator.

The turbine will be rapidly tuned to the wave frequency in order to increase the efficiency. This will be aided by the systems ability to be soft started in order to bring in onto speed more quickly (electricity from the grid can be used to power the generator, thereby allowing it to operate as a motor).

Feasibility:
Environmental impact: Medium. The wall will increase its environmental impact.
Maintenance: Low. All the critical components are outside of the water. The parabolic wall creates a calm patch of sea where the repair crew can anchor their boat.
Manufacturability: Medium. The wall complicates it, but the greater energy density is a great reward and it allows the use of less energy extracting equipment. The majority of the structure will be built out of steel, this will ease manufacturing.
Developed by: Oceanlinx (previously known as Energetech).
Source: http://www.oceanlinx.com. [2007, 11 March].

2.32 OE Buoy



Classification:

- Above waterline WEC with an OWC PTO system.
- Development stage: sea testing.

Key Statistics:
Size: 28 t model.

The OE Buoy is a floating OWC system based on a vertical column with a horizontal water intake, a configuration called the “backward bent duck buoy”. A large, quarter scale prototype was deployed near Galway, Ireland, however no data on its performance was available. Following successful testing of the prototype, the company has plans for a full scale, 1MW device.

Feasibility:
Environmental impact: Low. It does not have any open moving parts that pose a threat to marine life.
Maintenance: Low. All the critical components (turbines and generators) are house outside of the water. This allows easy access and reduces corrosion.
Manufacturability: Medium. The structure can be manufactured from steel in most shipyards, but the turbines are rather complicated with medium efficiency.
Developed by: Ocean Energy Limited
Source: http://www.oceanenergy.ie[2007, 11 July].

2.33 Sperboy, Embley Energy, UK

The Sperboy operates on the 'oscillating water column' principal. It uses buoyant material to keep it a float and several cables to keep it at a constant height. There is an air column on the inside of the device that oscillates as the waves passes. The energy is extracted from the oscillating air by turbines that in turn transfer the energy to generators.

Classification:

- Above waterline WEC with an OWC PTO.
- Point absorber.
- Deep water, 13km to km 19from shore.
- Development stage: advanced testing and optimization.

Key Statistics:

- Unknown

Feasibility:

Environmental impact: Low. The system will not interfere with the seabed or the beach.

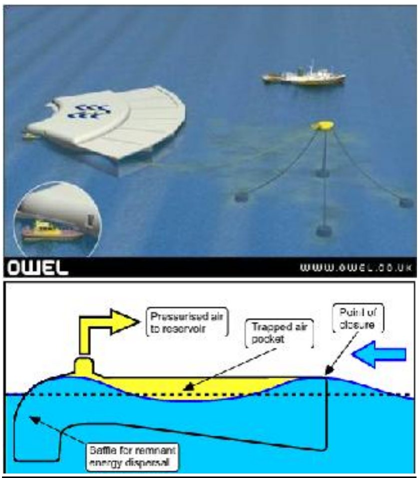
Maintenance: Low. All the critical components are outside of the water, thereby lowering corrosion.

Manufacturability: Good. The system can be premanufactured and it doesn't need a structure on the seabed.

Developed by: Embley Energy

Source: http://www.sperboy.com/ [2007, 11 March].

2.34 Offshore Wave Energy Ltd (OWEL), UK



The WEC is a horizontally floating duct which is made up of several sections which together forms one large system. The height of the duct, at the entrance, will be equal to the average wave amplitude and the length will be determined by the average wave length. The fact that the system consists of several sections and that it is length is longer than the average wave length, will allow it to be stable. The anchoring system allows the WEC to align itself with the incoming waves.

The incoming waves trap air against the top of the ducts. The air gets compressed more and more as the waves moves forward into the ducts because the ducts are narrower at the rear. The air is collected in a chamber before it is forced to flow through a turbine at the rear that in turn drives a generator. The prevailing energy in the waves is dispersed by the baffle at the rear in order to prevent them from reflecting back into the duct.

Classification:

- Above waterline with an OWC PTO system.
- Development stage: Scale model testing (15m).

Key Statistics:

Generation capacity: 12 MW

Size: 32 000t, 200m wide at the intake (front).

Unit cost: 2p per kWh.

Total cost: £18 million

Feasibility:

Environmental impact: Low. The system will have very little impact on marine life.

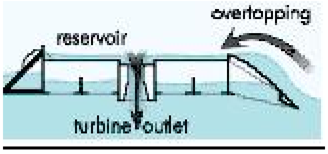
Maintenance: Low. All the critical components will be easily accessible and also exposed to very little corrosion because they are located outside of the water.

Manufacturability: Medium. It will be a large structure (large investments needed), but its generation capacity to surface area ratio will be better than that of most other systems because it focuses the waves.

Developed by: Offshore Wave Energy Ltd

Source: http://www.owel.co.uk/print/welcome.htm [2007, 20 April].

2.35 Wave Dragon



Classification:

- Above waterline WEC with an overtopping type PTO.
- Deep water, preferably more than 40 m.
- Development stage: Plans to install a 7MW device during 2008 off the Wales coast.

Key Statistics:
All statistics are for a 36kW/m wave climate.
Rated power: 10 MW
Weight: 22 000 - 33 000 t.
Reservoir: 5 000 m³ - 8 000 m³.
Estimated cost: 13.5 mill. Euros.
Unit cost: 0.11 euros/kWh

The Wave Dragon is a large floating structure whose main components are its reservoir and the two reflector arms. The reflectors are used to focus the waves on the central section; thereby increasing its amplitudes. The focused waves are forced to flow up a specially shaped ramp into the elevated reservoir.

Kaplan turbines are used to convert the low head of the water into mechanical energy. The turbines drive permanent magnet generators, thereby generating electricity on the same principal as conventional land based hydropower plants.

It is one of the heaviest (if not the heaviest) structures that are used to generate electricity from ocean waves.

Feasibility:
Environmental impact: Low. It will need a large anchoring system due to its shear size, but it will need a much smaller anchor than a number of buoy-like WECs with the same combined output.
Maintenance: Medium to low. The shear size of the device will make it very stable during storms; hence survivability should not be a problem. The size of Wave Dragon will prevent it from being retrieved for extensive maintenance.
Manufacturability: Medium to poor. It is a large structure that will be very difficult to transport and install. The turbines also need to be specially designed in order to use the relatively low head.

Source: http://www.wavedragon.net [2007, 11 March].

2.36 WavePlane

Classification:

- Above waterline with an overtopping type PTO.
- Line absorber.
- Near shore based.
- Development stage: full scale tests.

Key Statistics:
Generation capacity: 200 kW.
Size: 14 m-45 ton model.
Manufacturing cost: $500000-$650000

The WavePlane is a floating device that is anchored to the seabed by a cable. It uses a damping plate underneath it to limit its vertical movement when the wave passes by. Its shape also helps it to align itself with the incoming waves.

The wave crest is flushed into reservoirs, thereafter the water is accelerated through fins in order to induce more whirling in it before it is fed through a turbine. The system produces continues power, because the water is fed in, sequential order (firstly from the highest reservoirs and then from the lower ones), from the reservoirs to the turbine.

Feasibility:
Environmental impact: Low. It will not impact the beach and the anchoring cable will have minimal impact on marine life.
Maintenance: Low. All the parts are easily accessible and a prototype withstood a ten year high storm in Holland.
Manufacturability: Medium. The whole system can be prefabricated before installation. The WavePlane itself is more difficult to manufacture than most buoy concepts.
Source: http://www.waveplane.com/ [2007, 25 February].

2.37 CETO II

The shore based part of the CETO II is exactly the same as that of the CETO I (hydro power plant or a reverse osmosis plant).The off shore part however differs significantly. The large structure is replaced by a much smaller device. It consists of a submerged actuator that is connected to a (the same kind as the CETO I) pump through a rope/cable.

The buoyant actuator uses the swell to drive the pump. The water (that's pumped) is collected from all the devices in the wave farm before it is fed to the shore based part of the PTO.

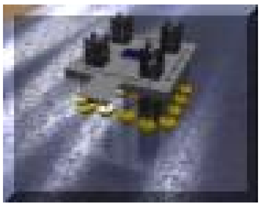
Classification:

- Floating WEC with a water-pump as PTO.
- Point absorber.
- Max distance off shore: 10km.
- Development stage: CFD modeling (CETO II) and sea trails of CETO I.

Key Statistics:
Size: Unknown
Time from deployment: 1-2 years

Feasibility:
Environmental impact: Medium to low. The system will occupy less space on the seabed than CETO I, therefore it will have a smaller environmental impact.
Maintenance: Medium. The final stage of the PTO (hydro power plant and/or reverse osmosis) will be housed on land where it will not be exposed to the harsh ocean environment. The actuator will be submerged beneath the surface, thereby protecting it from overloading during storms and the pump will be near the seabed where storms will have very little effect on it.
Manufacturability: Good. The system uses well known and proven technology (the hydro power system and the reverse osmosis system can both be bought off the shelf). The off shore part of the system can be premanufactured before installation (it also uses proven technology).
Developed by: Seapower Pacific Pty Ltd
Source: Mann, L.D., Burns, A.R. & Ottaviano M.E.2007. *CETO, a Carbon Free Wave Power Energy Provider of the Future.*

2.38 OMI Wavepump, Ocean motion international, USA



The system has a large floating base that has several sleeve pumps underneath it. When a trough passes underneath the base, a heavy ballast mass descends and pressurizes the water in the pump. All the pumps are connected to an accumulation tank where the high pressure water is stored before the high pressure water is used to drive a turbine. The turbine in turn powers a generator.

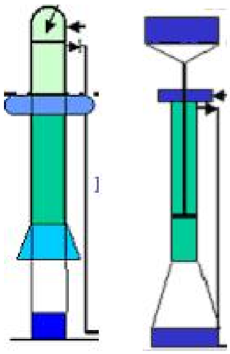
Classification:

- Above waterline with a water pump as PTO.
- Point absorbing device.
- Development stage: Unknown.

Key Statistics:
Rated power: 5-50 MW.

Feasibility:
Environmental impact: Low. Pollution will not occur because water is used instead of oil as hydraulic fluid.
Maintenance: Unknown. It's unknown what the major construction material will be. It is assumed that the generation system will be on top or inside the floating base where it is easily accessible.
Manufacturability: Unknown. It will depend of the size and material of the device.
Note: Too little information is available to properly evaluate the feasibility of the device.
Developed by: Ocean Motion International
Source: http://www.oceanmotion.ws/ [2007, 1 July].

2.39 WAP and WWP



The WAP has a capsule like structure with a flared open bottom and a sealed top. The WAP (wave air pump) is kept upright by a float that is situated below the waterline and it's anchored by cables. An air pocket is trapped inside the top of the device. The air will either be compressed or decompressed depending on whether it is a crest or trough that passes by. When a crest passes will compress the air, thereby feeding it to shore through a pipeline, but when a trough passé air is sucked into the device through one way valves. The air will be fed into a fossil fuel generator in order to reduce its consumption.

The WWP (wave water pump) operates on the same principal than the CETO III (see no 36 for more detail).

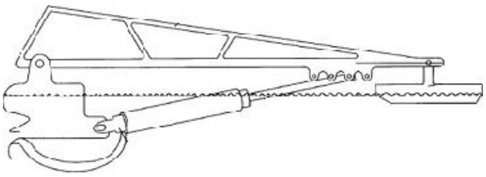
Classification:

- Floating WEC with a water pump as PTO.
- Point absorbing device.
- Development stage: Early testing stage.

Key Statistics:
Unit cost: 0.02$/kWh

Feasibility:
Environmental impact: Medium to low. The WAP does not have any open moving parts that can harm marine animals.
Maintenance: Low. The WAP will have very low maintenance since the two check valves are the only moving parts. The valves will be located above the water level where they will be easily accessible. The WWP will need more maintenance since its water pump will require more maintenance.
Manufacturability: Good. It is a simple structure that can be built in a shipyard, towed to the desired site and then installed.
Developed by: Renewable Energy Pumps
Source: http://www.renewableenergypumps.com/ [2007, 26 July].

2.40 Waveberg



A set of connected articulated floats flex when the waves pass under them. This bending motion is used to drive piston pumps which pumps seawater under high pressure to the shore where it is used to drive a turbine. This turbine powers a generator.

This system is very similar to no 1.

Classification:

- Above waterline WEC with a water-pump as PTO.
- Medium depth (50m)
- Development stage: scale model testing.

Key Statistics:
Generation capacity: 100 kW per unit.
Total cost: $1 700 per kW.
Size: 50m long.
Unit cost: $0.02 per kWh

Feasibility:
Environmental impact: Low. The device and the pipeline will have a small impact.
Maintenance: Low. It is a simple system.
Manufacturability: Good. It is an uncomplicated system that it uses common materials (plastic pipe and fiberglass).
Source: http://www.waveberg.com/ [2007, 11 March].

2.41 Wave-powered diaphragm pump

No picture available on website.

The systems base is a boxlike structure made out of concrete that is filled with rocks in order to keep it stable on the seabed. On top of the base is an octagonal steel structure that houses the sixteen cylindrical guide columns. Inside each columns is a pump that is made out of sixteen tyres with cylindrical spacers that connects them. All sixteen pumps are connected via non return valves to a single discharge pipeline that goes to shore.

The pumps are connected to a heavy ram that compresses them. The ram in turn is suspended by a 32 m diameter raft that has sufficient buoyancy to lift it when the crest of a wave passes.

The water, which is pumped by the pumps, can be allowed to flow through a conventional hydro turbine that is connected to a generator in order to generate electricity. The water can also be stored in a dam and used when the demand for electricity increases.

Classification:

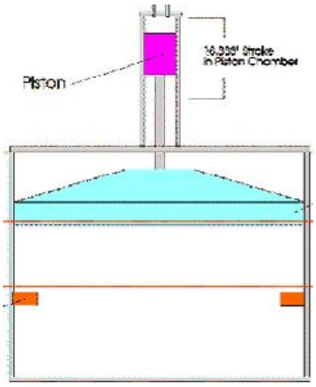
- Above waterline WEC with a water-pump as PTO.
- Development stage: Concept stage.
- Depth: 40-50m

Key Statistics:
Size: 32 m diameter raft.

Feasibility:
Environmental impact: Low. If the device can be built in large amounts it can help to put old unwanted tyres to good use, therefore it can actually be an asset to the environment.
Maintenance: Low. The PTO itself will be very easy to maintain, since it will be situated on the shore where it is easily accessible. The pumps should have a long life because rubber has a very long fatigue life.
Manufacturability: Good. Manufacturing should be easy because easy to work with materials (steel, concrete and old tyres) are used.

Developed by: South African inventor (name unknown).
Source: http://www.engineeringnews.co.za [2007, 1 July].

2.42 Seadog



Classification:

- Above waterline WEC with a water-pump as PTO.
- Point absorber.
- Depth: 20m.
- Development stage: prototype testing.

A buoyancy block, inside of a chamber, is used to drive a piston pump. The pump pumps seawater (under high pressure) to the shore where it is used to drive a hydroelectric system in order to generate electricity or to desalinate seawater.

In a typical installation, several devices will be connected in parallel in order to produce a large flow rate of high pressure seawater. The systems capacity can easily be expanded simply by increasing the amount of pumps.

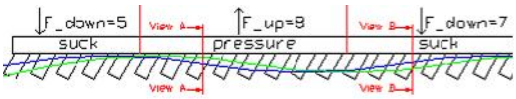
One of the major advantages of the system is that the water can be accumulated in the reservoir until the electrical demand increases. But on the other hand efficiency will be low, because the system can not tune itself to the frequency of the waves.

Feasibility:
Environmental impact: Medium to high. The seabed must be prepared in order to build the base structures for the pumps. This includes the removal of rocks, leveling of the seabed and the laying of mats for scour protection.
Maintenance: Low. Bio-fouling on and inside the pipes and pumps will be a great problem. The pto itself will need minimal maintenance, since it will be easily accessible and it will also be protected from the extreme impact of the ocean.
Manufacturability: Medium. The device requires a proper concrete base on the seabed. This will increase the installation cost. The device consists mainly of steel and concrete, which is easy to use during manufacturing.

Key Statistics:
Generation capacity: 55 l/min-82 l/min at a head of 34m-38m.
Size: It is11m high and 7.8 tons.
Unit cost: 2.08cents kWh.
Total cost: $217 million for a 750 megawatt plant.

Developed by: Independent Natural Recourses Inc.
Source: http://www.inri.us/pages/2/index.htm [2007, 11 March].

2.43 Leancon



The system developed by Leancon works on the same principal as the SWEC. It uses a total of 60 tubes which is situated in two rows and is connected to a v-shape (the v-shape allows it to align with the waves) structure. The crests compress the air, thereby forcing the high pressure valve open and allowing the air to flow into the high pressure collecting tube. This tube feeds the turbine which extracts energy from the air. The low pressure air that excites the turbine is allowed to flow back into the tubes that encounters a trough (the air flows through a pipe and then a one way valve into the low pressure tubes). This will result in a more continues air flow and it will further allow the use a of normal air turbines instead of Wells turbine (the last mentioned is more expensive).

The system's length will be longer than the average wave length; therefore the device will always encounter a trough and crest simultaneously. The vertical forces (that is caused by the peak and trough respectively) will tend to cancel each other out. This will allow the system to be quite stable and allow the use of lighter materials and a smaller anchor.

Classification:

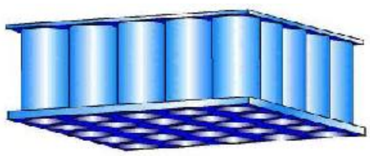
- Above waterline WEC with a PTO that utilizes pressure difference.
- Multiple point-absorbing WEC (MAWEC).
- Development stage: Early testing stage.

Key Statistics:

- Unknown

Feasibility:
Environmental impact: Low. The designer claims that the system will use a very small mooring system.
Maintenance: Medium. The main components will be easily accessible. The durability of the system will depend on the quality of the materials that will be used, especially the valves.
Manufacturability: Medium. The system can be premanufactured.
Developed by: Leancon
Source: http://www.leancon.com [2007, 11 March].

2.44 Pneumatically Stabilized Platform(PSP), USA



The PSP uses water columns to provide stabilization for a floating platform. The platform is composed of many vertical tubes, each one forming an OWC, on top of which structures (for example, natural gas drilling and liquefaction equipment) can be placed. Each column is connected by an air tube (containing a turbine) to several other water columns, and as a wave passes by, the water levels in the columns will change, driving air between the columns and through the turbines. Since the OWCs extract the wave energy, the waves are quickly reduced in size as they pass under the platform, giving it a high degree of stability. Small-scale tests of the platform concept have been conducted, however no demonstrations of its power generation capability have been performed

Classification:

- Above waterline WEC with a PTO that utilizes pressure difference.
- Multiple point-absorbing WEC.
- Multi absorbing WEC (MAWEC).
- Development stage: Model testing and

Feasibility:
Environmental impact: Low. Although the device will be large it will offer very little obstruction to marine animals. The shear size of the device will make it very stable; therefore it will need a relatively small anchoring system.
Maintenance: Low. The PTO will be outside of the water and it will be easily accessible. The structure will mainly be built out of concrete, therefore corrosion should be low.
Manufacturability: Good. Construction will be easy because due to the use of concrete. The device can be constructed in sections in a shipyard

computer simulating.

and then towed to the desired location where they will be assembled.

Key Statistics:

- Unknown

Developed by: Float Incorporated
Source: http://www.floatinc.com/ [2007, 1 July].

2.45 WaveBob

The WaveBob is a free floating point absorber that uses a hydraulic system to convert the energy of the waves into electricity (there is very little available information about the system). The hydraulic system uses biodegradable fluids in order to prevent pollution in case a leakage occurs.

The system has an onboard control system that changes the natural frequency of the device according to the predominant wave frequency. It also has an overload protection system that protects the device during extreme weather conditions.

Classification:

- Above waterline WEC.
- Point absorber.
- Depth: >50m
- Development stage: Optimization.

Feasibility:
Environmental impact: Low. The mooring system will have the only noticeable environmental impact and this should be low.
Maintenance: Unknown. Too little information is available.
Manufacturability: Unknown. The structure will be made out of steel; this will ease manufacturing since it can be built in almost any shipyard using known processes. The complexity of the PTO is unknown.

Key Statistics:
Rated power: 1 MW
Size: 15m diameter
Weight: 440 tons

Developed by: Wavebob
Source: Bedard, R. & Hagerman, G. 2004. *Offshore Wave Energy Conversion Devices.* EPRI.

2.46 Archimedes Wave Swing

It consists of two cylinders the lower one is fixed to the seabed and the upper one is allowed to move swell. An air pocket is trapped inside the upper cylinder; this pocket is compressed when the peak of the wave passes. This forces the float down, thereby compressing the air, when the trough passes the compressed air forces the float back up. This causes the float to oscillate.

Electricity is generated through a linear generator. Magnets are attached to the inside of the float (upper cylinder) and they generates electricity when they move relative to the inside coil.

Classification:

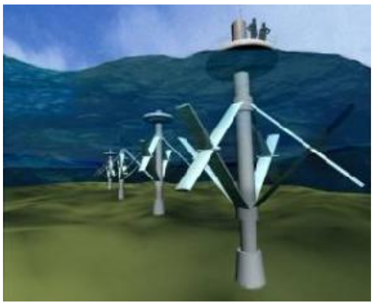
- Bottom mounted WEC with a linear-generator as PTO.
- Point absorber.
- Far from shore.
- Development stage: full scale tests.

Feasibility:
Environmental impact: Medium. It will use a larger piece of ocean floor than the buoy type concepts, but it will not influence the sensitive beachfront. It doesn't use hydraulic oils, thereby lowering pollution risks.
Maintenance: Medium. The whole system will be submerged making maintenance difficult, but this also protects it during storms. The device will have to be floated in order to perform extensive maintenance.
Manufacturability: Medium. It is a large structure and it will be difficult to transport the structure to the desired location, but the fact that it is made from steel eases construction.

Key Statistics:
Generation capacity: >1.2 MW.
Depth: > 6m below surface.
Size: 9.5m diameter.
Cost estimate: $4-6 million.

Developed by: AWS Ocean Energy Ltd.
Source: http://www.waveswing.com [2007, 25 February].

2.47 Wave Rotor, Denmark



The Wave Rotor uses two types of rotors, a Darius and a Wells rotor. These rotors are used to generate electricity from the up, down and circular currents in the ocean. The system uses the same principal as wind turbines to generate electricity.

The system can achieve good efficiencies because it uses a direct drive system (the shaft is connected to a generator through a gearbox).

Classification:

- Bottom mounted WEC with a mechanic to electrical PTO system.
- Development stage: Computational modeling and the design a half scale model.

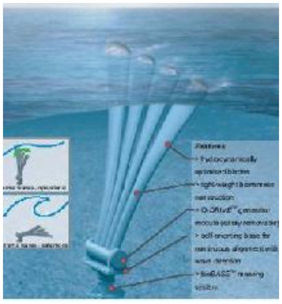
Feasibility:

Environmental impact: Medium. It will not have a significant impact on the environment, but due to the base it will have a lager impact than buoy types.
Maintenance: Low. It will not have high maintenance, but most of its critical components are under water, complicating services.
Manufacturability: Medium. It uses proven technology, but the base that is required complicates the construction.

Key Statistics:
Size: 40m diameter.

Developed by: Ecofys
Source: http://www.ecofys.com/com/news/pressreleases2002/ Pressrelease02aug2002.htm [2007, 11 March].

2.48 bioWAVE



The device is said to move in the same way as an ocean plant if a wave passes. This swaying motion is converted into electricity by the specially developed O_DRIVE *TM* that is situated at the hinge point at the bottom of the device.

The device will protect itself if a storm approaches by lying flat on the seabed.

The system is very similar to the Oyster and the WaveRoller. The main difference between the devices is their PTOs.

Classification:

- Bottom mounted WEC with water-pump serving as PTO.
- Development stage: unknown.

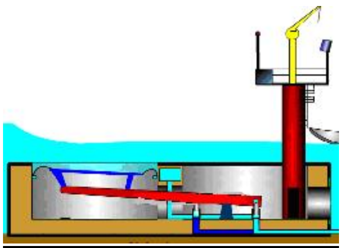
Feasibility:

Environmental impact: Low. There are no fast moving parts that can harm marine creatures and the anchor will also have a very small impact.
Maintenance: Medium. The generation system is near the bottom of the ocean, this will make maintenance more difficult.
Manufacturability: Medium. The device itself is easily manufactured, however the PTO may be more difficult to manufacture (there is no information about the PTO).

Key Statistics:
Generation capacity: 500kW, 1000kW and 2000kW.

Developed by: Biopower Systems
Source: http://www.biopowersystems.com [2007, 13 June].

2.49 CETO I



The CETO is an Australian invention and it is a fully submerged system that sits on the seabed. The wave crests cause a disc to move down, but it will rise again during the trough. The vertical motion of the disc is used to drive two pumps in order to produce high pressure water (in excess of 6 400 kPa). The water is pumped to shore through a 125mm pipe where it is used to drive a generator in order to produce electricity or it can be used to produce fresh water through reverse osmosis.

Classification:

- Bottom mounted WEC with water-pump serving as

Feasibility:

Environmental impact: Medium to low. The system will occupy a much larger peace of seabed than buoys, but it will not have any anchoring

PTO.

- Medium depth, 20m.
- Development stage: full scale testing.

Key Statistics:
Size: 20.4m long and 4.6m high.

cables within which marine animals can get entangled.
Maintenance: Medium. All the critical components will be housed inside the hull of the system, hence protecting them. The production units will not have a tower; this will make access more difficult.
Manufacturability: Good. The system uses well known and proven technology. The system can also be premanufactured and then towed to the desired site where it will be submerged.
Developed by: Seapower Pacific Pty Ltd
Source: Mann, L.D., Burns, A.R. & Ottaviano M.E.2007. *CETO, a Carbon Free Wave Power Energy Provider of the Future.*

2.50 Oyster

The oyster is an oscillating device that will be deployed near shore on the seabed (it is very similar to the WaveRoller). It will use a double acting piston pump in order to pump seawater to the shore. The water will be used to generate electricity through a hydroelectric power system.

The cost of the pipe line should be low, because the device will be deployed near shore. This will however decrease the efficiency of the device, because a lot of the energy in the waves is depleted due to friction when the wave reaches shallow water.

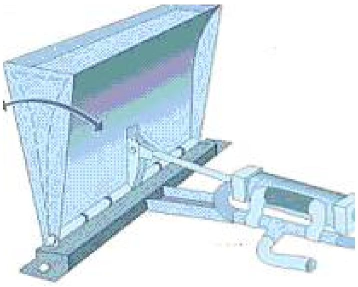
Classification:

- Bottom mounted WEC with water-pump serving as PTO.
- Depth: 12m.
- Development stage: Design optimization and testing during 2007.

Key Statistics:
Rated power: 300-600 kW per unit.

Feasibility:
Environmental impact: Medium. It will occupy a modest amount of space on the ocean bed, but it will have minimal impact on the more sensitive beach.
Maintenance: Medium to low. The pump is totally submerged, making access difficult, but the electricity generation system (which is most critical) is on the shore. The units can also be serviced separately, allowing uninterrupted power generation.
Manufacturability: Good. The system uses mostly proven technology and the newly developed parts are easy to manufacture. The system is more complicated than the WaveRoller.
Source: http://www.aquamarinepower.com/ [2007, 25 July].

2.51 WaveRoller, AW-Energy, Finland



Classification:

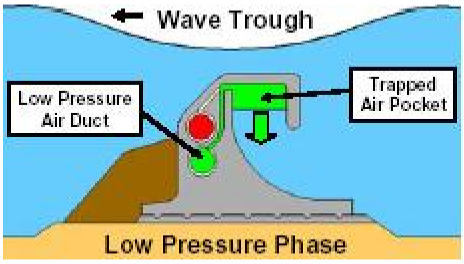
- Bottom mounted WEC with water-pump serving as PTO.
- Near shore based (in the breaking waves).

Key Statistics:
Generation capacity: Depends on the number of modules installed.

The WaveRoller is a bottom-mounted device based on an inverted pendulum design. The device has a large plate which moves back and forth in response to incoming waves, driving a hydraulic piston and providing 10-15kW of power per device. The design calls for the WaveRoller devices to be deployed in groups of 3-5, with each group using a common generation system. A 1:3 scale prototype of a group of devices was demonstrated at the EMEC in Orkney, and a single full-scale WaveRoller was recently (April 2007) deployed in Peniche, Portugal. Contingent on the success of the prototype, a larger farm will be deployed in Portugal during 2008.

Feasibility:
Environmental impact: Medium. It will occupy a modest amount of space on the ocean bed, but it will have minimal impact on the beach.
Maintenance: Medium. The pump is totally submerged, making access difficult, but the electricity generation system (which is the most critical component) is on the shore. The units can also be serviced separately, allowing uninterrupted power generation.
Manufacturability: Good. The system uses mostly proven technology and the newly developed parts are easy to manufacture.
Developed by: AW-Energy
Source: http://www.aw-energy.com [2007, 25 February].

2.52 SWEC (Stellenbosch wave energy converter)



Classification:

- Bottom mounted WEC with pressure difference type PTO.
- Bottom mounted WEC with water-pump serving as PTO.
- Development stage: Early testing stage.
- Depth: 15-20m

Key Statistics:
Generation capacity: 5MW

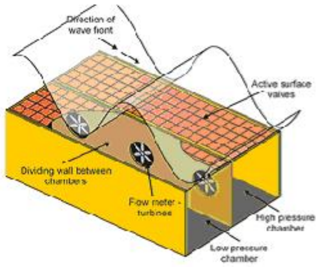
The picture on the left is a section view of the collector of the SWEC. The collector is mounted on the seabed forming a 'v' and the PTO is situated at the end point of the 'v'. The crest of the waves compresses the trapped air pocket, thereby opening the high pressure valves and allowing the air to flow into the high pressure collection pipe. If the trough passes the air pressure also drops, opening the low pressure valves and allowing air from the low pressure tube to flow back into the cavity.

This setup results in continues air flow in one direction. That's why a one direction turbine is used to extract the energy from the air (the turbine is situated between the high and low pressure collecting tubes).

Feasibility:
Environmental impact: Medium. The device requires a relatively large structure that will occupy the seabed. However it has no moving parts that interfere with marine life.
Maintenance: Medium. Sand will accumulate near the base of the structure that will have to be removed. The PTO is outside the water, but the large amount of valves will require more maintenance.
Manufacturability: Medium. The device requires a lot of under water installation which is quite expensive.

Developed by: Mr. Muller from University of Stellenbosch
Source: Ocean Energy in South Africa (slide show). Retief, D.

2.53 WaveMaster



The pressure difference between the two chambers is utilized by several turbines. These turbines powers generators in order to generate electricity.

The system utilizes the pressure difference between the peaks and troughs of the waves. If a trough passes, the pressure is lower outside than in the low pressure chamber. The valves allow the water to flow out of the low pressure chamber. If the peek passes, the pressure outside is higher than inside the high pressure chamber. Then valves allow water to flow into the high pressure chamber.

Classification:

- Bottom mounted WEC with pressure difference type PTO.
- Development stage: concept.

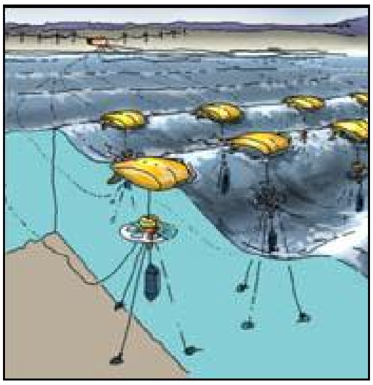
Feasibility:

Environmental impact: Large. It will occupy a large peace of seabed.
Maintenance: High. The system is totally submerged and it is complicated.
Manufacturability: Complicated. The system will require a large and complicated structure that will require a lot of maintenance.

Key Statistics:

Source: http://www.oceanwavemaster.co.uk/ [2007, 11 March].

2.54 Magnetohydrodynamic (MHD) Ocean Wave Energy Conversion System (MWEC)



Couples to up/down motion of heave based systems. A shaft transfers wave motion to the MHD generator which is deep underwater (no wave motion). The shaft forces the conducting fluid through powerful permanent magnets. Low voltage/high current electrical energy is generated via the MHD interaction. An electrical inverter converts the electrical energy to commercial quality 60 Hz AC power Power is transmitted to shore from multiple generating stations and connected to the grid.

Classification:

- Floating, point absorber WEC.
- Linear generator PTO.
- Development stage: concept (100kW prototype).

Feasibility:

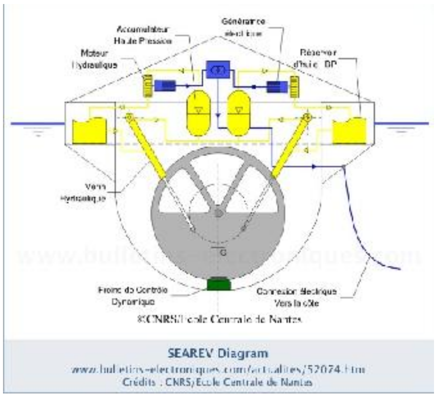
Environmental impact: Low. The device has a small footprint.
Maintenance: Medium. The device is modular and can be towed to the nearest port for maintenance work.
Manufacturability: Medium. The PTO is apparently less complex and efficient compared to common turbine generators.

Key Statistics:

- Efficiency = 0.5

Developed by: Scientific applications and research associates (SARA)
Source: http://www.sara.com/RAE/ocean_wave.html [2008, 5 May].

2.55 SEAREV



SEAREV Diagram

SEAREV, a second generation offshore system, includes a sealed, watertight floater with a charged wheel inside, which acts as an embedded pendulum. The upper half of the horizontal axis wheel with a 9-meter diameter is empty. Weight is concentrated in the concrete-filled lower half, thus explaining the pendulum effect. Sea swell and waves make the SEAREV floater oscillate, causing the pendulum wheel to swing back and forth. As the floater and pendulum each has its own movement, the relative floater-wheel movement activate a hydroelectric system that converts mechanical energy into electricity. Hydraulic pumps connected to the pendulum wheel charge the high pressure accumulators that discharge their energy into hydraulic engines that drive electric generators. An underwater cable conveys the electricity to land. Several SEAREV floaters can be anchored offshore, creating a park or farm.

Classification:

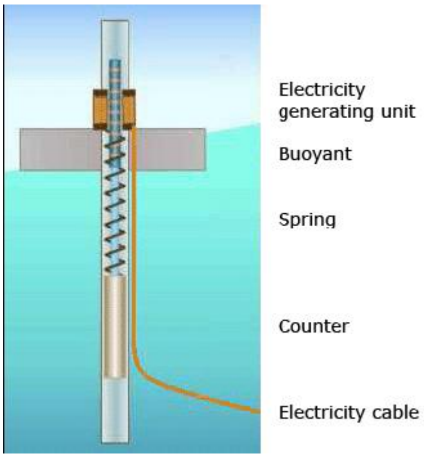
- Floating device, similar to Salter Duck
- Development stage: 1/12 prototype
- 500 kW full scale 2009

Key Statistics:

Feasibility:
Environmental impact: Low. The device has a small footprint.
Maintenance: Medium. The device is modular and can be towed to the nearest port for maintenance work.
Manufacturability: Medium. The PTO consists out of off the shelf components.

Developed by: CNRS, the Regional Council of Pays de la Loire and the French Energy Agency ADEME.
Source: http://192.107.92.31/test/owemes/29.pdf [2008, 15 May].

2.56 Brandl Generator



The Brandl Generator is made up of four components: the floating body, the spring with its hanging counter weight and the directly connected linear generator. The motion of the sea-waves induces relative movement in the 'Brandl' generator; the oscillating movement between the floating body and the counterweight is hydraulically transmitted to the linear generator.

All moving parts are encased in a closed unit, simplifying maintenance and holding service costs down.

Classification:

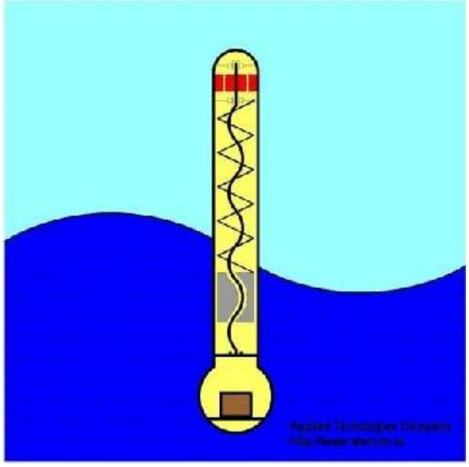
- Floating device
- Development stage: 1/12 prototype
- 500 kW full scale 2009

Key Statistics: Germany

Feasibility:
Environmental impact: Low. The device has a small footprint.
Maintenance: Medium. The device is modular and can be towed to the nearest port for maintenance work.
Manufacturability: Medium. The PTO consists out of off the shelf components.
Developed by: Brandl Motor

Source: http://brandlmotor.de [2008, 19 May].

2.57 Float Wave Electric Power Station (FWEPS)



The module of FWEPS is an oblong axisymmetrical capsule-float which is located on the sea surface. Inside the capsule there is a mechanical wave energy converter, consisting of an oscillatory system and drive, and a linear generator and energy accumulator.

Under the wave effect the capsule-float and inner oscillatory system of the mechanical converter are in continuous oscillatory motion, while the drive engaged with the system provides a continuous turn for the electric generator.

Classification:

- Floating device
- Development stage: prototype sea trails
- 10 kW full scale

Key Statistics: Russia

Feasibility:

Environmental impact: Low. The device has a small footprint, but is visible above sea level.
Maintenance: Medium. The device is modular and can be towed to the nearest port for maintenance work.
Manufacturability: Medium. The PTO consists out of off the shelf components.
Developed by: Applied Technologies Company

Source: http://atecom.ru/wave-energy/ [2008, 19 August].

2.58 SRI International

SRI International is an independent, non-profit R&D organisation. SRI's generator utilizes patented electroactive polymer artificial muscle (EPAM™) technology, and offers a renewable method to continually power wave recording ocean buoys. SRI launched a prototype buoy in Tampa Bay, Florida.

The prototype testing was sponsored by Hyper Drive, a Japanese based company.

Classification:

- Supplies power to wave measuring buoys
- Small scale power supply

Key Statistics:

Feasibility:

Environmental impact: Low. Technology applied to existing wave buoys.
Maintenance: Medium. Maintenance on complex material will require skilled labor.
Manufacturability: High. Artificial muscle material will most likely be imported.
Developed by: SRI International

Source: http://www.sri.com/news/releases/080307.html [2008, 19 August]

2.59 Langlee Wave Power

Langlee wave energy technology focuses on converting the horizontal sub-surface energy contained in ocean waves. The Langlee device orientates itself during wave loading. It uses a hydraulic P.T.O. A unit is typically 140m long and 25m wide.

Classification:

- Submerged system
- Similar to WaveRoller

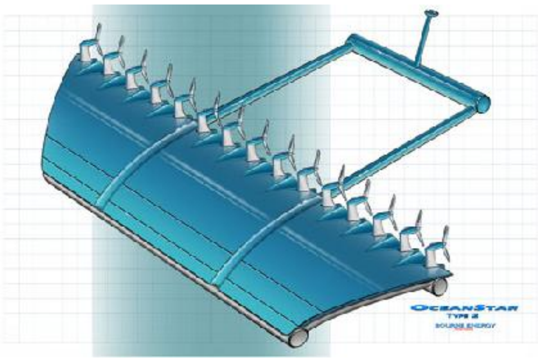
Feasibility:
Environmental impact: Low visual impact. Sub-surface system
Maintenance: Medium. Technology is based on proven offshore technology.
Manufacturability: Low.

Key Statistics: Norway

Developed by: Langlee Wave Power. Julius Espedal CEO.

Source: http://www.langlee.no [2008, 19 August]

2.60 Oceanstar



The Oceanstar is a submerged WEC that utilises sub-surface pressure to drive multiple turbines.

Classification:

- Submerged offshore system

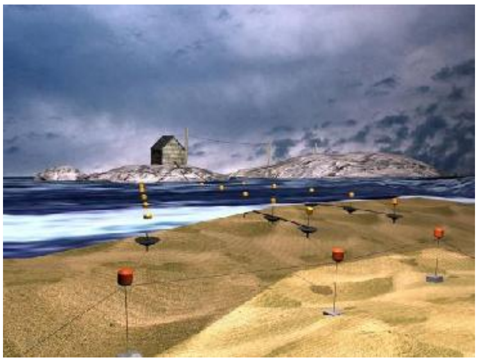
Feasibility:
Environmental impact: Low
Maintenance: Medium. Device can be towed to nearest port
Manufacturability: ?

Key Statistics: Country of origin: America

Developed by: Bourne Energy

Source: http://www.bourneenergy.com/future.html [2008, 19 August]

2.61 Pelagic Power



The Pelagic Power WEC consists of a linear piston pump, a water anchor and a surface buoy.

Classification:

- Submerged buoy/pump system

Feasibility:
Environmental impact: Low
Maintenance: Medium. Maintenance more expensive for submerged systems
Manufacturability: Low

Key Statistics:

Developed by: Pelagic Power

Source: http://www.pelagicpower.com/index.php?p=1-1-1 [2008, 19 August]

2.62 Poseidon

Poseidon is an offshore, floating WEC consisting of 10 OWC flotation units. It has a length of 230m. It has a patented mooring system which allows the device to orientate itself into the dominate wave direction.

Sea trails of a 1:10 prototype is scheduled for Aug 2008 off the coast Lolland, Denmark.

Classification:

- Offshore, floating OWC

Feasibility:
Environmental impact: Low
Maintenance: Medium. Offshore location makes accessibility an issue
Manufacturability: Medium.

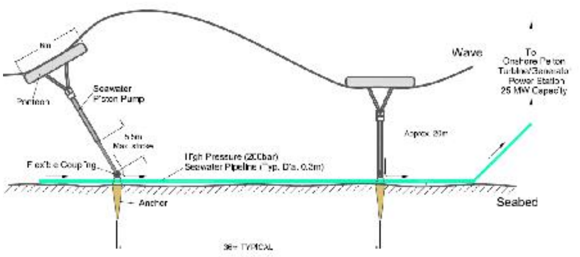
Key Statistics:

- Efficiency 35%
- Danish

Developed by: Floating Power Plant

Source: http://www.poseidonorgan.com/ [2008, 22 August]

2.63 SurfPower



SurfPower is a pontoon anchored to the seabed via hydraulic cylinders that operates as a piston pump. Upward and lateral motion of the pontoon forces fluid from the piston pump, at high pressure, (200 bar) to a collection main on the seabed. This high pressure fluid is delivered to an onshore pelton turbine that drives an asynchronous electrical generator.

Classification:

- Nearshore (+- 20m) point absorber
- P.T.O onshore

Key Statistics:

Feasibility:
Environmental impact: Low
Maintenance: Medium. Maintenance to the submerged piston pump could be an issue
Manufacturability: Medium.

Developed by: Seawood Design Inc
Source: http://www.surfpower.ca [2008, 22 August]

2.64 SyncWave Power Resonator

SyncWave Power Resonator makes power by capturing the motion differential (phase lag) between two dissimilar float structures. The phase lag is continuously maximized under varying swell frequencies via a proprietary variable inertia tuning system located inside the large oscillator float. Power is captured by a hydraulic power take-off, driving a permanent magnet DC generator. DC power from several SyncWave units in a wave farm will be collected and converted to AC power in a sea-bed mounted collector hub, then transmitted to shore by subsea cable for interconnection to a load. The SyncWave Demonstration machine depicted here is a half-scale device of 100 kilowatts capacity, expected to deliver 25kW average power throughout a typical year. The oscillator, (the large central float,) is approximately 30m tall.

Mooring?

Classification:

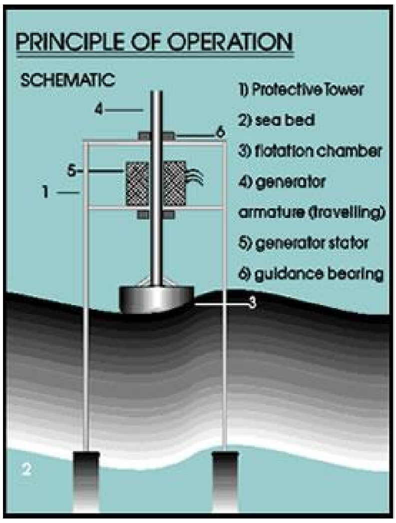
- Nearshore point absorber (?)
-

Key Statistics: Canadian

Feasibility:
Environmental impact: Low
Maintenance: Medium.
Manufacturability: Medium.

Developed by: SyncWave Systems
Source: http://www.syncwaveenergy.com/index.html [2008, 22 August]

2.65 Direct Energy Conversion Method (DECM)



DECM is a neashore point absorber with a linear generator P.T.O. It consists out of a floatation unit that oscillates relative to a fixed reference. The floatation unit is hoisted above the sea level during extreme storms to ensure survivability.

Trident Energy plans for sea trails off the English east coast in 2008.

Classification:

- Near- and offshore point absorber

Feasibility:
Environmental impact: Low
Maintenance: Medium. One moving part reduces maintenance
Manufacturability: Low.

Key Statistics: English

Developed by: Trident Energy
Source: http://www.tridentenergy.co.uk [2008, 22 August]

2.66 WET-NZ

WET-NZ is a subsurface device that is designed to convert kinetic and potential wave energy. One module has a 500 kW generation capacity. It uses a direct-drive P.T.O and will be deployed in water depths ranging from 20 – 100m.

Classification:

- Near- and offshore point absorber

Feasibility:
Environmental impact: Low
Maintenance: ?
Manufacturability: ?

Key Statistics: New Zealand

Developed by: Wave Energy Technology – New Zealand
Source: http://www.wavenergy.co.nz/home [2008, 22 August]

2.67 OEMP

Picture not available due to patent restrictions

The Ocean Energy Management Project (OEMP) device is a nearshore point absorber WEC. A floatation unit oscillates relative to a fixed reference eliminating the need for complex mooring configurations. The device has the freedom to swivel in the presence of steep waves. It uses a hydraulic P.T.O and is designed for deployment in a water depth of 23m.

<u>Classification:</u>

- Nearshore point absorber

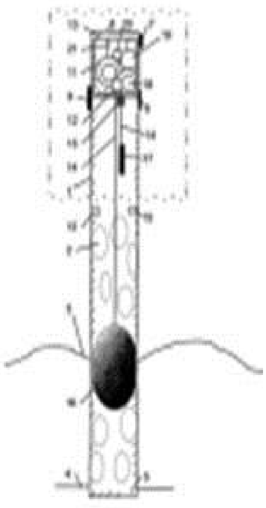
<u>Feasibility:</u>
<u>Environmental impact</u>: Medium. Visual impact due to P.T.O and support structure above water
<u>Maintenance:</u> Medium. Complex swivel mechanism
<u>Manufacturability:</u> Medium.

<u>Key Statistics:</u>

<u>Developed by</u>: OEMP
<u>Source:</u> Mike Houser & Cameron Price

2.68 EGWAP (Electricity generated wave pipe)

The EGWAP is a modular device above sea level.



<u>Classification:</u>

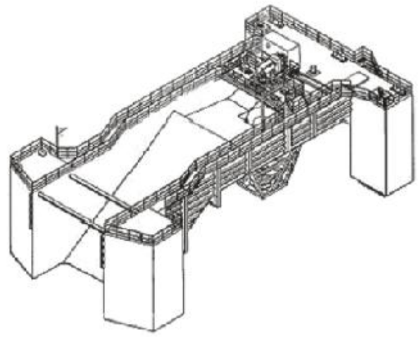
- Nearshore

<u>Feasibility:</u>
<u>Environmental impact</u>: ?
<u>Maintenance:</u> ?
<u>Manufacturability:</u> ?

<u>Key Statistics:</u>

<u>Developed by</u>: Able Technologies L.L.C
<u>Source:</u> http://www.abletechnologiesllc.com/ [2008, 24 August]

2.69 Floating Wave Power Vessel (FWPV), Sea Power, Sweden



FWPV is an overtopping device for offshore operation developed by Sea Power International, Sweden. It consists of a floating basin supported by ballast tanks in four sections. A patented anchor system allows the orientation of the vessel to the most energetic wave direction. A pilot plant has been developed and deployed in the '80s near Stockholm, Sweden while a 1.5 MW vessel is planned to be deployed at 50-80 m depth 500 m offshore Mu Mess, Shetland.

Classification:

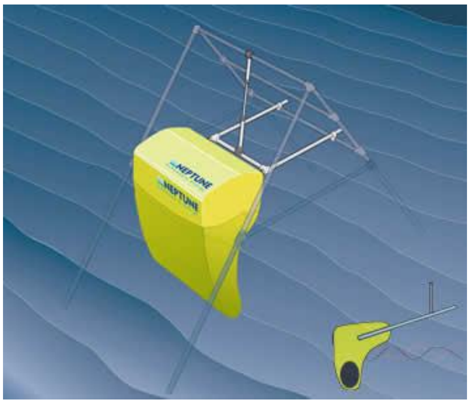
- Offshore overtopping device

Feasibility:
Environmental impact: Medium. Above water floating vessel
Maintenance: Medium.
Manufacturability: Medium.

Key Statistics:

Developed by: Sea Power International
Source:

2.70 Triton, Neptune Renewable Energy Ltd., UK



The device operates in the nearshore and consists of an axi-asymmetrical buoy attached to an A-frame which would be piled into the sea bed. The axi-asymmetrical buoy is designed to generate a counter phase upstream wave and a much reduced downstream wave; this maximises capture from the wave and improves overall efficiency. In order to tune the buoy to the incident wave regime, the mass can be controlled by pumping sea water into and out of the hollow cavity inside the buoy. Power take off is achieved via a piston and hydraulic arrangement.

Classification:

- Nearshore point absorber

Feasibility:
Environmental impact: Low.
Maintenance: Medium. Complex swivel mechanism
Manufacturability: Medium.

Key Statistics:

Developed by: Neptune Renewable Energy
Source:
http://www.neptunerenewableenergy.com/wave_technology.php [2008, 24 August]

2.71 MotorWave

The Motorwave consists out of 70 PVC buoys. Each buoy has a volume of 4 m^3. A MotorWave unit can pump water 50 m high by using wave action to crank a uni-directional gear, like a bike pedal.

Classification:

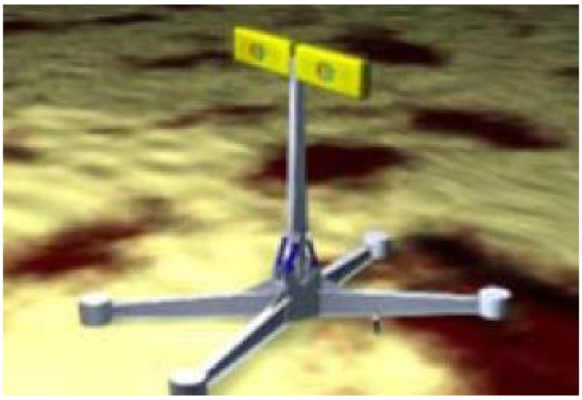
- Attenuator/combined point absorber system

Feasibility:
Environmental impact: Low.
Maintenance: Medium. Device comprise of lots of units that might require maintenance.
Manufacturability: Medium. Simple concept and system

Key Statistics:

Developed by: Lucien Gamborota, Hong Kong University
Source: http://www.motorwavegroup.com/new/wii.html [2008, 3 October]

2.72 EB Front



The EB Front is a small seabed-mounted bottom-hinged WEC. Similar to the WaveRoller, Oyster and Bio-Wave. Converts energy contained in surge as apposed to heave.

Classification:

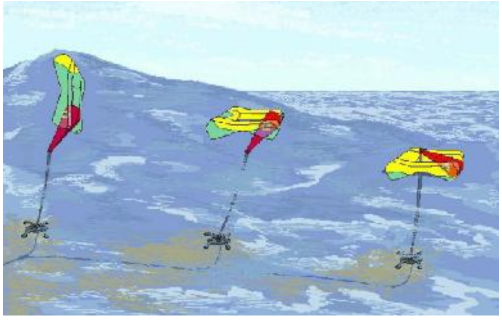
- Point absorber/terminator?
- Near-shore deployment

Feasibility:
Environmental impact: Low.
Maintenance: Medium.
Manufacturability: Medium. Simple concept and system

Key Statistics: Fully submerged

Developed by: Lancaster University and The Engineering Business Ltd.
Source:
*ukerc.rl.ac.uk/pdf/DTI_V06002040000_**EB**_Frond_Phase_2r.pdf*
[2008, 6 October]

2.73 Lever Operated Pivoting Float (LOPF)



LOPF is like a “see saw“ with a heavy generator on one end and the anchor on the other. All sized buoys can operate in all sea conditions beside that with floating ice. Buoys can ne unhooked form mooring for easy maintenance. At present there is 3 different sizes of buoy available ranging from 70 W to 5 kW. Survivability claimed for 15-20 years lifetime of buoy. Concept taken over by Resen Waves. www.ResenWaves.com and email info@ResenWaves.com [Sept 2013]

Classification:

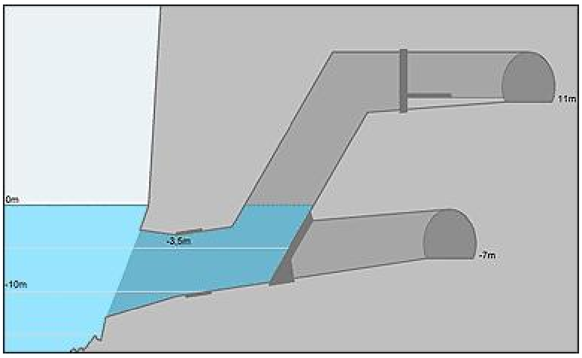
- Point absorber

Feasibility:
Environmental impact: Low.
Maintenance: Medium.
Manufacturability: Medium. Simple concept and system

Key Statistics:

Developed by: SwellFuel Christopher Olson
Source: *http://swellfuel.com/* [2008, 13 October]

2.74 Tunneled WEC, Denmark



SeWave, in cooperation with Wavegen, have developed a novel approach to shoreline OWCs. The system is based on blasting a series of tunnels in a shoreline cliff, which are eventually linked to form a water column. Power take-off will be accomplished using a standard air turbine system. Although significant complications during the blasting are possible, the company believes that the design represents a feasible method of implementing wave power in the Faroe Islands. Several suitable sites have been located, and the company has already completed basic design work and scale model testing [106]

Classification:

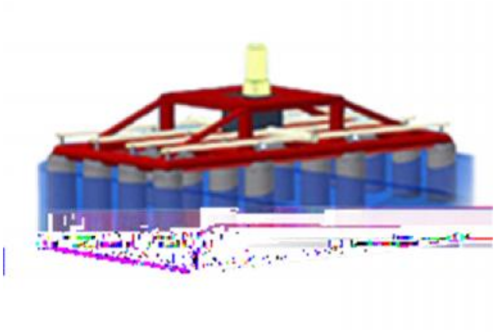
- OWC
- Invisible, soundless

Feasibility:
Environmental impact: High. The device requires extensive blasting.
Maintenance: Medium.
Manufacturability: High. Site specific

Key Statistics: Faroe Islands

Developed by: SeWave Ltd
Source: *http://www.sewave.fo/Default.asp?sida=1256* [2008, 14 October]

2.75 WavePumps



The PSP is a platform consisting of various wave pumps.

Classification:

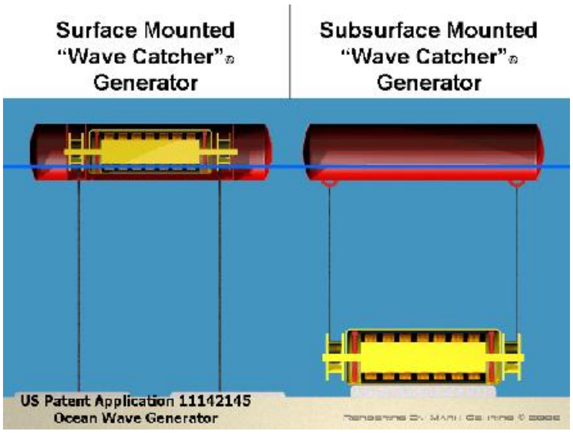
- Array of wavepump point of absorbers

Feasibility:
Environmental impact: Medium.
Maintenance: Medium.
Manufacturability: Medium. Simple concept and system

Key Statistics: Norway

Developed by: OWWE Ltd
Source: *http://www.owwe.net/?o=wavepumps* [2008, 14 October]

2.76 Wave Catcher



The Wave Catcher consist of a long buoyant surface buoy cylinder that is lifted by each passing wave. As the cylinder is lifted it pulls on its anchor lines. The anchor lines in turn pull on their support pulley on which they are wound around. The support pulley is turned by the pulled anchor line which turn the generator's rotor and flywheel. The generator's flywheel keeps the rotor turning until the next wave lifts up the surface and its anchor line once again turns the pulley.

Classification:

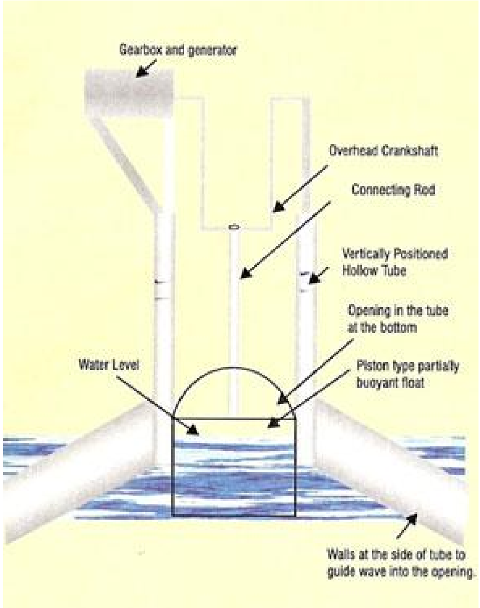
- Point absorber

Feasibility:
Environmental impact: Medium.
Maintenance: Medium.
Manufacturability: Medium. Simple concept and system

Key Statistics: USA

Developed by: Offshore Islands Ltd
Source:
http://www.offshoreislandslimited.com/Ocean_Wave_Generator1
.html [2008, 14 October]

2.77 IWave



It is a floating device tethered with chains to piles driven to ocean bottom. The wave action raises the heavy partially buoyant piston that drives the overhead crankshaft by half turn. The receding wave drops the piston completing the balance half turn. One revolution is obtained for every wave. Using gear box and generator the current is produced continuously.

Classification:

- Point absorber

Feasibility:
Environmental impact: Medium.
Maintenance: Medium.
Manufacturability: Medium.

Key Statistics: India

Developed by: T.SAMPATH KUMAR
Source: *http://waveenergy.nualgi.com/* [2008, 14 October]

2.78 Wave Turbine

Looks like a type of surge WEC.

Classification:

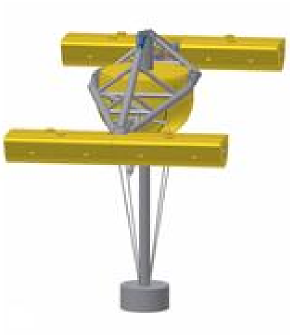
-

Feasibility:
Environmental impact: Medium.
Maintenance: Medium.
Manufacturability: Medium.

Key Statistics: Scotland

Developed by: Green Cat Renewables Ltd
Source:
http://www.greencatrenewables.co.uk/waveenergy.html [2008, 14 Oct]

2.79 Ocean Treader



Classification:

- Point absorber
- 500kW
- 50m long, 20m beam, 20m draft

Key Statistics: Scotland (Aberdeen)

Ocean Treader comprises a Sponson at the front, a Spar Buoy in the center and a second Sponson at the aft end. As the wave passes along the device first the forward Sponson lifts and falls, then the Spar Buoy lifts and falls slightly less and finally the aft Sponson lifts and falls. The relative motion between these three floating bodies is harvested by hydraulic cylinders mounted between the tops of the arms and the Spar Buoy. The cylinders pressurise hydraulic fluid which, after smoothing by accumulators, spins hydraulic motors and then electric generators. The electricity is exported via a cable piggy-backed to the anchor cable. Ocean Treader is directional and has been proven to passively weather-vane to face the wave train, and it also has active onboard adjustment to allow for offset due to the effects of current.

Feasibility:
Environmental impact: Medium.
Maintenance: Medium.
Manufacturability: Medium.

Developed by: Green Ocean Energy Ltd
Source:
http://www.greenoceanenergy.com/index.php/about
[2008, 14 October]

2.80 DEXA WEC

Classification:

- Attenuator

Key Statistics: USA

Based on Cockerell Raft. Consisting of two buoyant pontoons, hinged together, and dampened with a hydraulic power take-off system.

Feasibility:
Environmental impact: Medium.
Maintenance: Medium.
Manufacturability: Medium.

Developed by: DEXA Wave UK Ltd
Source:
http://www.dexawaveenergy.co.uk/index.php?page=1
[2008, 14 October]

2.81 Pico Power Plant, Wave Energy Centre, Azores, Portugal

An OWC power plant, rated at 400kW, was installed on the shoreline of the island of Pico, in the Azores. The plant uses a concrete structure, mounted on the seabed/shoreline, with a Wells turbine used for power takeoff. Originally built in 1995-1999, various problems caused testing of the prototype to stop. Testing resumed in 2005, with much of the original equipment still intact (notably, the generator and turbine), and the plant was connected to the local power grid. Unfortunately, the presence of mechanical resonances in the structure prevented the plant from operating at optimum power levels, limiting it to power production in the 20-70kW range. Efforts to improve the plant are ongoing [103, 104].

Classification:
- Shorebased OWC

Feasibility:
Environmental impact: Medium.
Maintenance: Medium.
Manufacturability: Medium.

Key Statistics: Azores (Portugal)

Developed by: European Commission & Instituto Superior Técnico
Source: http://www.pico-owc.net/
Wave Energy Centre (WavEC)
[2008, 22 October]

2.82 Vizhinjam OWC, India

The Vizhinjam OWC is built around a concrete caisson, which was installed a short distance from a pre-existing breakwater structure. The prototype uses a Wells turbine installed vertically above the column, which is directly coupled to an 110kW induction generator and into the grid. The output was highly variable, from 0-60kW in only a few seconds, and the induction generator frequently had a net consumption of power. Improvements were made to the power system, including the use of a pair of turbines to power the generator; these allowed the device to have more flexibility in adapting to the varying wave conditions. The improved design produced up to 10kW of average power, and research into improved power systems continues [18].

Feasibility:
Environmental impact: Medium.
Maintenance: Medium.
Manufacturability: Medium.

Classification:
- Shorebased OWC

Key Statistics:

Developed by:
Source:
[2008, 22 October]

2.83 Burin Wave power pump, Canada

The Burin Wave Pump is a point absorber type pump. A floating buoy oscillates with the waves, moving against a submerged, damped base and driving seawater through a piston. The main application is direct use of the pumped sweater for aquaculture, but desalination or power generation is also possible. Currently, the device is undergoing small-scale dockside trials.

Classification:

- Point absorber, wavepump

Feasibility:
Environmental impact: Medium.
Maintenance: Medium.
Manufacturability: Medium.

Key Statistics:

Developed by: College of the North Atlantic
Source: http://www.cna.nl.ca/OAR/research.asp#WPP [2008, 22 October]

2.84 Sloped IPS buoy, Edinburgh, UK

The Sloped IPS Buoy is a variation on the IPS buoy that uses a sloped configuration to extract more energy from the waves. The floating buoy has a series of tubes reaching down into the water at a 45 angle, allowing it to oscillate with both the vertical and horizontal movements of the incoming waves. As in the IPS buoy, the movement of the buoy relative to a piston resting in the water column is used to power a hydraulic power take-off system. Basic wave tank tests have been performed on the design.

Classification:

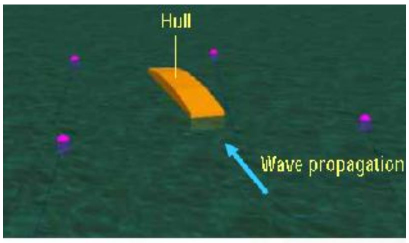
- Point absorber

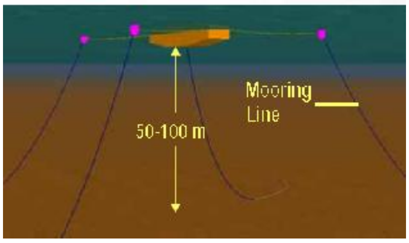
Feasibility:
Environmental impact: Medium.
Maintenance: Medium.
Manufacturability: Medium.

Key Statistics:

Developed by: University of Edinburgh
Source: http://www.cna.nl.ca/OAR/research.asp#WPP [2008, 22 October]

2.85 OCEANTEC, Spain





OCEANTEC is a floating, attenuator WEC developed by Tecnalia, a Spanish-based conglomerate of companies. The device uses a gyroscopic PTO to extract energy from pitch motion. The PTO system is completed encapsulated within the device therefore is no contact with sea water. A 1:4 scale prototype of the device was developed and deployed for sea trials in September 2008.

Classification:

- Attenuator

Feasibility:
Environmental impact: Low.
Maintenance: Medium: Relatively unique PTO
Manufacturability: Medium. Relatively unique PTO

Key Statistics:
Capacity: 500 kW

Developed by: Tecnalia
Source: http://www.wavec.org/index.php/55/wavec-seminar-2008/?PHPSESSID=d2e56b3b75a11d874d1b7608a0e5fdb6 [2009, 29 January]

2.86 Hidroflot S.L, Spain

A Hidroflot unit consists of a platform with 16 floats attached. A 1:6 scale prototype has been build and tested.

Classification:

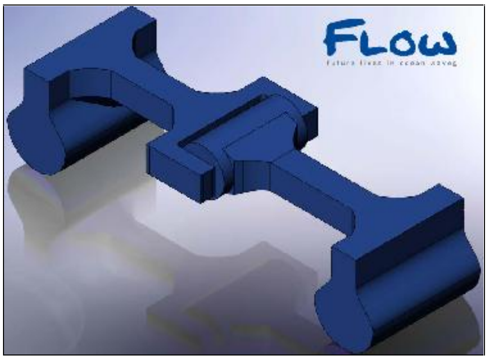
- Multiple point absorber

Feasibility:
Environmental impact: Low.
Maintenance: Medium:
Manufacturability: Medium.

Key Statistics:
Capacity: 6 MW

Developed by: Hidroflot S.L.
Source: http://www.hidroflot.com [2009, 29 January]

2.87 Flow, Portugal



The Flow WEC is a floating attenuator device which consists of articulated cylindrical steel floats connected in a central axis with a 3m diameter hosting the hydraulic PTO.

Classification:

- Attenuator

Feasibility:
Environmental impact: Low.
Maintenance: Medium:
Manufacturability: Medium.

Key Statistics:
Capacity: 1.5 - 2 MW

Developed by: Martifer Energy Systems
Source:
http://www.martifer.pt/EnergySystems/EN/wave/index.html [2009, 29 January]

2.88 Wave Treader, Scotland

The Wave Treader is based on the Ocean Treader device developed by Green Ocean Energy Ltd. The device is mounted to the foundation of an offshore wind turbine thus making it more cost competitive. The device comprises of sponsons mounted on the end of two arms. Hydraulic cylinders are attached between the arms and an interface structure, and as the wave passes along the device the sponsons and arms lift and fall stroking the hydraulic cylinders.

Classification:

- Attenuator
- 50m long, 20m beam

Feasibility:
Environmental impact: Low.
Maintenance: Medium:
Manufacturability: Medium.

Key Statistics:
Capacity: 500 kW

Developed by: Green Ocean Energy Ltd
Source:
http://www.greenoceanenergy.com/index.php/wave-treader#myGallery1-picture(3) [2009, 12 February]

2.89 Navatek Ltd, USA

Navatek Ltd is a naval architecture firm based in Honolulu, Hawaii. They designed a WEC device which converts reciprocating motion into rotary motion which lifts a weight through a system formed of belts and pulleys. Small scale model tests have been performed on an 8 ft prototype in a hydraulic laboratory.

Classification:

- Attenuator

Feasibility:
Environmental impact: Low.
Maintenance: High – lots of moving components:
Manufacturability: Medium.

Key Statistics:
Capacity:

Developed by: Navatek Ltd
Source: http://www.navatekltd.com/waveenergy.html [2009, 20 July]

2.90 Nautilus, Australia

Developed by Queensland Government and IVEC Pty Ltd. Physical model testing has been conducted in the University of Queensland's wave flume. Sea trails? A 50 x 200m unit can generate 2 MW in New Zealand's wave climate.

Classification:

- Attenuator

Feasibility:
Environmental impact: Low.
Maintenance: High – lots of moving components:
Manufacturability: Medium.

Key Statistics:
Capacity:

Developed by: IVEC Pty Ltd
Source: http://www.advancedwavepower.com/ [2009, 24 August]

2.91 Design Wave Energy Transforming Turbine, Georgia

Developed by Tbilisi State University. The device consists of a series of flexible wing reverse actuators connected to a single axis. It is designed to extract energy from the circular motion of water particles.

Contact person: Prof. Nodar Tsivtsivadze,
Head of Fluid Mechanic & Oceanology Laboratory of Tbilisi State University,
Addr. 1. Ilia Chavchavadze avenue, Tbilisi, Georgia.
E.mail:**nluka1@yahoo.com** Phone:+(99532) 22 23 72.

Merab Chirakadze E.mail: m.chiraqadze@yahoo.com

Classification:

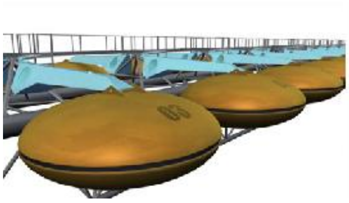
- Attenuator

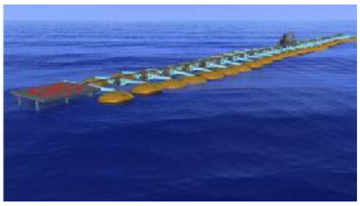
Feasibility:
Environmental impact: Low.
Maintenance: High – lots of moving components:
Manufacturability: Low.

Key Statistics:
Capacity:

Developed by: Tbilisi State University
Source: http://oceanrenewables.ning.com/video/m-z-a-27-05-2010-2 [2010, 22 July]

2.92 Centipod, USA





The Centipod is a floating platform with various floating pods attached to it. (Similar to Wavestar).

Classification:

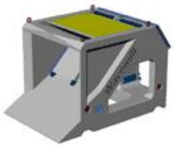
- Attenuator

Feasibility:
Environmental impact: Low.
Maintenance: High – lots of moving components:
Manufacturability: Low.

Key Statistics:
Capacity:

Developed by: Ecomerit Technologies
Source: http://www.ecomerittech.com/centipod.php [2010, 22 July]

2.93 Wavemill, Canada



The Wavemill is designed for nearshore and shoreline applications. The device consists of a curved wall which focuses incoming waves to drive seawater through a hydraulic pump. According to the IEA the pressurised seawater can be used for desalination (20 L/s) or electricity generation (up to 233 kW). Wave tank testing was done in 1998 and a small desalination unit was deployed in Nova Scotia in 2001.

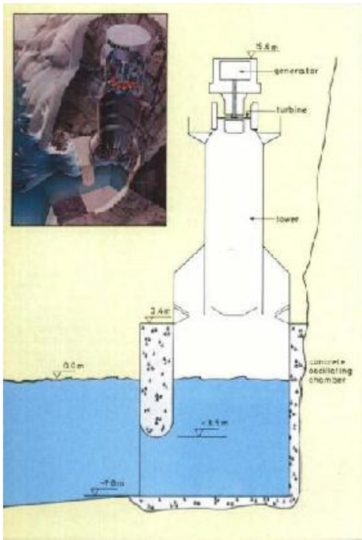
Classification:
- Attenuator

Feasibility: No development in recent times
Environmental impact: Medium (interrupt sedimentation, visual impact).
Maintenance: Medium –
Manufacturability: Medium. Large structure

Key Statistics:
Capacity:

Developed by: Wavemill Energy Corp
Source: IEA:IAOES: Ocean energy: Global technology development status March 2009

2.94 Multiresonant OWC, Norway



Kvaerner Brug's MOWC consists of a hollow concrete chamber with surmounted cylindrical steel tower approximately 10 m tall. The device has a half U-tube shape to promote resonance and uses a Well's turbine.

Classification:
- MOWC

Feasibility: MOWC still being research today
Environmental impact: Medium – shoreline construction
Maintenance: Medium – same as OWC:
Manufacturability: Medium.

Key Statistics:
Capacity: 500kW

Developed by: Kvaerner Brug's
Source:
http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05187462 [2010, 27 July]

2.95 Guangzhou Institute of Energy Conversion (GIEC), China

According to the IEA GIEC has been researching shoreline, concrete OWC systems since 1985. Their first device was rated at 1kW and was followed by a 20 kW system. In 2001 a 100 kW demonstration plant was deployed in the Guangdong Province and was grid connected for 2 years. GIEC also developed 5 kW floating, offshore OWC called a backward bent duck buoy.

Feasibility: OWC still being research today
Environmental impact: Medium – shoreline construction
Maintenance: Medium – same as OWC:
Manufacturability: Medium.

Classification:
- OWC

Key Statistics:
Capacity: 100kW

Developed by: GIEC
Source: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V4S
3&_user=613892&_coverDate=10%2F31%2F2009&_rdoc=1&_fmt=high&_orig
[2010, 27 July]

2.96 Onshore oscillating buoy, China

GIEC also developed a floating buoy device connected to the shore by a supporting structure. It has a hydraulic PTO and uses a hydraulic reservoir which allows for relatively stable power output.

Classification:
- MOWC

Feasibility: Heaving buoys still being research today
Environmental impact: High: shoreline, visual
Maintenance: Medium –
Manufacturability: Medium.

Key Statistics:

Capacity: 400kW, max average output of 50kW

Developed by: ***Guangzhou Institute of Energy Conversion (GIEC)***
Source: www.oreg.ca/docs/May%20Symposium/Liang.pdf
[2010, 27 July]

2.97 Sanze shoreline gully, Japan

In 1983 the Sanze shoreline gully was constructed. It is a 40 kW shoreline OWC consisting of steel and concrete. It functioned for several years before it was decommissioned and inspected for corrosion and fatigue.

Classification:

- OWC

Feasibility: OWC still being research today
Environmental impact: High: shoreline, visual
Maintenance: Medium –
Manufacturability: Medium.

Key Statistics:
Capacity: 40kW

Developed by:
Source:
http://www.et.teiath.gr/creta/Library/html/body_wavpost3.html
[2010, 27 July]

2.98 Isle of Islay, Scotland

A 75 kW demonstration OWC was designed by the Queen's University of Belfast in 1985 for a small gully close to the village of Portnahaven on the Isle of Islay. Device construction started on site in the summer of 1987 and it was grid connected in 1991.

Classification:

- OWC

Feasibility: OWC still being research today
Environmental impact: High: shoreline, visual
Maintenance: Medium –
Manufacturability: Medium.

Key Statistics:
Capacity: 75 kW

Developed by: Queen's University of Belfast
Source:
http://www.aislingmagazine.com/aislingmagazine/articles/TAM17/Wave.html

[2010, 28 July]

2.99 Osprey, UK

Osprey is a 2 MW nearshore OWC steel structure device. During deployment the device was destroyed before it could be secured to the sea floor.

Classification:

- Nearshore OWC

Feasibility: OWC still being research today
Environmental impact: Medium: visual
Maintenance: Medium –
Manufacturability: Medium.

Key Statistics:
Capacity: 2 MW

Developed by: Wavegen
Source: IEA:IAOES: Ocean energy: Global technology development status March 2009

2.100 Sakata, Japan

In Sakata Japan a breakwater OWC was build in 1988 and operated until 1991. It was 20 m wide in 18 m water depth.

Classification:

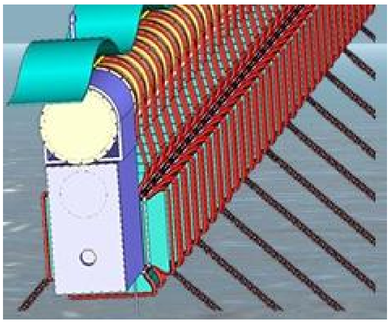
- Nearshore OWC

Feasibility: OWC still being research today
Environmental impact: Low: build in industrial harbour
Maintenance: Medium –
Manufacturability: Medium.

Key Statistics: 60kW
Capacity: 60 kW

Developed by: Ministry of Transport
Source: http://www.uni-leipzig.de/~grw/lit/texte_099/26__1994/26_1994_breakwater.htm

2.101 Etymol, Chile



Etymol is an offshore, submerged device which utitlises the pressure differential of passing waves.

Classification:

- Nearshore OWC

Feasibility: Not much is known
Environmental impact: Low: subsurface
Maintenance: Medium –
Manufacturability: Medium.

Key Statistics:
Capacity: 60 kW

Developed by: F-Tec Ingenieria Ltd
Source: http://www.etymol.com/A__UK_0100.aspx [2010, 28 July]

2.102 Seaheart, Spain

Classification:

-

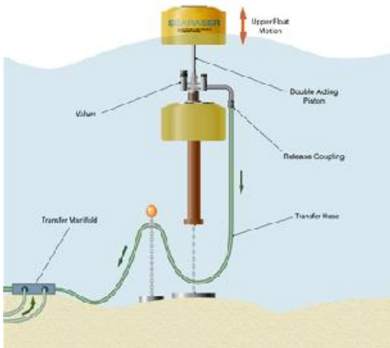
Feasibility: Not much is known
Environmental impact: Low: subsurface
Maintenance: Medium –
Manufacturability: Medium.

Key Statistics:
Capacity:

Developed by: Oceanic Power
Source:

2.103 Searaser, UK

Searaser is buoy type device consisting of top float, double acting piston, reactor float and single point mooring. The device pumps high pressure seawater which can be stored in a reservoir (50m head has been achieved). During sea trails in April 2009 the prototype 83 delivered 0.77kW of power. Similar to CETO and Seadog.



Classification:

- Offshore buoy pump
- Storage possible

Feasibility: High:
Environmental impact: Low
Maintenance: Medium – Lots of moving parts
Manufacturability: Medium.

Key Statistics:
Capacity:

Developed by: Dartmouth Wave Energy Ltd
Source: http://dartmouthwaveenergy.com/index.html [2010, 6 September]

2.104 WEGA, Portugal

The WEGA device is an articulated suspended body, semi-submerged, attached to a mount structure, which oscillates in an elliptical orbit with the passage of waves. The PTO is located on mount structure above water reducing exposure to the corrosive environment and easing accessibility for maintenance.

The movement of the body drives a hydraulic cylinder which pushes high pressure fluid through an accumulator and an hydraulic motor, driving the generator that produces energy. The articulated body attaches to the mount structure through a rotary head which allows it to adapt to the direction wave propagation.
Multiple devices can be placed on a single mount structure according to the size and place of the structure.

Classification:

- Point absorber

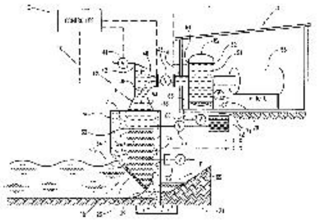
Feasibility: High:
Environmental impact: Low
Maintenance: Low – PTO above water
Manufacturability: Medium.

Key Statistics: Can be combined with offshore wind structure
Capacity:

Developed by: Sea for Life

Source: http://www.seaforlife.com/EN/index2.html [2010, 13 October]

2.105 Ovadia, Israel



The WEC consists of wave focusing walls built into a breakwater. Incident waves force water through a two-way valve into a water reservoir. When further wave energy enters the system oscillations in the reservoir is transmitted to an oil reservoir via a membrane. Oscillations in the oil reservoir drives and motor and electricity is generated.

Classification:

- OWC

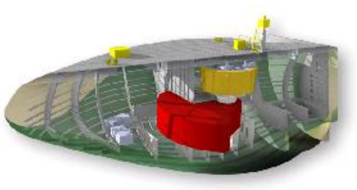
Feasibility: Medium:
Environmental impact: Medium
Maintenance: High – Complex system
Manufacturability: Medium.

Key Statistics: Built into a breakwater
Capacity:

Developed by: Shmuel Ovadia in 1995

Source: http://www.freepatentsonline.com/5461862.pdf [2011, 17 January]

2.106 Wello/The Penguin, Finland



The Penguin is a floating device, weighing 1600 tons, 30 m long with three point mooring. Extends 2 m above water surface. Utilises wave's orbital velocity to spin flywheel connected to electric generator. Sea trails 20 June 2011 at EMEC.

Classification:

- Floating

Feasibility: Medium:
Environmental impact: Medium
Maintenance: High – Complex system
Manufacturability: Medium.

Key Statistics:
Capacity: 0.5 – 1MW

Developed by: Wello
Source: http://www.wello.fi/penguin.php [2011, 16 November]

2.107 SeaRay – Columbia Power Technologies Oregon

SeaRay is a two linkage attenuator. The PTO is linear permanent magnet.

In its simplest form, there are two wings, forward and aft, and a cell in between. Each wing is directly connected to a generator and each wing and cell move independently.

Classification:

- Floating two linkage attenuator
- Development stage, modular proof of concept (4kW?).

Feasibility: Medium:
Environmental impact: Low
Maintenance: Medium, moving parts not easily accesed in operational mode.
Manufacturability: Good.

Key Statistics: **Attenuator**
Capacity: 1 MW

Developed by: Columbia Power Technologies
Source: http://www.columbiapwr.com [2012, 16 July]

2.108 Vigor, Sweden

The WEC is a flexible hose that is designed to span several wave periods. The hose has a water and air intake at one end and is connected to a 'power module' at the other end. The higher pressure wave crests progress from the hose inlet to its' outlet moving the trapped water and air in front of the crest towards the outlet similar to a screw effect..

In the power module the compressed air and water is released to the lower pressure water via a hydro turbine that is connected to a generator.

Classification:

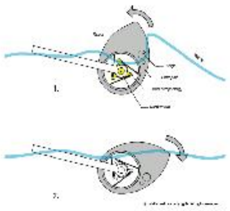
- At waterline with a hydro turbine PTO system.
- Development stage: Numerical simulations and Demonstration of concept in 50m basin.

Feasibility: Low. High R&D cost to develop flexing material.
Environmental impact: Low. The system will have very little impact on marine life.
Maintenance: Medium. Power unit with turbine is immersed in water.
Manufacturability: High. It will be a large structure (large investments needed).

Key Statistics: Flexible hose water pump
Generation capacity: 12 MW
Size: 200m long; water intake (front)
Unit cost: ~
Total cost: ~

Developed by: Vigor Wave Energy ab
Source: http:// www.vigorwaveenergy.com [2012, 23 July].

2.109 Weptos, Denmark



Weptos is composed of a V structure that faces into the oncoming waves. On the side of the V structure, Salter ducks span the length and are the primary wave energy converters. The inside of the ducks work on a ratchet mechanism that transfers the wave energy to a common axle.

A distinct advantage is the adjustable inside angle of the V structure that allows it to determine how much wave energy can be absorbed.

Classification:

- Floating
- Proof of concept, 1:8 scale test. 7m 'legs', 20 rotors.

Feasibility: Medium:
Environmental impact: Medium
Maintenance: High – Complex system
Manufacturability: Medium.

Key Statistics:
Capacity: 1MW

Developed by: Wello
Source: http://www.wello.fi/penguin.php [2011, 16 November]

2.110 Squid, Scotland

Once on site, an inflatable absorber that looks like a large balloon is filled with water. Sitting just under the surface, the absorber is moved by passing waves – and the energy from this motion drives a generator to produce electricity.

Classification:

- Floating

Feasibility: (No information available)
Environmental impact: (No information available)
Maintenance: (No information available)
Manufacturability: (No information available)

Key Statistics: Small scale deployment targeted.
Capacity: 10 kW

Developed by: AlbaTERN

Source: http://www.albatern.co.uk [2012, 16 July]

2.111 AquaGen SurgeDrive, Australia

As waves pass the buoyancy units of a SurgeDrive wave farm, they move in oscillation and the system transfers the pure wave forces out of the water, via tension transfer elements. From there, the energy conversion module is able to use these forces to generate electricity or desalinated water, using an innovative mixture of design and 'off the shelf' components. This dramatically simplifies the capture of wave energy because most components are above water and underwater components are minimised and simplified. This leads to a significant reduction in capital expenditure (less expensive, corrosion resistant materials required), maintenance (hence lower electrical / desal generation costs) whilst also enabling the flexibility for the system to not only survive storms but to continue to generate during them.

Classification:

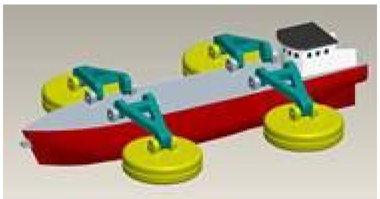
- Above waterline WEC using a mechanical to electrical PTO system.
- Far off shore (5-20 km).
- Development stage: concept.

Key Statistics:

- Unknown

Feasibility:
Environmental impact: High. Large amount of moorings in a wave farm.
Maintenance: Medium. It has few moving parts and it is below the surface, limiting the impact of storms.
Manufacturability: Medium. It doesn't have a complex structure, but it will not have a high efficiency. Therefore it will require a lot of modules.
Invented by: AquaGen Technologies
Source: http:// http://www.aquagen.com.au/ [2012, 22 July].

2.112 Mobile wave energy harvester, USA



Mobile wave energy harvester proposed by Fraunhofer Center for Manufacturing Innovation. The vessel contains a PTO system (most likely hydraulic) and banks of batteries. Wave energy is captured by pontoons attached by lever arms to the ship. Vessel must travel from the low energy area of the port to an area of higher energy to feed generated power into grid. This mobility increases survivability, but also fuel costs. Sailing crew inactive during times of energy capture.

Classification:

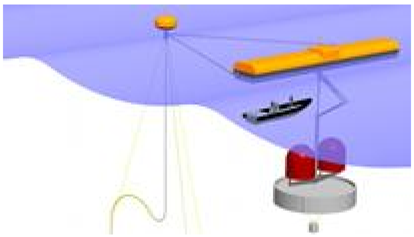
- Floating

Key Statistics:

Feasibility: Medium:
Environmental impact: Small
Maintenance: High –moving parts, PTO and lots of batteries
Manufacturability: Medium.

Developed by: Fraunhofer USA
Source: http://www.fhcmi.org/Projects/02.html [2012, 27 July]

2.113 Intentium offshore wave energy converter, Norway



The system consists of a float, double acting pump, buoyancy controlled water anchor and PTO consisting in accumulator, water turbine and generator. 1:30 scale tests conducted in their home made wave tank. WAMIT model of float developed by Marintek in Sintef.

Classification:

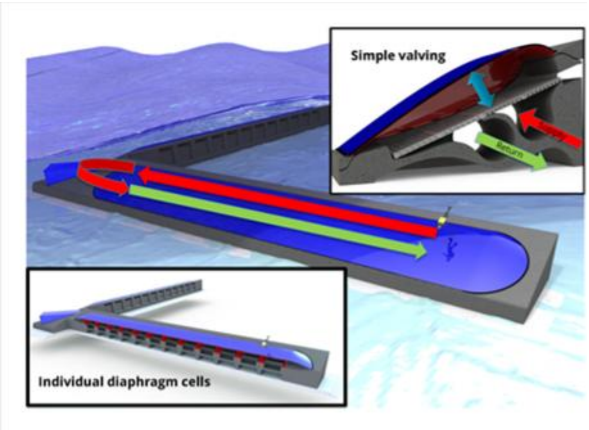
- Wavepump

Feasibility: Medium: Various wave pump devices
Environmental impact: Medium
Maintenance: Medium
Manufacturability: Medium.

Key Statistics:

Developed by: Intentium Norway
Source: http://www.intentium.com/concept/index.html [2012, 30 July]

2.114 Bombora, Australia



Bombora is similar in design as the SWEC with the distinct difference of having a flexible membrane that pumps and sucks air locked in the caisson chambers.

The system typically operates in water depths of 5 – 15 m and has a natural storm protection characteristic by being seabed mounted. Similar to the SWEC the multi chamber arrangement allows for air flow rectifying due to a high and low pressure duct and control valves. At this stage the design uses a directional low pressure turbine turbine.

Classification:

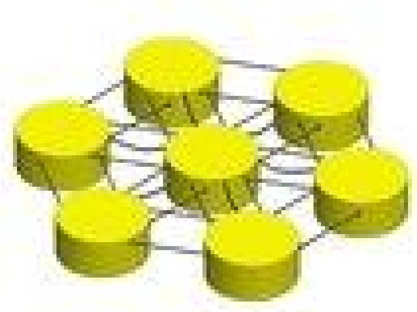
- Bottom mounted WEC with Low – pressure air turbine.
- Near shore 5 – 15 m depth.
- Proof of concept, TRL 3 level.

Environmental impact: Medium. The device requires a relatively large structure that will occupy the seabed. However it has no moving parts that interfere with marine life.
Maintenance: Medium. Sand will accumulate near the base of the structure that will have to be removed. The large amount of valves will require more maintenance. The durability of the flexible membrane and time degradation is awaiting reliability results.
Manufacturability: Medium. The device requires a lot of underwater installation which is quite expensive.

Key Statistics:
Capacity: 1.5 MW

Developed by: Bombora
Source: http://www.bomborawavepower.com.au [2012, 20 October]

2.115 Vert Labs, Scotland



VERT's wave energy converter transforms kinetic energy of ocean waves into pneumatic energy in the form of compressed air, and then transfers compressed air to the turbine and electric generator. Each Energy Capture module ('CELL') has rated power of 35kW (on wave height H=2m, period T=4s). A CELL takes more energy from the sea, but after accounting for all losses a user receives 35kW from electric generator. The system is scalable to meet the needs of specific application: by adjoining several cells the power output can be increased (3 cells = 105kW).

Every CELL consists of 7 buoyant floats, each of them has pneumatic compressors inside. Floats are connected by lever arms that drive compressors when the waves impact the adjacent floats. Compressed air is collected from compressors into pneumatic pipes with non-return valves that join into a bigger pneumatic pipe that transports air with minimal losses of 3.1% per 1 km. Compressed air is then stored or converted directly to electricity on a platform using a standard turbine and a generator.

Classification:

- Floats mounted with mushroom anchors to seabed floor
- VERT's device can be applied in any marine conditions on the waves of 1.5-2 meters or more

Key Statistics:

Capacity: 35 kW (each cell)

- High stability of output - provides full rated power 50-60% of the year

Environmental impact: Medium, this visual impact of these devices may be cause a problem.

Maintenance: Medium. Easy access since devices are floating , however the connection and piping which leads the compressed air to the turbine will require significant maintenance

Manufacturability: device can be expanded as needed, for separate cells can be added to the array as needed thus the size of the installation is determined by size of the project.

Developed by: Vert labs

Source: http://www.vertlabs.org [2013, 19 February]

2.116 Gyro-Wave_gen

A gyro-wave energy transducer is mounted on the buoyant body for translating the pendulum-like motions of the buoyant body into rotational motion. The gyro-wave energy transducer includes a gimbal comprised of first and second frames, with the first frame being pivotally mounted to the second frame and the second frame being pivotally mounted to the buoyant body. A gyroscope is mounted to the first frame for rotation about an axis perpendicular to the axes of rotation of the first and second frames. A motor/generator is coupled to the gyroscope for maintaining a controlled rotational velocity for the gyroscope. Transferring members are associated with one of the first and second frames for transferring torque of one of the first and second frames to the gyroscope about an axis that is perpendicular to that of the gyroscope which results in rotation of the other of the first and second frames. An electrical generator is responsive to the relative rotational movement of the first and second frames for generating electrical energy. A storage battery is mounted on the buoyant body for storing and releasing electrical energy and is operatively coupled to the motor/generator and the electrical generator. A control circuit is associated with the generator and the motor/generator unit of the gyroscope and is responsive to the time rate of change of current produced by the generator for controlling the rotational velocity of the gyroscope in order to maintain maximum power output from the electrical generator.

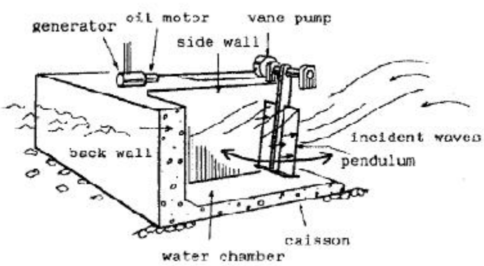
Classification:
Moored by two point catenary mooring
Small scale testing done to date

Environmental impact: Medium
Maintenance: Medium
Manufacturability: Medium

Key Statistics:

Developed by: GyroWaveGen

2.117 Pendulor



The Pendulor consists of a pendulum and a large vane pump placed on the pendulum shaft as a part of it. Incident waves become standing waves in the water chamber of which water flows to be reciprocally at the node. The pendulum is driven by the flow and the pendular motion drives a generator via the pump and two oil motors combination.

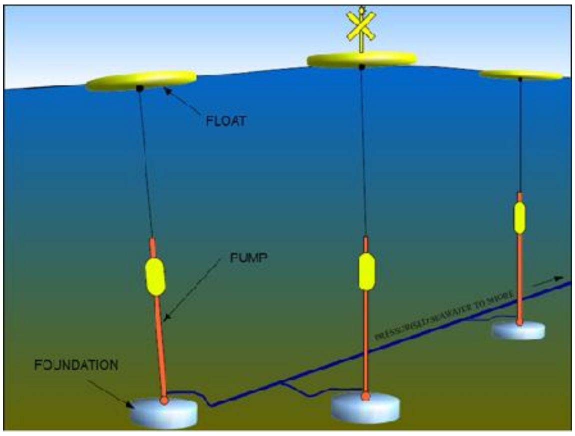
Classification:
Shore mounted

Key Statistics:

Efficiency between 40 to 60 %

Environmental impact: Medium
Maintenance: Medium
Manufacturability: Medium
Developed by: Muroran Institute of Technology, Harbor Research Centre
Source:
http://www.isope.org/publications/proceedings/ISOPE/ISOPE1999/papers/I99v1p133.pdf

2.118 Seatricity



A float travels up and down with the waves and operates a pump to pressurise sea water which is piped ashore. Many individual pumps are connected together to produce substantial amounts of pressurised water.

Once ashore the pressurised sea water is used to drive a standard hydroelectric turbine to produce electricity.

This pressurised sea water can also be used for directly producing fresh water by the reverse osmosis desalination process. Both fresh water and electricity can be produced simultaneously

Classification:
- Floats mounted to seabed floor
- Full plant demonstration in Orkney, UK

Key Statistics:
Capacity:

Environmental impact: Medium
Maintenance: Medium, easy to service and access
Manufacturability: Good, inexpensive to manufacture
Developed by: Seatricity
Source: http://www.seatricity.net [2013, 19 February]

2.119 EB Frond

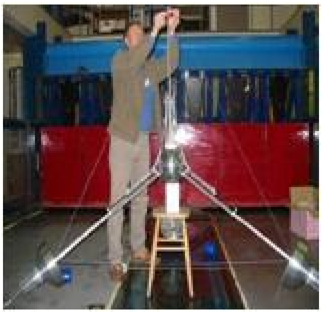
EB Frond is a wave generator with a collector vane at the top of an arm pivoted near the seabed. The arm oscillates and is driven by the water motion in the waves. The pendulum motion can be tuned to the dominant frequency of the waves. Hydraulic cylinders connect the arm and a structure which delivers high pressure oil to a hydraulic motor connected to an electrical generator. The afore mentioned structure is mounted to the seabed in a nearshore location and remains submerged at all times.

Classification:
- Development stage

Key Statistics:
Capacity: 263kW

Environmental impact: ?
Maintenance: ?
Manufacturability: ?
Developed by: Lancaster University
Source:
http://ukerc.rl.ac.uk/pdf/DTI_V06002040000_EB_Frond_Phase_2r.pdf

2.120 TETRON



The TETRON device utilizes both the heave and surge motion of the waves. The TETRON device uses an immersed sphere at the centroid of a tetrahedron cable-stayed structure with double-acting, tube-pump, power take-off in telescopic struts; a Pelton turbine; and an electric generator. Very little information published on this device.

Classification:

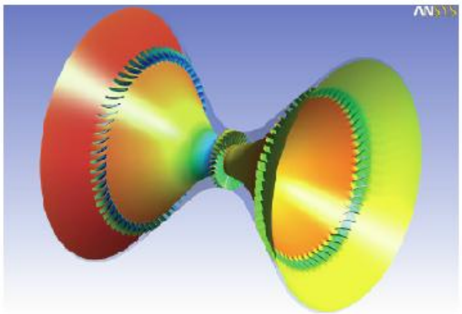
- Point Absorber
- Scaled prototype only wave tank tested

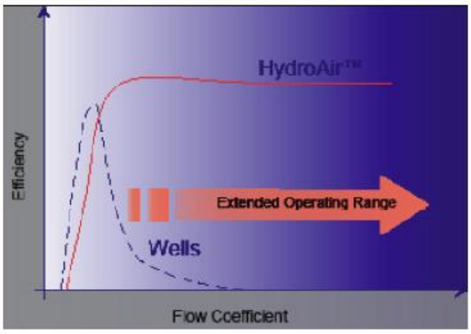
Key Statistics:

Capacity:

Environmental impact: ?
Maintenance: ?
Manufacturability: ?
Developed by: Joules Energy Efficient Services Ltd, Ireland
Source:
http://www1.eere.energy.gov/water/hydrokinetic/information.aspx?type=tech&id=012d6bc8-4cf8-43fc-aaab-a20cb491b7a0

2.121 HydroAir





OWC concept with specialized turbine. The HydroAir turbine is a variable radius turbine and comprises two sets of static guide vanes located on either side and at a larger diameter than that of the rotor. These vanes are connected by a shaped duct to provide a route for the airflow. Air enters the duct at a relatively low velocity and acquires a swirl motion as it passes through the inlet guide vanes. The air then accelerates as it passes down the narrowing duct toward the turbine rotor. The air drives the rotor, and then decelerates as it travels back through the expanding duct before passing over the outlet guide vanes. The process is repeated (in reverse) for the next wave cycle. The efficiency of the HydroAir turbine is considerably higher than the Wells turbine.

Classification:

- OWC

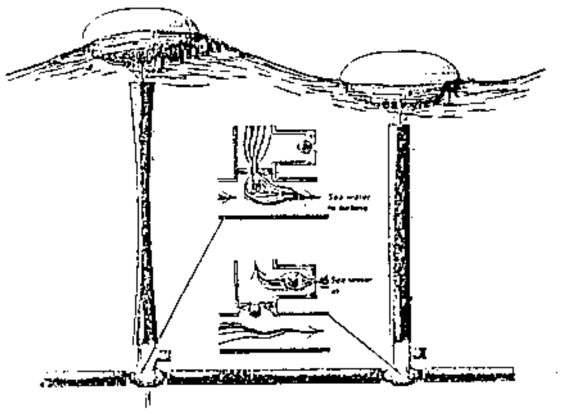
Key Statistics:

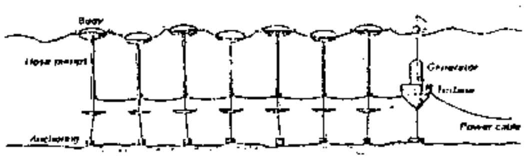
Capacity:

- 500kW

Environmental impact: ?
Maintenance: ?
Manufacturability: ?
Developed by: Dresser Rand
Source: http://www.dresser-rand.com/literature/general/2210_HydroAir.pdf

2.122 Swedish Hose-Pump





The Swedes use a hose pump, which is inserted between the float and a large damper disk, which is slack anchored to the seabed. When the waves lift the float, the hose is lengthened, and its volume is reduced. Hereby the water is pressed out and accumulated in a hose, that transport water from several pumps to a joint high pressure water turbine. When the wave lowers the float, the hose turns back to its original volume, and sea water is drawn in through valves.

Classification:

- Point absorber

Key Statistics:

Capacity:

Environmental impact: ?

Maintenance: ?

Manufacturability:?

Developed by:

Source:

http://www.ces.iisc.ernet.in/energy/paper/SEHandbook/wavepower.html

2.123 Danish Wave Energy Power Float Pump

The wave power converter consist of a float 2.5 meter in diameter, connected by a rope to a seabed mounted piston pump, installed on 25 meter deep water 2,5 km from shore. The converter is designed to absorb an average maximum power of 1 kW.

Classification:

- Point absorber

Key Statistics:

Capacity:

- 140kW

Environmental impact: medium

Maintenance: high

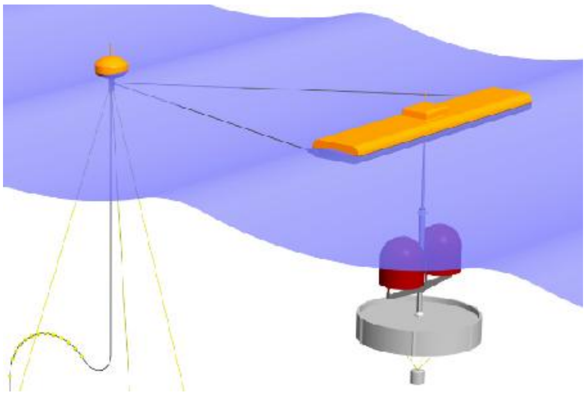
Manufacturability: medium

Developed by: Danish Wave Power (DWP)

Source:

http://www.waveenergy.dk/files/hanstholmfase2B.pdf

2.124 IOWEP: Intentium offshore wave energy project



The focus of the device is on the dominant wave direction and wave crest length by use of a wider float, the use of a double acting pump, a buoyancy controlled water anchor and a PTO consisting of accumulator, water turbine and generator. Using a wider stabilized float, results in a wider wavefront being captured and hence more energy being harvested. The PTO has hydro-power similarities, and is disconnected from the moorings.

Classification:

- Development Stage

Key Statistics:

Capacity:

Environmental impact:

Maintenance: high

Manufacturability: medium

Developed by: MARINET

Source: http://openwaveenergy.org/open-wave-energy-projects.html#owep_project

2.125 Bolt Lifesaver device

"Lifesaver" is a point absorber Wave Energy Converter (WEC),consisting of:

- Up to five independently operating power take-off units (PTO), each moored independently to the sea bed. During the trials at FabTest three PTOs will be used. Each PTO has an installed (nameplate) capacity of 80 kW.
- An all-electric power conversion system
- A patented drive train solution

"Lifesaver" 's iconic hull design provides buoyancy and water displacement and has 10m inner diameter, 16m outer diameter and 1m depth – which at that size increases the contribution of energy produced from roll and pitch motion yet limiting the weight and cost of the floater. The low profile of "Lifesaver" 's hull reduces the undesired drag forces, enables controlled movements to reduce the peak loads of high impulse sea forces during more aggressive sea states and reduces any cumulative visual impact of a collection of devices. The circular '"Lifesaver" ' shape reduces unwanted yaw, sway and surge motion.

Classification:

- Full scale sea testing trails

Key Statistics:

Capacity:

Depends on number of PTO's on the device, each PTO has the capacity of 80kW. 3 to 5 PTO's will be placed on the device.

Environmental impact: medium

Maintenance: medium

Manufacturability: good

Developed by: Bolt Wave Energy

Source: http://www.boltwavepower.com

2.126 Hyperbaric Coppe UFRJ device

Also see
http://www.youtube.com/watch?v=GA_UgVm9bvU

Plant made up of modules which allows for plants capacity expansion. Each module consists of 10 m diameter buoy, 22 m long mechanic arm and a pump connected to a closed circuit of fresh water. The buoy's alternating movement moves the arm with it which activates the hydraulic pump. The hydraulic pump through a closed circuit injects fresh water kept on a high pressure system formed by a hydropneumatic accumulator and hyperbaric chamber. Pressures of the water stream which turns the turbine match those of a large hydro plant.

Classification:

- Full scale sea testing
- Attenuator

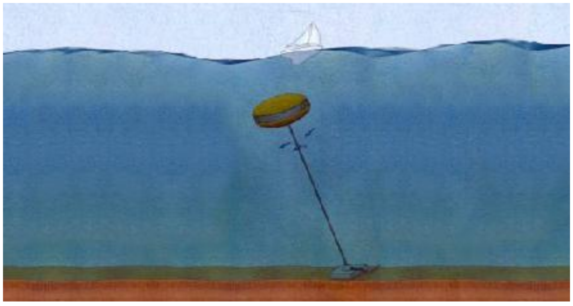
Key Statistics:

Capacity:

Environmental impact: medium
Maintenance: medium
Manufacturability: good

Developed by: Coppe Federal University of Rio de Janeiro
Source: http://www.boltwavepower.com

2.127 Eel Grass



AeroVironment has developed an innovative device for harnessing the ocean's energy. Anchored to the sea floor and floating beneath the surface, its turbine generates clean energy as the float moves horizontally through the water, responding to pressure changes from passing waves. Unobtrusive, silent and reliable, it is an attractive alternative to other ocean-energy devices. Again very little explanation of the device given.

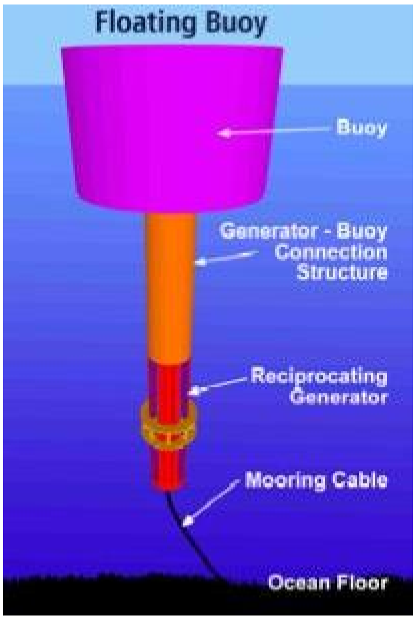
Classification:

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:

Developed by: Aero Vironment Inc
Source:
http://www.avinc.com/engineering/marine_energy

2.128 Electric Buoy



Electric Buoy - The Generator housing moves up and down with the motion of the Buoy on the ocean's surface while the Damping Plates hold the Generator Coil in a stable position. The relative motion between the magnetic field in the generator housing and Generator Coil creates an electric voltage in the Generator Coil.

Platform Generators - In the platform configuration the generators sit on a platform and buoy floats move the generator's coil up and down as waves and swell pass underneath.

Classification:

Key Statistics:

Capacity:

with a 15 meter buoy with AMI's generator can create between 145 and 330 KW in a 2 meter swells

Environmental impact:

Maintenance:

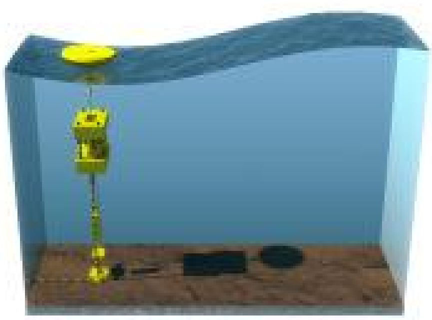
Manufacturability:

Developed by: Aqua-Magnetics Inc

Source:

http://www.amioceanpower.com/home.html

2.129 Akervoll-patents



Bases on the floating-absorber principle. It consists of :

- absorbers on the surface which follow the movement of the waves;
- running rod or flexible drive line which transfers the power generation from the absorber to the main module;
- the main module which contains a buoyancy element, transmission/gear generator and it is placed 30-50 m below sea level;
- tension leg between the main module and anchoring system keeps the device in place;
- a weight is used as a counter-weight when the wave lowers the absorber;
- anchoring system which combined with the tension legs keep the main module in a fixed position subsea

Classification:

Key Statistics:

Environmental impact:

Maintenance:

Manufacturability:

Developed by: Euro Wave Energy

Source: http://www.eurowaveenergy.com/

2.130 Syphon wave generator

Classification:

Key Statistics:
Capacity:

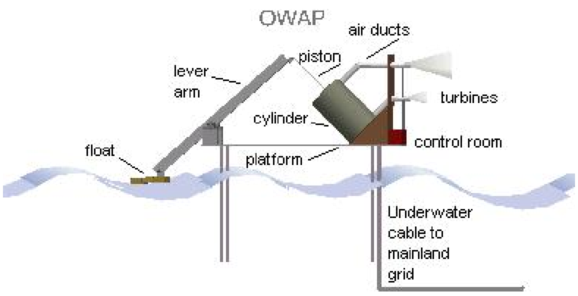
The syphon wave generator comprises: a horizontal pipe with one or more pipes at each end extending down below the water surface, a turbine and generator mounted inside the horizontal pipe and a means for filling the unit with water. The waves passing under the unit cause different water levels at different pipes creating a siphon. The water siphoning across the horizontal pipe spins the turbine and generator to create electricity

Disclosed is a syphon wave generator for generating electric power from a wave-driven water body in a fast, easy, inexpensive and efficient manner such that the unit has few moving part, is very inexpensive to build and maintain and can withstand storms.

Environmental impact:
Maintenance:
Manufacturability:

Developed by: GEdwardCook
Source: http://www.gedwardcook.com/

2.131 Ocean Wave Air Piston



Classification:

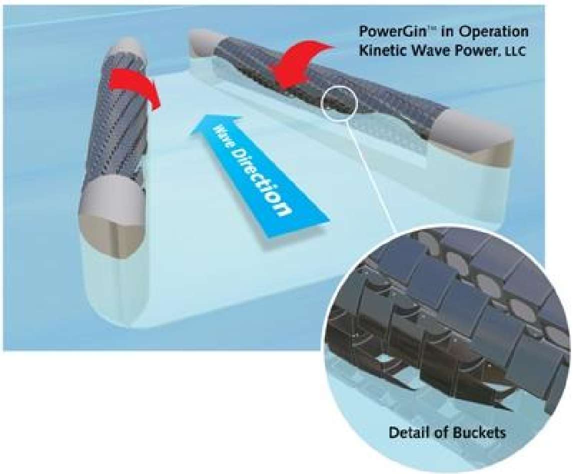
Key Statistics:
Capacity:

The OWAP is a point absorber wave energy converter (WEC) using an oscillating air column to drive the electricity producing part of the device. As ocean waves pass through the float area, the float rises and falls pushing a piston through a cylinder filled only with air. As the piston drives the air first down then back up it pushes air through a bi-directional air turbine on the bottom of the cylinder then through a bi-directional air turbine on the top of the cylinder. Electricity is produced by both turbines. This electricity is then sent to the mainland via an underwater cable.

Environmental impact:
Maintenance:
Manufacturability:

Developed by: Green Ocean Wave Energy
Source:
http://greenoceanwaveenergy.com/technology%203.html

2.132 PowerGin



A typical PowerGin™ has rotors that are 80 - 100 feet long and 10 feet in diameter. The size is somewhat dictated by the wave period and energy output specification. Wave energy is focused by the wave ramp and the rotors and is funneled into the "buckets" called energy capture units on the ramp side of the rotor. In the case of smaller wave states; the water moving up the wave ramp artificially becomes a larger wave and crests to help fill the buckets. The buckets are mounted in a dense spiral pattern around the perimeter similar to hydro electric turbine blades which provide a high surface area to catch wave energy. As the buckets on the ramp side of the rotor fill with wave water, the rotors begin to turn. Water is emptied out of the bucket instantaneously when it is submerged under the water by a patented gravity driven flap on the bottom. The flap slams shut in one direction and opens in the other. The two rotors rotate in opposite directions which maintain balance and continuous rotary power flow.

The cones located on each end of the rotors house the power take off equipment. During rough seas the PowerGin™ will continue to make electricity until the waves become too rough and the wave ramp will draft the device under water to protect it from damage.

Classification:

Key Statistics:
Capacity:
20 MW per PowerGin

Environmental impact:
Maintenance:
Manufacturability:

Developed by: Kinetic WavePower
Source:
http://www.kineticwavepower.com/tech.html

2.133 Nodding Beam

Nodding Beam = Power is a wave energy conversion system that utilizes the simple concept of a nodding beam, typically used to pump oil, and linear generators that are mounted on a robust concrete barge to convert energy directly from ocean waves into electricity.

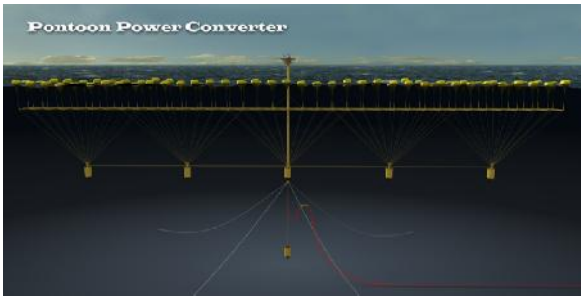
Classification:

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:

Developed by: Nodding Beam = Power Limited
Source: http://www.noddingbeam.com/wave-power-technology

2.134 Pontoon Power Convertor



The Pontoon Power Converter (PPC) is a floating wave energy converter based on working pontoons, hydraulic pumping cylinders, hydroelectric turbine and generator mounted on a patent pending ballasting and load-bearing structure, with slack moorings suitable for a wide range of water depths and many offshore locations.
Designed to protect against extreme conditions, pontoons submerge prior to storm.

Classification:
Scaled Prototype stage, design problems found with fatigue of design

Key Statistics:
Capacity:
15-20 MW per turbine/generator

Environmental impact:
Maintenance:
Manufacturability:

Developed by: Pontoon Power
Source: http://www.pontoon.no/

2.135 Energy Conversion Platform ECP

The Protean™ technology is best conceptualized as a highly adaptable and configurable ocean energy extraction platform. This generic platform can then be easily configured to allow for integration with any number of complementary technologies. As an example the Protean™ Energy Conversion Platform (ECP) can be enhanced by integrating optional modules to extract energy from wind, wave and solar power. Additionally the Protean™ ECP can be fitted with an optional energy storage system to better control the consistency of the energy produced.

Classification:
Full scale prototype in design process. Currently a 1:3 scaled model has been tested.

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:

Developed by: Protean Energy, Australia
Source: http://www.proteanenergy.com/

2.136 Electric Generating Wave Pipe (EGWaP)

The EGWAP incorporates a specially designed, environmentally sound, hollow, non-corroding pipe (also known as a tube or container) whose total height is from the ocean floor to above the highest wave peak. The pipe is anchored securely beneath the ocean floor. When the water level in the pipe rises due to wave action, a float rises and a counterweight descends. This action will empower a main drive gear and other gearings to turn a generator to produce electricity. The mechanism also insures that either up or down movement of the float will turn the generator drive gear in the same direction. Electrical output of the generator is fed into a transmission cable.

Classification:

Key Statistics:

Capacity: 123000 units with combined capacity of 48 GW

Environmental impact:

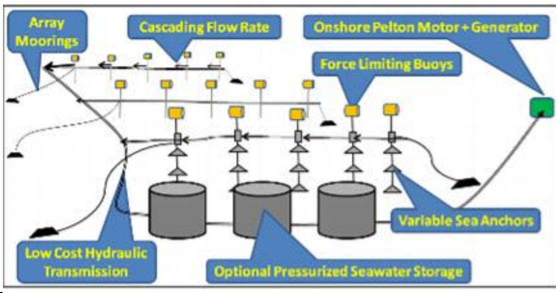
Maintenance: medium

Manufacturability:

Developed by: Able Technologies, L.L.C

Source: http://www.abletechnologiesllc.com/

2.137 OHS



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Arrays of (point-absorbing) buoys producing pressurized seawater, conveyed using seafloor hydraulic transmission line to onshore conversion/generation. The arrays are positioned offshore in water depths of 20m (minimum required) to 100m (preferred maximum due to mooring cable cost). "Slack" or catenary array moorings attach each end to the seafloor. With this architecture, undersea operations are not required during deployment - a major cost savings - and tidal changes have no effect on the pumping action of the buoys, as each pump adjusts to changing ocean depth. For other systems using direct bolt-down of each device, tidal change is a major issue.

Hydraulic system. Onshore generators. Patent pending variable sea anchors suspended beneath each pump provide the resistance against buoy rising, to create the pressure fed into lateral pressure line. This means the pumps do not need individual moorings - a big cost saving. By operating in low waves (under 1m), annual availability is above 90% most locations. To prevent overstressing, above 3.5m wave the forces are capped. Designed for low cost - containerized for shipping - deployed from moving vessel no undersea operations needed – array moorings at each end.

Classification:
Developing a pilot plant

Key Statistics:

Capacity: 249 kW

Environmental impact:

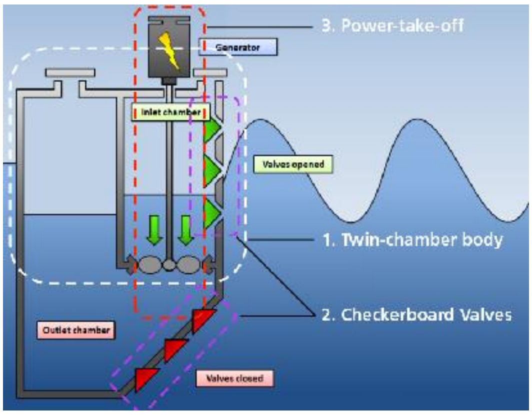
Maintenance: medium

Manufacturability:

Developed by: Atmocean Inc and Ocean HydroPower Systems Ltd (UK)

Source: http://www.atmocean.com/1.html

2.138 Drakoo-B



The working principle of Drakoo (Dragon King of Ocean), being a twin-chamber oscillating water column system, is to transform waves into a continuous water flow which drives a hydro turbine generator. Firstly, an incoming wave increases the inlet chamber's water level, and a transfer of water from the inlet to the outlet chamber occurs. Secondly, once the water level outside the device falls, both chambers' water levels also fall, again leading to a flow from the inlet to the outlet chamber. The two-step action of the water columns occur continuously in waves. Meanwhile, the checkerboard valves regulate the water flow. The water flow is nearly constant and one-directional resulting in smooth rotation of the hydro turbine which in turn generates stable electricity efficiently. The Drakoo working principle has been proven with various scale models in lab tests and sea trials

Classification:
Sea trials conducted

Key Statistics:
Capacity:

Environmental impact:
Maintenance: medium
Manufacturability:
Developed by: Hann-Ocean
Source: http://www.hann-ocean.com/products/drakoo-wave-energy-converter/introduction/

2.139 Wavesurf

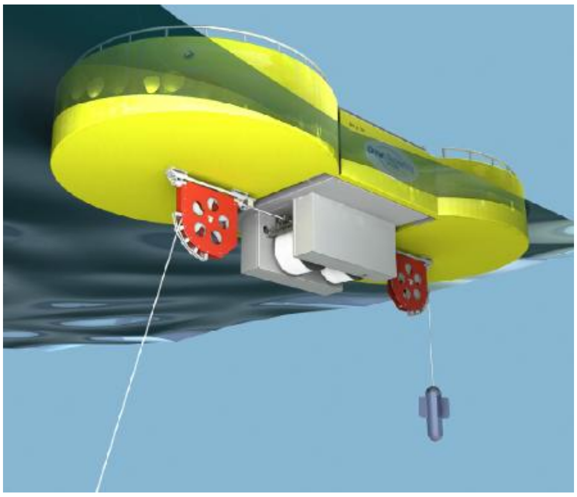
Point absorber, modular design, WaveSurfer consists of two bodies, a buoyant body that floats on the surface of water and a submerged body suspended from the buoyant body. The submerged body consists of electric generators and horizontally-aligned rotors.

Classification:
Full scale models in commercial use

Key Statistics:
Capacity: 1kW to 1MW per unit

Environmental impact:
Maintenance: medium
Manufacturability:
Developed by: Ocean Energy Industries
Source: http://www.oceanenergyindustries.com/

2.140 Ocean Harvester



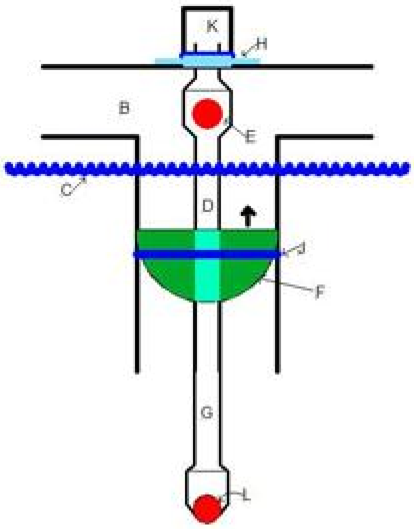
The Ocean Harvester captures energy from the rise of each wave with the use of a winch system, which provides sufficient length of stroke for the largest wave on the selected site. A patented mechanical PTO with a counterweight efficiently converts the highly fluctuating energy that is absorbed from the waves into a smooth power and force through system. This way the PTO and power electronics can be sized for the average energy instead of the peak energy. The key advantage with this is considerable reduction in the cost of the PTO, as well as high efficiency and load factor of the generator and power electronics, all together resulting in low cost of energy.

Classification:
Scaled testing

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Ocean Harvesting Technologies
Source: http://www.oceanharvesting.com/

2.141 OWWE-Rig



The OWWE (Ocean Wave and Wind Energy) The picture shows a hybrid wave and wind power rig called 2Wave1Wind. 10 modules of 600m can produce 1 TWh a year at the price of £ 0,04/kWh in wave climate of 40 kW/m wave front.

The main parts are two tubes D and G. G somewhat wider than D. Tube D is welded to the platform (B) and tube G to the buoy F. Waves move the buoy down and the wave pump takes water through the valve L and when the buoy moves upwards, the valve E opens for pressurized water to the chamber K. The tube H leads water to the turbines. The pneumatically stabilized platform (B) floats at pressurized air, which makes the sea level inside the platform (J) lower than the sea level outside (C)

The main structure is a float with several basins. The float can be trimmed and the height above sea desired the water pressure at the turbines. OWWE-Rig can be equipped with hinged walls to make it more efficient. OWWE-Rig is constructed as a hybrid wind and wave energy converter. The wind-turbines are of the type in normal use.

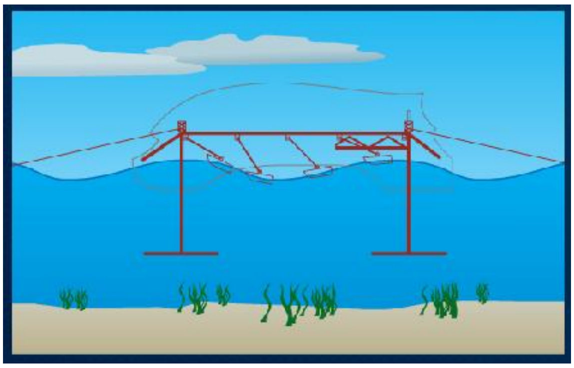
Classification:
Scaled testing

Key Statistics:

Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Ocean Wave and Wind Energy (OWWE)
Source: http://www.owwe.net/?o=home

2.142 Hybrid Float



The Perpetuwave Wave Harvester technology is based on a floating platform, with the elongated Hybrid Float design incorporated beneath the deck. The Hybrid elongated floats operate from trailing arms offering the most robust and light weight design possible. The angular motion of the floats offered by the trailing lever arm is in the direction of wave travel as well as upwards. This also captures the substantial horizontal directional component of the wave energy (the direction of wave travel) as well as the typically converted vertical energy component. Extracting the horizontal directional energy component also minimises wave reflection, reduces impact loads of breaking waves on to the floats and structure, and allows a series of floats to be placed one behind another in a commercially viable array Hybrid Float System include: the floats which are rectangular in shape with the long side parallel to the wave fronts Energy is transferred from the array of light weight hybrid floats and attached trailing arms to a common generator via a simple direct drive system. By harvesting only the upward motion of the floats, a high ratio of positive float buoyancy results and this helps to further reduce reflection of the wave to further improve the genuine viability of an array formation. The simple direct drive train operates with efficiencies of extracted energy delivered to the generator of approximately 90%. A one way clutch transfers the upward motion of the floats to drive a step up gear box which then drive the common generator for improved drive train and generator utilisation.
The drive train also provides excellent serviceability with any one float being able to be removed from service independent of the rest of the power plant. Off the shelf components are used throughout to complete the cost effective and practical energy solution.

Classification:
Scaled testing

Key Statistics:
Capacity:
Currently 850 kW

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Perpetuwave Power
Source: http://www.perpetuwavepower.com/

2.143 Resolute WEC

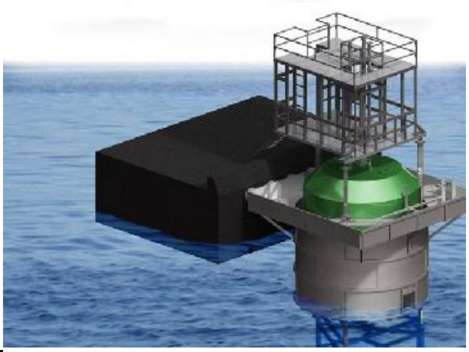
Oscillating Wave Surge Converter. Bottom-mounted hinged flap. Limited information available

Classification:
Scaled prototype testing

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Resolute Marine Energy, Inc
Source: http://www.resolutemarine.com/

2.144 SeaNergy Wave



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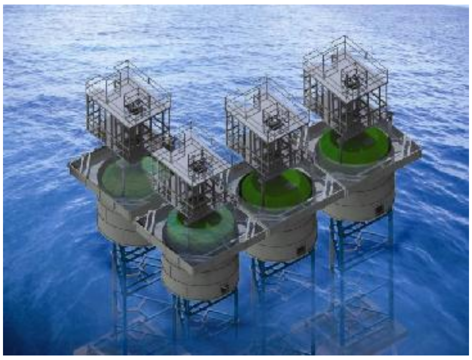


Innovative efficient wave energy system creating clean electricity and desalination. Based on the principle of a ball popping up from under water, this produces a burst of energy. This burst of energy is harnessed by this system.

<u>Classification:</u>

<u>Key Statistics:</u>

<u>Capacity:</u>
250 kW per cluster

<u>Environmental impact:</u>

<u>Maintenance:</u>

<u>Manufacturability:</u>

<u>Developed by:</u> SeaNergy Wave

<u>Source:</u> http://www.israeltrade.org.au/seanergy-electric/

<u>Classification:</u>
Wave tank testing carried out

<u>Key Statistics:</u>

<u>Capacity:</u>

<u>Environmental impact:</u>

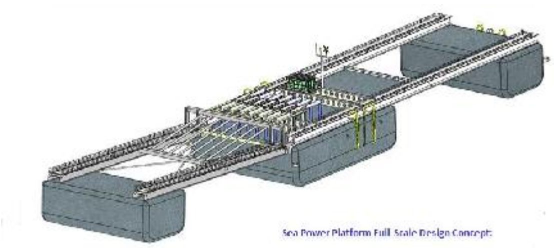
<u>Maintenance:</u>

<u>Manufacturability:</u>

<u>Developed by:</u> Sea Power Ltd

<u>Source:</u> http://www.seapower.ie

2.145 Sea Power Platform



Classification:
Wave tank testing carried out

Key Statistics:

Capacity:

The **Sea Power Platform** Wave Conversion Device consists of a floating central inertial body about which are fitted power-producing floating bodies connected to the central body via the power take-off and damping system. The device consists of 2 pontoons- the Main pontoon and the Forward pontoon. The pontoon floats are manufactured in concrete and are thus very low cost.

The **Sea Power Platform** works by using the relative motion between the 2 pontoons to drive a series of deck-mounted C-Pumps. The device combines pitch and heave of the pontoons to maximize the energy extraction from the incident wave. This multimode operation ensures the device extracts the full wave energy potential.

The system also includes:
A water-based proprietary Power Take Off system developed by Sea Power.
A PTO Damping Device which is under development.

The C-pump is a highly efficient, double acting, reciprocating device designed to deliver large quantities of raw seawater at high pressures. The pump uses a specialized surface coating as abrasion protection from sea water and contaminants. A series of C-Pumps will be incorporated into the **Sea Power Platform**

Environmental impact:

Maintenance:

Manufacturability:

Developed by: Sea Power Ltd

Source: http://www.seapower.ie

2.146 WavePiston

Classification:
Wave tank testing carried out scaled model of 1:30

Key Statistics:

Capacity:
1 MW per generator (10 strings)

The system is built from prefabricated modules that can be produced at a low cost. Each module consists of an energy collector and a simple pump. The energy collector is a plate that can slide back and forth. The pump consists of a cylindrical chamber with a piston inside that is powered by the movement of the energy collector.

The modules are mounted on a linear structure. This structure consists of a polyethylene pipe for power transfer and 2 steel wires that provides the structural strength. The structure is stretched out between to mooring points.

The mechanical movement of the plates pumps pressurized sea-water into the polyethylene pipe. The pressurized water can easily be used for power generation using standard turbine/generator technology due to the fact that numerous plates result in a steady flow of pressurised water.

Building the system from modules makes it easy to transport, deploy, and repair. If a module fails, it will not compromise the entire system. Faulty modules can be replaced or fixed on location, when weather allows. The modules are purposely designed to be as simple and robust as possible, in order to keep the cost low and cope with wear and corrosion encountered in marine environments.

The most important feature of the WavePiston system is the employment of force cancellation. As the elongated structure have a length of several wavelengths, each plate in the structure will be subjected to a different load due to the stochastic nature of wave movement. Depending on the phase of the waves acting on the individual plates the force will either be in the direction of the waves or against the direction of the waves. Thus, the sum of the forces acting on all plates will be relatively small, as the force on counter-moving plates will tend to cancel each other out. Thus system has inherent robustness.

Environmental impact:

Maintenance:

Manufacturability:

Developed by: Sea Power Ltd

Source: http://www.seapower.ie

2.147 WaveEl

The Waves4Power Buoy is characterized by:

- A buoy with a long vertical tub (the acceleration tube) passing through it
- A water piston inside the tube connected to a power conversion system
- A mooring system allowing the buoy free vertical movement while securing it on station
- A connection system from the buoy to the local power grid

The acceleration tube, which is open in both ends, is sticking down below the buoy about 25 meters. At still, the water line inside the tube will be at the same level as the waterline outside the buoy. At the depth of the tubes lower opening there is practically no turbulence induced from surface waves thereby practically insulating the water column in the tube from being affected by the ocean wave action. The buoy and the acceleration tube represent one body of a two body oscillating system where the other body is the inert water mass present in the acceleration tube.

The water piston in the tube is attached to a hydraulic piston in a hydraulic cylinder. The water column in the tube is forced to follow the water piston.

A: Without damping of the piston the water in the tube will stand more or less still when the buoy/tube unit heaves with the waves and no energy is captured.

B: If the piston is locked the water in the tube will follow the buoy/tube unit in its wave induced movement and the same result is achieved that no energy is captured from the waves.

Between these two conditions energy can be tapped by loading the hydraulic piston so that the movement of the water piston is dampened and thus creating a gigantic hydraulic pump, which is the basic principle of the WaveEL Buoy energy converter.

The hydraulic pump is connected to an accumulator feeding a hydraulic motor with a generator that converts the hydraulic power to electric power.

Proven survivability of buoy by mimicking the shape of weather and navigation buoys

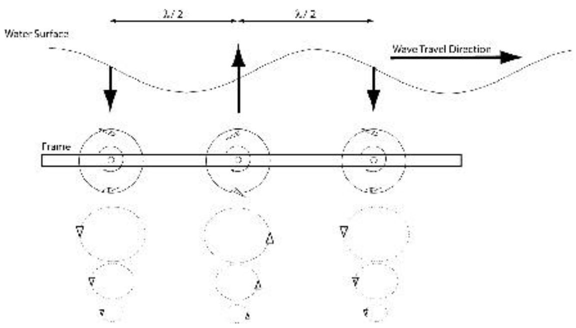
The WaveEL works by principle of a two body oscillating system. The buoy with the characteristic long vertical acceleration tube below and the water column in the tube. The movement of a the water column is dampened by a water piston which is connected to a hydraulic piston in a cylinder. By loading the hydraulic piston the relative motion between the wave induced heave of the buoy/tube and the large water mass – that is still and not affected by the wave motion – is dampened and a gigantic hydraulic pump is created which pumps oil to a hydraulic motor which in turn rotates a generator.

Classification:
Sea Trials

Key Statistics:
Capacity:
250kW

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Waves 4 Power
Source: http://www.waves4power.com/

2.148 Cyclonical Wave Energy Converter



Two hydrofoils that rotate around a shaft aligned with the wave crests and operated under feedback control achieve wave termination

Atargis Energy's Cycloidal Wave Energy Converter (CycWEC) uses two-bladed, horizontal axis turbines deployed in deep ocean water (~100 m deep) to generate economical, clean renewable energy.

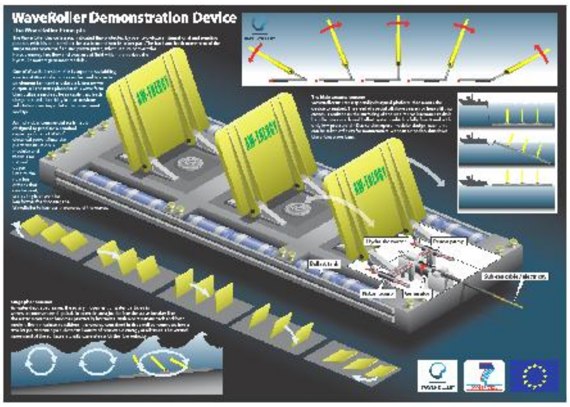
The Atargis CycWEC is installed on a fixed support and operates fully underwater, invisible from the shore, in deep ocean swells. These swells have tremendous energy--a single meter of wave front can contain 20 to 70 kW, enough to power several homes. Using feedback flow control to synchronize with the incoming wave, the CycWEC can completely terminate the incoming wave, extracting more than 95% of the wave energy.

Classification:
Scaled Testing in wave tank

Key Statistics:
Capacity:
5MW

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Atargis Energy Corporation
Source: http://www.atargis.com/index.html

2.149 Wave Roller



Classification:
Full scaled testing

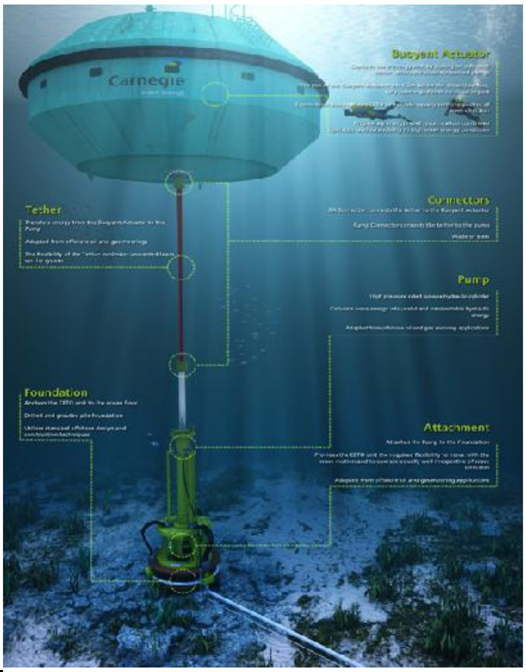
Key Statistics:
Capacity:
0.5 to 1 MW depending on wave conditions

WaveRoller is a device that converts ocean waves to energy and electricity. The machine operates in near-shore areas (approximately 0.3-2 km from the shore) at depths of between 8 and 20 meters. It is fully submerged and anchored to the seabed. A single WaveRoller unit (one panel) is rated at between 500kW and 1000kW, with a capacity factor of 25-50% depending on wave conditions at the project site.

As the WaveRoller panel moves and absorbs the energy from ocean waves, the hydraulic piston pumps attached to the panel pump the hydraulic fluids inside a closed hydraulic circuit. All the elements of the hydraulic circuit are enclosed inside a hermetic structure inside the device and are not exposed to the marine environment. Consequently, there is no risk of leakage into the ocean. The high-pressure fluids are fed into a hydraulic motor that drives an electricity generator. The electrical output from this renewable wave energy power plant is then connected to the electric grid via a subsea cable.

Environmental impact: invisible, sits on sea bed
Maintenance:
Manufacturability:
Developed by: AE-Energy
Source: http://aw-energy.com/

2.150 CETO



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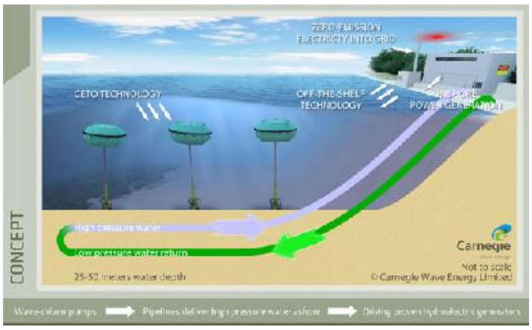


Fully submerged buoy (1-2 m below the surface) tethered to a seabed mounted pump. The unit delivers high pressure fluid ashore via a subsea pipeline, the high pressure fluid drives hydroelectric turbines onshore generating electricity or direct desalination of water. The buoy captures the wave energy thus pulling on the flexible tether driving the seabed mounted pumps.

Classification:
Drilled and grouted pile foundation
Full scale sea testing has been carried out

Key Statistics:

Capacity:
240kW

Environmental impact: submerged so little visual **impact**

Maintenance:

Manufacturability:

Developed by: Carnegie Wave Energy Limited

Source: http://www.carnegiewave.com

2.151 OE Generation Platform

Floating OWC. Has an 'L' formation, where the water enters into device from the long side of the L. Survivability has been tested in artic oceans and has been proven.

Classification:
Sea trials carried out on 1:4 model

Key Statistics:

Capacity:

Environmental impact:

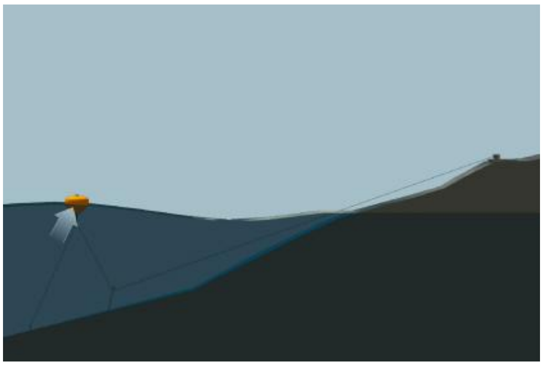
Maintenance:

Manufacturability:

Developed by: Ocean Energy Ltd

Source: http://www.oceanenergy.ie

2.152 Purenco



Purenco's WEC (wave energy converter) absorbs energy from ocean waves, and converts it to useful energy, in the form of a controlled flow of hydraulic high pressure fluid. The hydraulic energy is then either converted further into electrical electricity through a turbine and a generator, or is used to pressurize seawater to power a reverse osmosis plant producing freshwater. The patented Purenco concept is based on floating buoys connected by wire to a self-tightening winch, further connected to a gear transfer machinery and a hydraulic conversion system which outputs energy in a useful form (e.g. electricity or pressure for desalination of seawater). When a buoy is moved by the waves, the wire is pulled out, and the winch is forced to rotate outward, by means of which mechanical energy is transferred from the waves into the winch machinery. From this outward rotation is mechanical energy is tapped, which is converted mechanically (geared up) and then hydraulically smoothed and temporarily stored.

Classification:
Sea trials

Key Statistics:

Capacity:

Environmental impact:

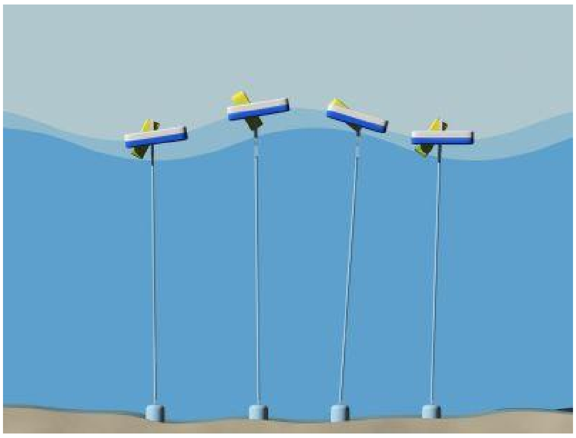
Maintenance:

Manufacturability:

Developed by: Straumekraft AS

Source:
http://www.straumekraft.no/Core_technology.aspx

2.153 Lever operated pivoting float



The wave energy buoy is patented and is a very simple device: that is, a horseshoe shaped float with a lever in the center section that is anchored to the ocean floor. It activates as a wave lifts or pushes the buoy. The end of the lever that is anchored to the ocean floor cannot move up as waves lift the buoy, causing a gearbox and generator, fastened on the lever, to activate as the buoy moves up and the other end of the lever, which is fixed to the seabed, remains at a fixed elevation. The gearbox and generator are integrated within the hinge in the buoy.

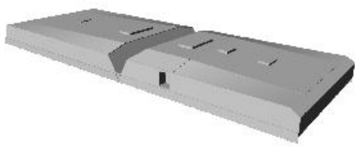
Proven survivability.

Classification:
Sea trials

Key Statistics:
Capacity:
1-5kW per unit

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Resen Waves
Source: http://www.resenwaves.com

2.154 Crest Wing



The Crestwing Wave Energy Converter (WEC) works on the surface of the ocean and consists of two connected floating pontoons anchored at the sea bottom.

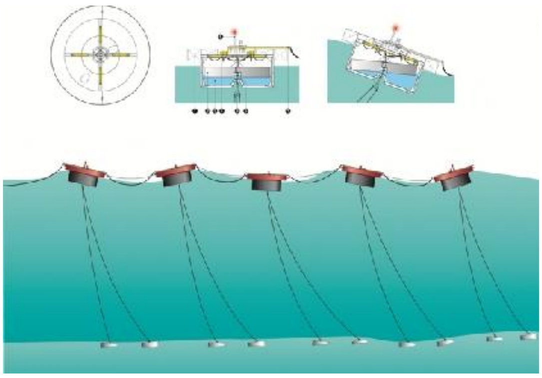
The connected pontoons swing around the hinge when the top of the waves passes under the floats. The pontoons relative motion is converted into usable energy through a linear PTO system.
The pontoons are pushed upwards from the below passing wave and again dragged down by the same passing wave. Complex hydrodynamic conditions occur under the pontoons when the wave formation pushes the unit up and down simultaneously.
The energy from waves can be divided into fifty percent potential energy and fifty percent kinetic energy. Crestwing absorbs both the potential energy as the kinetic energy which is the back ground for the high efficiency.

Classification:
Scaled sea testing

Key Statistics:
Capacity:
1 MW per unit

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Wave Energy Fyn
Source: http://www.waveenergyfyn.dk

2.155 Yeti Cluster System



Working principle:
Our patented unique solution does just that with great efficiency as it utilizes the moment differences between a semi-submersed floating outer body in water and a inner floating body placed within a closed tank of the outer body (partially full of water) .

As the outer floating body pitches due to wave propagation, the water inside the tank hence the inner body (floating) in the closed tank stay parallel to the ground/sea floor. The inner floating body is connected to the outer floating body by means of hinges allowing only single axis movement (in this model).

Power take off units installed between the floating bodies, resists the pitch motion of the outer floating body with the buoyancy force created by the inner floating body. This resistance or momentum difference between one (almost) stationery body and one moving body is converted to mechanical power

YETI CLUSTER unit absorbs wave energy from all directions and works on the basis of, among others, negative GM(*). Such feature, in combination with having a simple self adjusting variable damping / active control (PTO) system on board (used for varying the damping in line with the encountered wave excitation force thus causing/keeping the unit conversion responsive) is enabling it to harness in-coming irregular wave energy efficiently and economically both in low and high energy density areas of deployment.

Up to fifteen minutes of potential energy that each YETI CLUSTER unit is designed to store internally (as a buffer) eliminates the need of complicated electronics, control systems and equipment in power generation. All the components used are standard components in their respective industries.

Classification:
Sea trials

Key Statistics:
Capacity:
5kW – 5MW

Environmental impact:
Maintenance:
Manufacturability: makes use of standard components
Developed by: Avium A.S
Source: http://www.avium.com.tr

2.156 Blue Power Energy

Blue Power Energy have developed a new type of Power Take Off Unit (PTOU) for a wave energy device. The process involves converting the linear heaving motion of a wave energy buoy into rotational kinetic energy using our innovative linear/rotary gear box. The gear box drives a flywheel which then drives a standard Permanent Magnet electric generator

Classification:
Ready to be fitted to WEC for trials

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Blue Power Energy
Source: http://www.bluepower.ie

2.157 SARAH pump

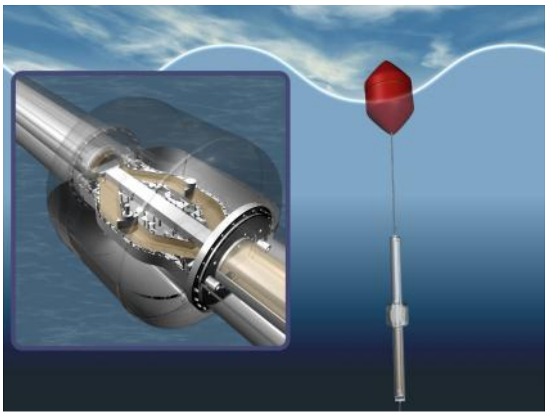
S.A.R.A.H.'s pump (Sea Activated Reciprocating Action Hydraulic Semi-submersible pump). Capacity comparable to hydroelectric generation of Hoover dam or Canada's James Bay, 25 kW per meter.

Classification:

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: College of the North Atlantic
Source:
http://www.cna.nl.ca/news/newsletters/Fall%202006.pdf

2.158 CorPower Wave Energy Converter



The compact WEC systems are of the point absorber type, with a buoy on the ocean surface absorbing energy from waves. The WEC is located at a depth between the surface and sea bottom where it is protected from rough seas. Force is transferred to the WEC by a buoy tether, and it is moored to the sea bed.

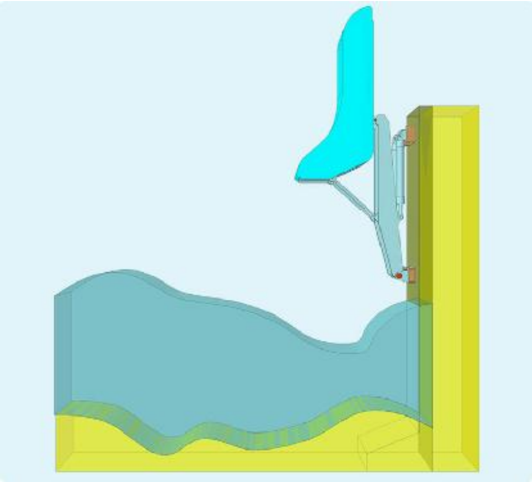
Flexible connection points automatically minimize harmful lateral forces on the WEC. Our WEC has a unique Power Take-Off (PTO) design that combines the high load capabilities from hydraulics with the efficiency of a direct mechanical drive. Temporary energy storage is provided by a two-step approach, smoothing the electrical power output compared to the power profile of typical ocean waves and minimizing the cost of electronic components. The system has been designed for low inertia and high structural efficiency, allowing the use of active phase control to optimize power absorption.

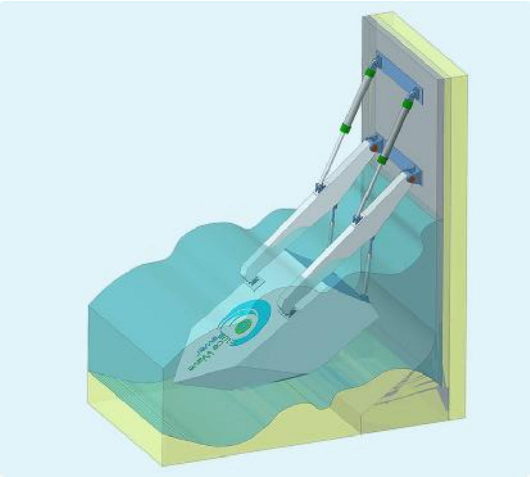
Classification:

Key Statistics:

Environmental impact:
Maintenance:
Manufacturability: low cost claims made
Developed by: CorPower Ocean

2.159 Wave Clapper/ PowerWing





The EWP convertors draw energy from wave power throughout uniquely shaped buoys, “The Wave Clapper” and the “Power Wing” that rise and fall with the up and down motion, lifting force, change of water level, hydraulic air lock, and incident flux of waves.

The “Wave Clapper” and the “Power Wing” are fully equipped with sensors which continuously monitor the performance of the various subsystems and surrounding ocean environment. As a result, Data is transmitted to shore in real time.

In the event of upcoming storms, the system automatically “recognizes” the type of waves, and independently “decides” whether to raise the buoys over the water level, or to create a process of buoy submersion into the ocean, in order to protect the system from mechanical injuries.

The EWP technologies (The Wave Clapper and the Power Wing) are “smart” wave generation systems, which use uniquely, shaped buoys to capture and convert wave energy into low-cost, clean electricity.

While examining the operation principles of wave energy convertors with traditionally shaped buoys, we came to the conclusion, that such shapes enable generating only a calculated amount of power at the expanse of lifting force of surfacing. However, the possibility to recover from an incident flow was not utilized. As a result, we have improved the buoy shapes, in a way which enables generating power both at change of water level and from an incident flow. When the “Wave Clapper” and “Power Wing” are operating at different height of waves, their buoys provide a stable operation at different waves’ height.

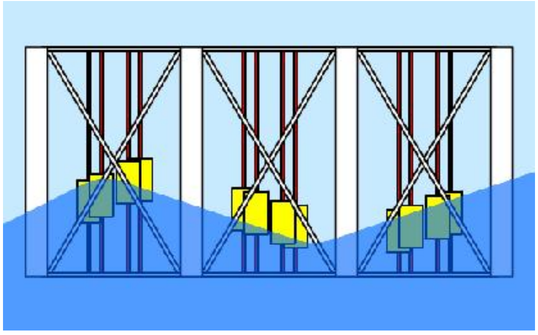
The Wave Clapper – For places & structures that are suffering from “space restrictions” (which means, not enough space to implement the traditional large-scale floaters), we propose the “Wave Clapper” shape, which enables to put the floaters with very small spaces between one another and prevent the need in safe gaps between the floaters.

Classification:

Key Statistics:
Capacity:
Modular units, number of units determine capacity

Environmental impact:
Maintenance:
Manufacturability: low cost claims made
Developed by: Eco Wave Power
Source: http://www.ecowavepower.com

2.160 Horizon Platform



Classification:
R&D stage

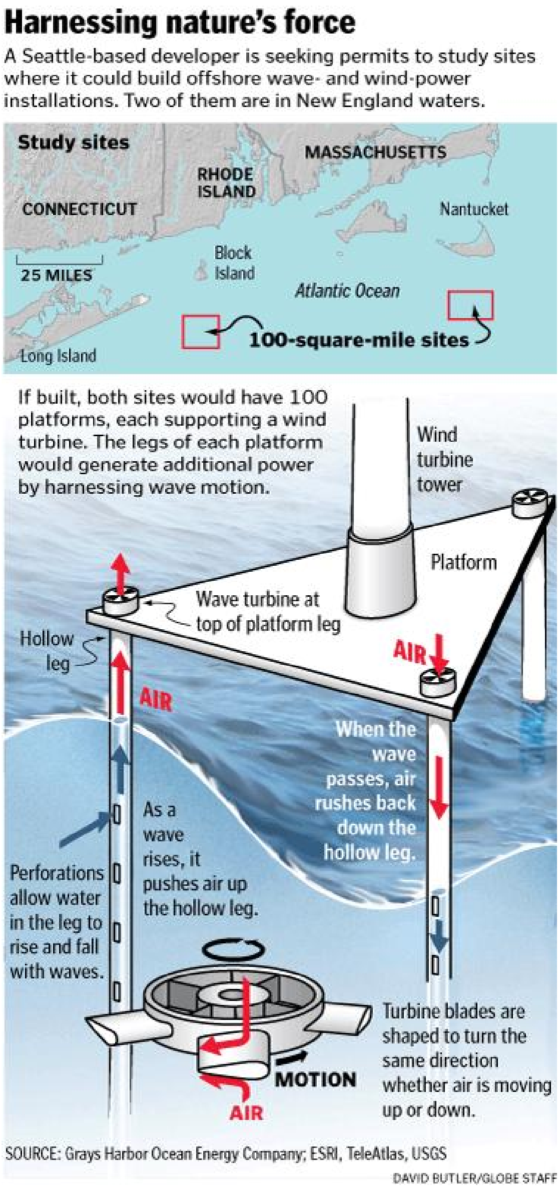
Key Statistics:

Capacity:
Modular units, number of units determine capacity

To leverage economies of scale, platforms typically contain hundreds of floats grouped in scores of clusters. The floats are weighted such that they are half submerged when at rest in still water. This allows the floats to perform equal work on both their up-strokes and downstrokes. The floats are connected to a drive mechanism which turns a generator. The resistance of the generator impedes the movement of the floats. This is why the floats in the animation become almost completely submerged before they exert enough lifting force to do their share of the work turning the generator. The same physics apply when waves recede. The floats don't start to fall until they are almost completely out of the water, and their own weight then overcomes the generator's resistance. The sizing of the generator is such that it requires the combined effort of the floats to drive it at speed. As shown in the metrics panel at the bottom of the animation, when an individual float reverses direction, it briefly stops - performing no work. Although each float in a cluster passes through the same transitions, their differing positions cause them to encounter the transitions at slightly different times - so that the overall cluster still performs work.

Environmental impact:
Maintenance:
Manufacturability:
Developed by: ELGEN Wave
Source: http://www.elgenwave.com

2.161 Titan Platform



Hybrid technology wind turbine and harnesses wave energy. Combining wave and wind energy in a hybrid power generation system appears to be economically and technically feasible. Waves are a more steady energy source than wind. Wave power is predictable at 90% accuracy up to 48 hours in advance, and up to 50% accuracy five days in advance. This makes it more attractive to utilities as a power source. When the wind suddenly drops the waves keep on surging past. Moreover wave power is even more complementary to wind power - in high winds the wind turbines have to brake or stop to avoid breaking. However that is usually when the wave power is strongest, so power generation from the hybrid system is maintained.

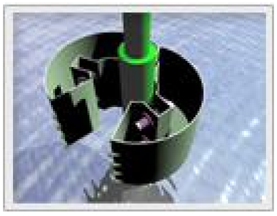
Classification:

Key Statistics:

Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Grays Harbour Ocean Energy Company
Source: http://www.graysharboroceanenergy.com/

2.162 Seacap



Seacap a wave energy system is backed by a fixed platform, it consists of oscillating buoys tours around recessed seabed piles.

Capturing the energy developed by the vertical reciprocating movement of the wave which acts on the float is in both directions.
The system is equipped with a safety device (patent pending) that the float dive under water, sheltered from the weather, in exceptional conditions beyond the operational limits.
Direct kinematic transmission hydraulic cylinders provide a particularly high performance that is further enhanced by the integrated use of motion control float
The effect of tides on the lift cylinders is negligible thanks to an innovative tidal compensation (patent pending).
The modular construction from many elements already existing and long in electrical and mechanical engineering to optimize the investment and operating costs and thus reduce the cost per kWh produced

Classification:
Prototype currently under construction

Key Statistics:
Capacity:
300-500 kW

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Hydro cap energy
Source: http://www.hydrocap.com/seacap.php

2.163 Irish Tube Compressor (ITC)

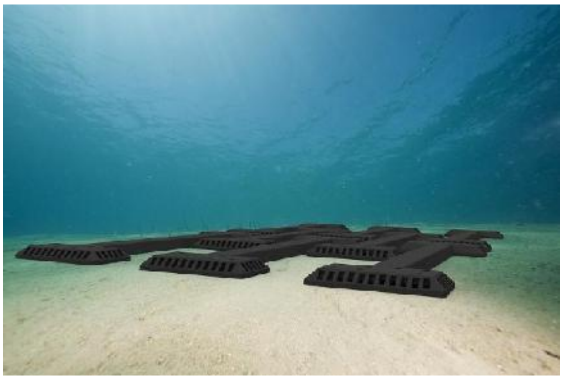
The device is based upon reinforced but flexible tubes lying on the water and with controlled air and water admission to the open ends whereby the air and water is driven forward in successive 'slugs' by the ocean waves acting on the tube(s) and the resulting water head and air pressure is converted to electricity by conventional means or used directly in other processes such as water desalination

Classification:
Wave tank testing

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Jospa Ltd
Source: http://www.jospa.ie

2.164 DMP Device



Unlike floating buoys or Aquamarine Power's signature "Oyster" design, both proposed in Oregon, M3'S design doesn't pierce the surface of the ocean or impact coastal views. Instead, it sits on the ocean floor at depths between 50 and 100 feet. It generates power by responding to water pressure from the waves above, which alternately inflate and deflate a pair of airbags that turn a central turbine to generate power.

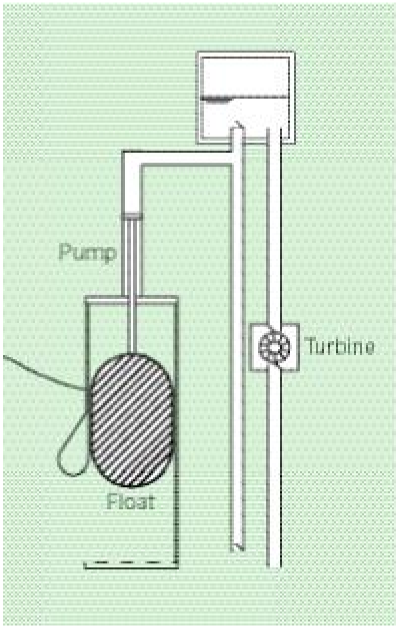
Classification:
Wave tank testing 1:6 prototype

Key Statistics:

Capacity:

Environmental impact: invisible from the surface
Maintenance:
Manufacturability:
Developed by: M3 Wave LLC
Source: http://m3wave.com/default.htm

2.165 CONWEC



The ConWEC device absorbs wave energy by means of a float which oscillates up and down inside a cylindrical structure with a submerged opening through which waves can act. The energy in the waves is converted to mechanical energy by a pump with its piston rigidly connected to the float. Seawater can be pumped into an energy storage in the form of a pressure tank (or possibly an elevated water reservoir) from which a turbine can be run to complete the conversion to electrical energy. Alternatively, a hydraulic fluid other than seawater may be used if the hydraulic system is a closed loop.

Classification:
Wave tank testing and scaled sea testing

Key Statistics:

Capacity:
300kW

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Norwegian University of Science and Technology
Source: http://www.caddet-re.org/html/299art4.htm

***2.166* WAG (Wave activated generator)**

WAG uses the sectorial Well's turbine wing made of the ABS resin, and generates electricity to the wave of the low wave height efficiently. The style made of aluminum article of cast metal tube is used, and this device can be used at ease under a severe system requirements. There are two kinds of three aspect 12V(FTW-12 type) or three aspect 24V(FTW-24 type), and the ratings output voltage of the generator can be used by charging with the storage battery of ratings DC12V or DC24V by rectifying it to direct current.

Classification:

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Ryokuseisha
Source:
http://www.ryokuseisha.com/eng/product/power_supply/ftw/ftw.html

***2.167* Wavestore**

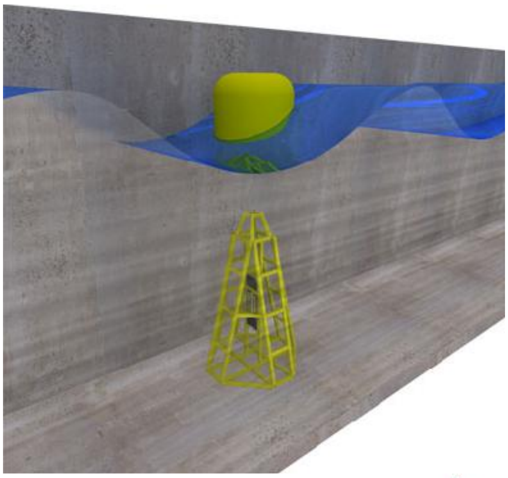
The WAVESTORE system will be moored in an exposed deep water ocean environment. Waves break up the ramp into a reservoir that has a surface maintained constant relative to sea level by use of a submerged float supporting the reservoir. This provides a constant pressure of sea water on a turbo-alternator fed from the reservoir exhausting into the sea. This stabilised pressure allows the alternator to be directly synchronised into the loading national grid network avoiding the need for unnecessary conversion machinery or battery storage of energy. The pressure head will be set by the onboard controller as determined by the height of the waves. The freeboard of both the main body and the float is set by the water level in the weather, leeward, and float buoyancy tanks. The system heave is resisted by the pendulous dashpot tray suspended in the relatively stable water beneath the surface. The working volume is cube shaped which will be set to fully exhaust for each average wave period. This geometry should allow efficient conversion.

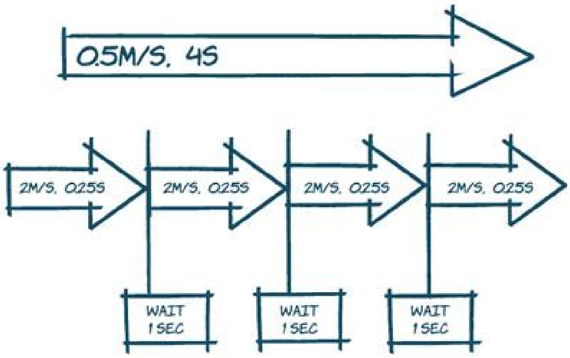
Classification:
scaled sea testing

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Portsmouth Innovation Ltd
Source:
http://homepage.ntlworld.com/b.spilman/wavestorejune27_003.htm

2.168 Snapper





The device works like a typical linear generator in which a set of magnets mounted in a translator is moved up and down inside multiple coils of wire of an armature. However, there is a crucial difference with Snapper: alongside the armature coils is a second set of magnets of alternating polarity.

Instead a new approach was conceived where the continuous slow movement of the wave power machine is divided into a sequence of rapid bursts. The maximum force applied during each burst is well defined according to maximum force that can be transmitted by a coupling. Varying drive speeds are accommodated by the variation in the delay between bursts of motion

Energy must be stored during the waiting periods. The Snapper machine uses a spring and a magnetic coupling in the force transmission path. As the applied force increases, the spring stretches and stores energy. When the force exceeds a certain threshold the magnetic coupling can no longer transmit the force and it snaps allowing the energy stored in the spring to be released quickly and efficiently

Classification:
scaled wave tank testing

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Snapper Consortium
Source: http://www.snapperfp7.eu/snapper-s-background

2.169 Waveline Magnet Wave Energy Convertor (WM7)

Attenuator device. Break through high efficiency device at low cost. Inventor calculates that 1MW of power can be achieved for less than £1.5m.
The device is buoyancy-neutral and adheres to the surface of the water so it follows precisely the contour of the wave as the wave passes ‘through’ the device, thus survivability should not an issue.

Environmental impact:

Classification:
Scaled (1:50) wave tank testing

Key Statistics:
Capacity:
Full size capacity 15MW

Maintenance:
Manufacturability:

Developed by: Sea Wave Energy Ltd (SWEL)
Source: http://www.swel.eu/

2.170 Straum OWC

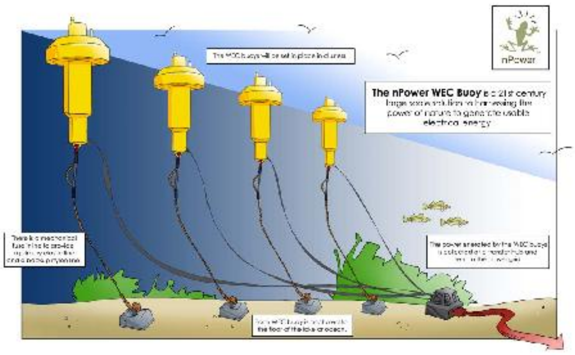
OWC. Robust design with good availability and low maintenance needs are well known requirements in the power generation business and these requirements will be emphasized in the further development of the OWC Power concept.

Classification:

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Straum
Source: http://www.straumgroup.com

2.171 nPower WEC



A kinetic energy harvesting technology called nPower®. nPower® uses the energy of motion to power devices without using fossil fuels or generating emissions.

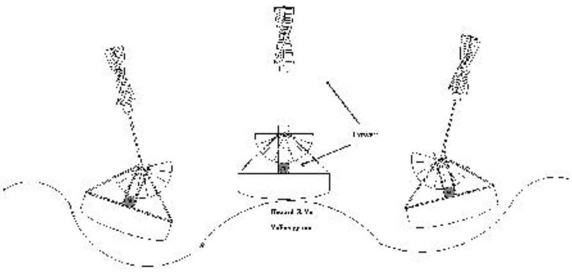
Classification:

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: nPower WEC
Source: http://www.npowerpeg.com

2.172 Yu Oscillating Generator "YOG"

Not much known



Classification:

Key Statistics:
Capacity:

Environmental impact:
Maintenance:
Manufacturability:
Developed by: Yu Energy Corp
Source: http://www.yuenergy.com