Table of contents

1. Evaluation criteria

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

- Environmental impact
- Maintenance
- Manufacturability

The Environmental impact and the Maintenance will be further divided into:

- High
- Medium
- Low

The Manufacturability will be further classified as:

- Good
- Medium
- Poor

Environmental impact

The environmental impact and the visual impact of both the device and its PTO will be evaluated under 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 evaluated according to 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.

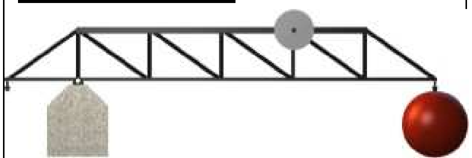
Manufacturability

This will include the manufacturing and installation cost of the WEC.

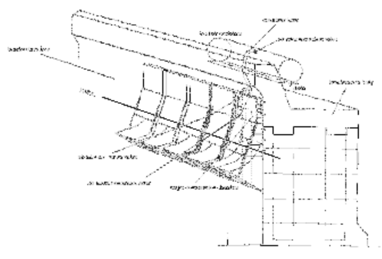
Good: The WEC is made from readily available components and/or materials, for instance steel and concrete. It will also require minimal preparation of the desired installation site and should be easy to install.
Medium: These WECs will require some custom made components and may require some exotic materials. 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

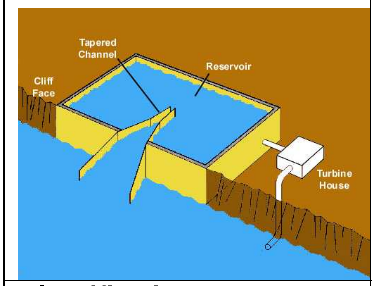
2.1. S.D.E Energy Ltd. 	Buoyant metal plates are attached to a wall (it can for instance be attached to a breakwater). These plates use the up and down motion of the swell to drive hydraulic rams. The high pressure oil is used to drive hydraulic motors, the motors in turn drives generators in order to generate electricity. It is a shore based system; it can be used on brake waters or to protect vulnerable property.
Classification: • Shore based with hydraulic PTO. • Development stage: test/early production • Line absorber.	**Feasibility:** **Environmental impact:** High. It requires a large structure that will occupy a large are of beachfront (the beach is very ecologically sensitive). **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.
Key Statistics: **Generation capacity:** 1MW up to 200MW (estimated cost $130 million). **Unit cost:** $0.02/kWh.	**Developed by:** S.D.E Energy Ltd **Source:** http://www.sde.co.il/ [2007, 25 February].

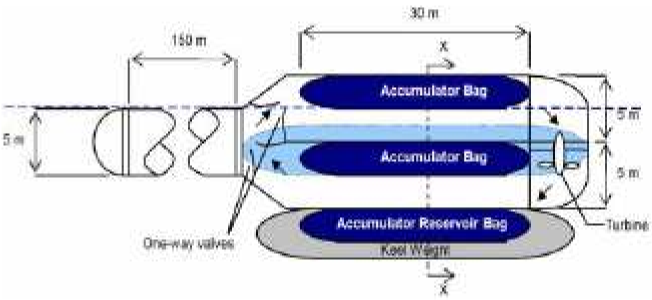
2.2. Wave Energy Machine 	A float, at the end of a truss, is used to cause a "teeter-trotter" effect in the truss. The truss is allowed to pivot at the hinge point that's situated at the base (the base is situated on the beach). The motion of the structure is translated into mechanical energy by a cam 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.	**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.
Key Statistics: • Unknown	**Developed by:** Unknown. **Source:** http://www.waveenergymachine.com/ [2007, 11 March].

2.3. Limpet 	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	**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 witch will increase installation costs, but the installation can be eased if the system is designed as an integral part of a breakwater.
Key Statistics: **Generation capacity:** 500 kW	**Developed by:** Wavegen **Source:** http://www.wavegen.co.uk

2.4. WECA 	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 witch in turn will transfer the energy to a generator.
Classification: • Shore based with OWC type PTO. • Development stage: Unknown	**Feasibility:** Note: Too little information is available to properly evaluate the feasibility of the device.
Key Statistics:	**Source:** http://www.daedalus.gr/DAEI/PRODUCTS/RET/General/RETWW1.html

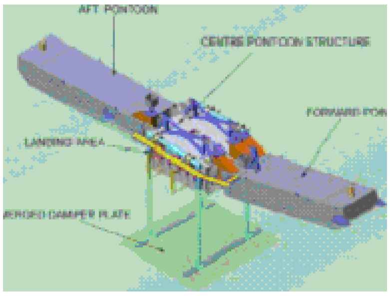
2.5. Seawave Slot-Cone Generator 	The SSG concept is based on the over topping principal. The system uses a total of three reservoirs placed on top of each other to capture the crest of the incoming wave and a specially designed multistage turbine to convert the head into mechanical energy (the system 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.	**Feasibility:** **Environmental impact:** High. If it is built on the shore, but low if it is built off shore (it will totally occupy that beach that 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.
Key Statistics:	**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.	**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.
Key Statistics:	**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.
<u>Classification:</u> • Above waterline with an hydraulic PTO. • Development stage: Scale model testing in wave tank.	**<u>Feasibility:</u>** **<u>Environmental impact</u>:** Low. The floating device will have a low environmental impact since it does not have any components that pose a threat to marine life. **<u>Maintenance:</u>** 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. **<u>Manufacturability:</u>** Medium. The device will use very little off the shelf components, but the manufacturing techniques for the concerned materials is common.
<u>Key Statistics:</u> **<u>Generation capacity:</u>** 1MW (expected). **<u>Size:</u>** 150m long with a 7m diameter	**<u>Source:</u>** 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*

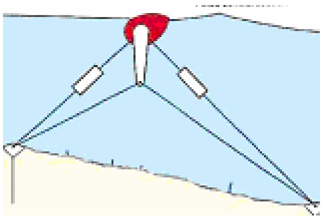
2.8. Energen Wave Generator 	There is very little information available on the exact working principal of the device, the author assumes that it's an attempt to protect the patent of the device. It is a floating device that will be anchored in such a way that it will face the incoming wave direction. 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.
<u>Classification:</u> • Above waterline WEC with hydraulic PTO. • Development stage: 2D tests, 3D tests coming soon.	**<u>Feasibility:</u>** It's very difficult to evaluate the concept do to the little information that's given. **<u>Environmental impact</u>:** Low. It a floating device that seemingly wouldn't need a large anchoring system. **<u>Maintenance:</u>** 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. **<u>Manufacturability:</u>** 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.

Key Statistics: **Rated power:** 1-1.5MW expected for S.A wave climate.	**Developed by:** Energen International **Source:** http://www.energeninternational.com/contact.html [2007, 10 October].

2.9. McCabe Wave Pump  	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: See 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].

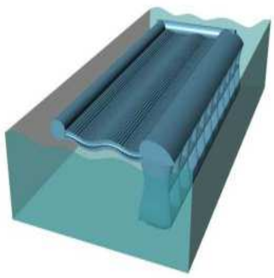
2.10. Pelamis 	It is a semi submerged system that consists of several cylindrical sections (made out of steel) that are connected with hinged joints. Hydraulic pumps are used to utilize the bending motion inside the joints, which is caused by the passing waves. The high pressure oil is used to generate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

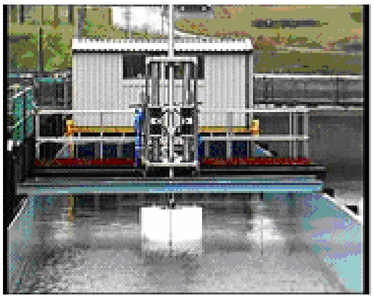
2.11. Salter Duck 	The passing waves cause the Duck to rotate in a nodding motion; this motion is used to pump hydraulic fluid or to compress air. If the hydraulic principal is utilized the fluid will drive a hydraulic motor witch in turn drives an electrical generator in order to generate electricity, 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.	**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.
Key Statistics: • Unknown	**Developed by:** Prof Steven Salter **Source:** http://www.oceanenergy.ie [2007, 11 June].

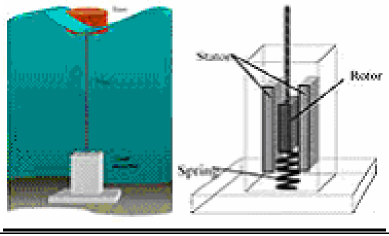
2.12. Wave Rider 	A hydraulic system inside the specially shaped buoy converts the slow rolling action of the waves into high-pressure hydraulic fluid flow. The hydraulic circuit drives a small turbine witch generates electricity. The buoys can be connected in parallel and the electricity, if so, the electricity will be collected by a grid before its fed into the grid.
Classification: • Above waterline WEC, hydraulic PTO. • Line absorber.	**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.
Key Statistics: **Generation capacity:** 10 to 400 MW farms.	**Developed by:** SeaVolt Technologies **Source:** http://www.seavolt.com/ [2007, 25 February].

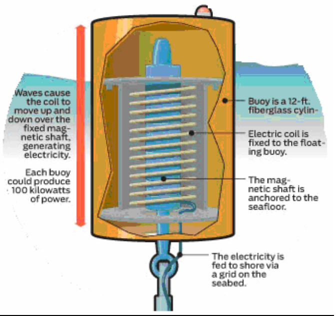
2.13. Wave Star 	The Wave Star consists has 20 partially submerged hemisphere-shaped floats that each drives a hydraulic pump. The approaching wave pushes the floats up in sequential order. The compressed oil (at about 200 bar) is collected from each pump and fed into a common accumulation system. The accumulator feeds the oil to a hydraulic motor witch in turn drives a 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).	**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.
Key Statistics: **Generation capacity:** 3 MW estimated.	**Developed by:** Wave Star Energy **Source:** http://www.wavestarenergy.com/ [2007, 25 February].

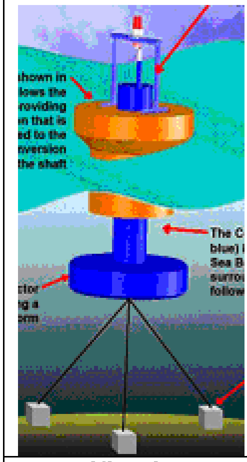
2.14. WaveBlankect 	Thin polymer films, that are filled with water, forms a blanket that floats on the surface. The motion of the waves causes the hydraulic chambers to compress or relax. The pressure difference between the chambers is utilized, in a closed loop system, to generate electricity. The system uses its flexibility to withstand rough waves.
Classification: • Above waterline WEC with hydraulic PTO. • Development stage: concept.	**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.
Key Statistics: • Unknown	**Invented by:** Benjamin Gatti **Source:** http://www.windwavesandsun.com/ [2007, 25 February].

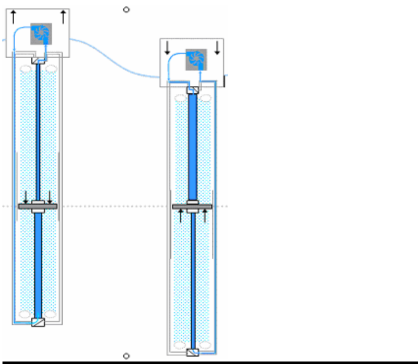
2.15. WEC 	The system is very similar to the Manchester Bobber. The system consists of several egg-shaped buoys that are connected to a platform. The buoys use the up and down motion of the waves to drive hydraulic pumps. The high pressure oil is used to drive a hydraulic motor witch in turn drives an electrical generator.
Classification: • Above waterline WEC with hydraulic PTO. • Multiple point absorber. • Development stage: test (1:3 scale model).	**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 witch will make it expensive to build.
Key Statistics: **Generation capacity:** Estimated to produce2.52 MW from 6 m waves. **Size:** 36 m by 36 m. **Unit cost:** 2.8 EUR/kWh. **Manufacturing cost:** 3-4 million euros.	**Developed by:** Fred Olsen in conjunction with Marintek/Sintef laboratories in Trondheim. **Source:** http://www.seewec.com/ [2007, 25 February].

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].

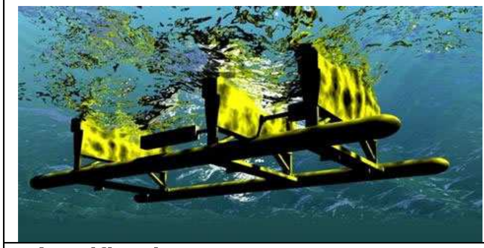
2.17. Seabased AB 	The system uses a three-phase permanent magnet linear generator to generate electricity. The linear generator is mounted on the seabed and it is driven by a floating buoy. The system will have high efficiency because it uses a direct drive conversion system. The designers of the system 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.
<u>Classification:</u> • Above waterline WEC with a linear generator PTO. • Point absorber. • Varying depth (more than 50m preferred). • Development stage: concept.	**<u>Feasibility:</u>** **<u>Environmental impact</u>**: Low. The base will have a small impact. **<u>Maintenance:</u>** Medium. The most critical components are underneath the water, making it more complicated to service than floating concepts. **<u>Manufacturability:</u>** Medium. The base is the most complicated component to install due the under water labor that's necessary.
<u>Key Statistics:</u> **<u>Generation capacity:</u>** 1 MW farms.	**<u>Invented by</u>:** Seabased AB in cooperation with Uppsala University Sweden. **<u>Source:</u>** http://www.seabased.com/ [2007, 11 March].

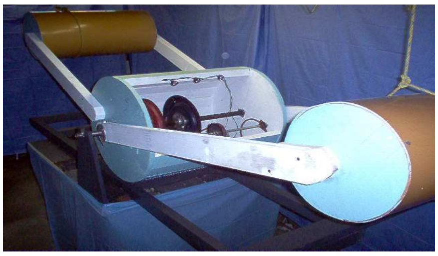
2.18. Wave Energy Buoy 	The buoy has permanent linear magnets that are attached to the shaft. These magnets induce a current in the coil that's housed inside the buoy. This unregulated AC voltage (from the buoys) is fed via a cable to a junction box on the seabed where it is converted to 12000V DC. The DC voltage will be changed back into AC on the shore before its fed into the grid.
<u>Classification:</u> • Above waterline WEC using a linear generator as PTO. • Point absorber. • Medium depth (30m, 2 tot 3 km from shore). • Development stage: concept.	**<u>Feasibility:</u>** **<u>Environmental impact</u>:** 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. **<u>Maintenance:</u>** Low. It has few moving parts and if it is made of durable materials, it shouldn't have high maintenance. **<u>Manufacturability:</u>** Good. It can be premanufactured and then installed, therefore good manufacturability.
<u>Key Statistics:</u> **<u>Generation capacity:</u>** 100kW/buoy. **<u>Size:</u>** 3.6m height.	**<u>Developed by:</u>** Prof von Jouanna and prof Wallace (Oregon State University). **<u>Source:</u>** http://www.popularmechanics.co.za [2007, 25 February].

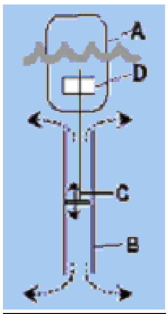
2.19. Aegir Dynamo 	The Aegir Dynamos' two major components are the buoyant base (that is anchored by three cables) and the float that moves up and down with the swell. The linear motion between the float and the base is converted into angular momentum (the details of this conversion process is unknown to the author). The angular motion is then used to drive the generator that is sealed inside the central column.
Classification: • Above waterline WEC using a mechanical to electrical PTO system. • Point absorbing device.	**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.
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	**Developed by**: Ocean Navitas **Source:** http://oceannavitas.com/ [2007, 26 July].

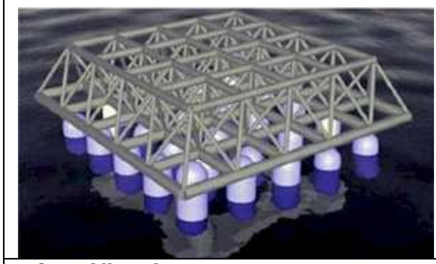
2.20. AquaBouy 	The AquaBuoy uses a cylindrical buoy as a displacer within witch the impulse turbine and generator is housed. The reactor is a water mass underneath the buoy witch is enclosed by a long vertical cylinder. A large neutrally buoyant disk inside the cylinder is used to drive the house pump (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.
Classification: • Above waterline WEC. • Point absorber. • Development stage: early production	**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.

Key Statistics: **Rated power:** 250kW per buoy. **Average output:** 56kW **Total cost:** $3million for 4 units. **Size:** 6m diameter buoy. **Water depth:** >50m	**Developed by:** Finerva Renewables **Source:** http://www.finerva.com/ [2007, 15 February].

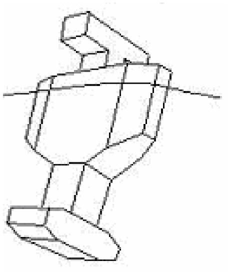
2.21. C-Wave System 	The system will have three neutrally buoyant walls that are connected to two hulls. The two outside walls will be positioned one wavelength apart. This will cause the two outside walls to move in opposite directions (the one will move forward while the other is moving backwards). The relative motion between the two outside walls will be used to drive a generator.
Classification: • Above waterline WEC using a mechanical to electrical PTO system. • Far off shore (5-20 km). • Development stage: concept.	**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.
Key Statistics: • Unknown	**Invented by:** C-Wave Ltd **Source:** http://www.cwavepower.com/ [2007, 25 February].

2.22. Floating wave generator 	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.
Classification: • Above waterline WEC using a mechanical to electrical PTO system. • Development stage: concept/early scale model testing.	**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.
Key Statistics: • Unknown	**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.	**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.
Key Statistics: **Generation capacity:** 120-250kW/buoy. **Size:** From 3-4m up to 10-12m diameter and 20m acceleration tube.	**Developed by:** Interproject Service AB (IPS) and Technocean (TO). **Source:** http://www.ips-ab.com [2007, 20 April].

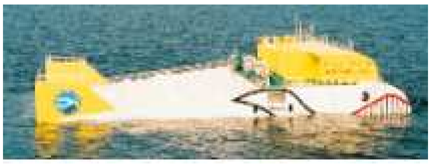
2.24. Manchester Bobber 	The system consists of a series of bobbers that's attached underneath a platform. The bobbers will harness the up and down motion of the waves in order to generate electricity (the exact principal is unknown to the author). The rig will be allowed to float freely, allowing it 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).	**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.
Key Statistics: **Generation capacity:** 5 MW (estimated).	**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.	**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.
Key Statistics: • Unknown.	**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.	**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.
Key Statistics: • Unknown	**Developed by:** Lancaster University **Source:** http://www.engineering.lancs.ac.uk/REGROUPS/ LUREG/Wavw/Wave_Current_Research.htm [2007, 11 March].

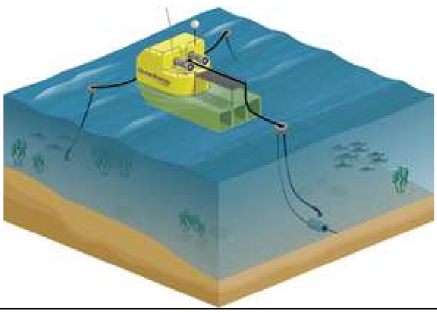
2.27. PowerBuoy 	The buoy like structure is been developed Ocean Power Technologies (an Australian company). The structure is loosely moored to the ocean floor hence allowing it to move freely up and down with the waves. The power takeoff, an electrical generator, a power electronics system and the control 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.
<u>Classification:</u> • 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.	**<u>Feasibility:</u>** **<u>Environmental impact</u>:** Low. It doesn't have a lot of cables witch sea animals can get entangled in and it also doesn't have any open moving parts. **<u>Maintenance:</u>** Low. All the critical components are protected by the elements since they are housed inside the buoy. **<u>Manufacturability:</u>** 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.
<u>Key Statistics:</u> **<u>Generation capacity:</u>** Currently 40kW but the goal is 500kW. **<u>Size:</u>** 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.	**<u>Developed by:</u>** Ocean Power Technologies **<u>Source:</u>** http://www.oceanpowertechnologies.com/ [2007, 15 February].

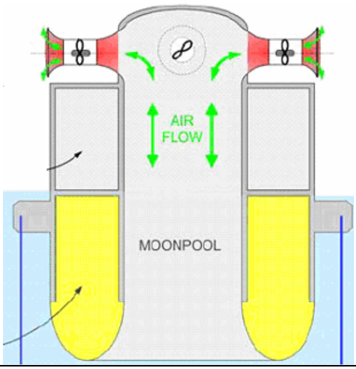
2.28. WET EnGen 	The system's main feature is its "Smart Float", the float moves up and down a rigid spar witch is at a 45° incline. The flo at is connected to a synthetic cable witch drives a shaft via a capstan. The rotational energy of the shaft can be used to generate electricity through a generator 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.
<u>Classification:</u> • Above waterline WEC using a mechanical to electrical PTO system. • Point absorber. • Development stage: Early commercializing.	**<u>Feasibility:</u>** **<u>Environmental impact</u>:** Low. Marine life will not get entangled in it and it does not make use of a large anchoring system. **<u>Maintenance:</u>** Medium to low. The synthetic cable and the joint at the bottom may cause problems due to fouling. **<u>Manufacturability:</u>** Medium. It is a simple structure, but the vast majority of the components must be tailor made for the system.
<u>Key Statistics:</u> **<u>Unit cost:</u>** 0.08-0.15$/kWh.	**<u>Developed by:</u>** http://Wave Energy Technologies Inc

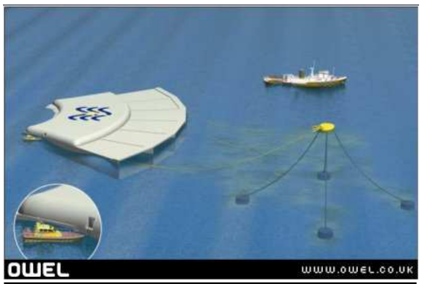
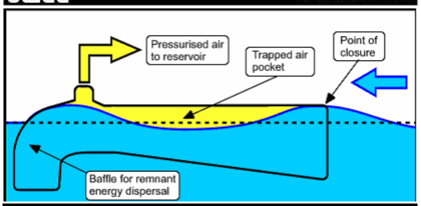
2.29. Mighty Whale 	The Mighty Whale operates on the OWC (oscillating water coulomb) principal. It has three chambers in the front witch houses trapped air pockets. The waves forces the air to oscillate, it's this motion that's used to drive air turbines witch in turn drive electrical generators. The 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.	**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.
Key Statistics: **Generation capacity:** 110 kW (prototype). **Size:** 50m (Length) x 30m (Breadth) and 12m (Depth) **Displacement:** 4 400t	**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	**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.
Key Statistics: **Generation capacity:** 1000kW. **Size:** 32m diameter.	**Developed by:** Orecon **Source:** Bedard, R. & Hagerman, G. 2004. *Offshore Wave Energy Conversion Devices.* EPRI.

2.31. Oceanlinx 	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).
<u>Classification:</u> • Above waterline WEC with an OWC PTO system. • Development stage: sea trails.	**<u>Feasibility:</u>** **<u>Environmental impact</u>:** Medium. The wall will increase its environmental impact. **<u>Maintenance:</u>** 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. **<u>Manufacturability:</u>** 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.
<u>Key Statistics:</u> **<u>Generation capacity:</u>** 321 kW in 2m waves with 7 sec period. **<u>Size:</u>** 20 m length, 40 m width, and a focal length of 5 m.	**<u>Developed by:</u>** Oceanlinx (previously known as Energetech). **<u>Source:</u>** http://www.oceanlinx.com. [2007, 11 March].

2.32. OE Buoy 	The buoy uses the oscillating wave coulomb principal to generate electricity. The up and down motion caused by the passing waves forces the air; that is trapped inside the chambers; to drive turbines (Self rectifying turbines are used in order to harness the up ad down motion of the waves; these turbines will spin in one direction no mater what direction the air flows). The turbines are connected to generators in order to generate electricity. The efficiency of the system is high during normal waves, but it reduces dramatically during extreme waves. This serves as a safety feature since it prevents the PTO form being overloaded.
<u>Classification:</u> • Above waterline WEC with an OWC PTO system. • Development stage: sea testing.	**<u>Feasibility:</u>** **<u>Environmental impact</u>:** Low. It does not have any open moving parts that pose a threat to marine life. **<u>Maintenance</u>:** Low. All the critical components (turbines and generators) are house outside of the water. This allows easy access and reduces corrosion. **<u>Manufacturability:</u>** Medium. The structure can be manufactured from steel in most shipyards, but the turbines are rather complicated with medium efficiency.
<u>Key Statistics:</u> **<u>Size</u>:** 28 t model.	**<u>Developed by:</u>** Ocean Energy Limited **<u>Source</u>:** http://www.oceanenergy.ie[2007, 11 July].

2.33. Sperboy  	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 coulomb on the inside 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.	**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.
Key Statistics: • Unknown	**Developed by:** Embley Energy **Source:** http://www.sperboy.com/ [2007, 11 March].

2.34. OWEL   	The WEC is a horizontally floating duct witch is made up of several sections witch 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).	**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.
Key Statistics: **Generation capacity:** 12 MW **Size:** 32 000t, 200m wide at the intake (front). **Unit cost:** 2p per kWh. **Total cost:** £18 million	**Developed by:** Offshore Wave Energy Ltd **Source:** http://www.owel.co.uk/print/welcome.htm [2007, 20 April].

<table>
<tr><td>2.35. Wave Dragon


</td><td>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.

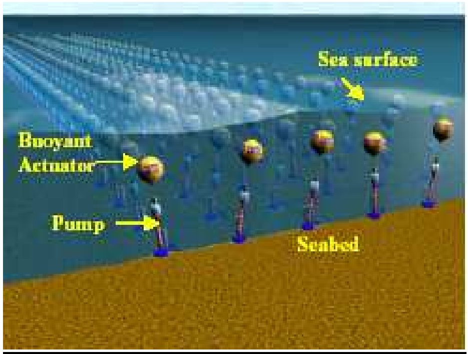
Kaplan turbines are used to convert the low head of the water into mechanical energy. The turbines drive permanent magnet generators, thereby generating electricity on the same principal as conventional land based hydropower plants.

It is one of the heaviest (if not the heaviest) structures that are used to generate electricity from ocean waves.</td></tr>
<tr><td><u>Classification:</u>
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.</td><td><u>Feasibility:</u>
<u>Environmental impact</u>: 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.
<u>Maintenance:</u> 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.
<u>Manufacturability:</u> 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.</td></tr>
<tr><td><u>Key Statistics:</u>
All statistics are for a 36kW/m wave climate.
<u>Rated power:</u> 10 MW
<u>Weight:</u> 22 000 - 33 000 t.
<u>Reservoir:</u> 5 000 m^3 - 8 000 m^3.
<u>Estimated cost:</u> 13.5 mill. Euros.
<u>Unit cost:</u> 0.11 euros/kWh</td><td><u>Source:</u> http://www.wavedragon.net [2007, 11 March].</td></tr>
</table>

<table>
<tr><td>2.36. WavePlane
</td><td>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.</td></tr>
<tr><td><u>Classification:</u>
Above waterline with an overtopping type PTO.
Line absorber.
Near shore based.
Development stage: full scale tests.</td><td><u>Feasibility:</u>
<u>Environmental impact</u>: Low. It will not impact the beach and the anchoring cable will have minimal impact on marine life.
<u>Maintenance:</u> Low. All the parts are easily accessible and a prototype withstood a ten year high storm in Holland.
<u>Manufacturability:</u> Medium. The whole system can be prefabricated before installation. The WavePlane itself is more difficult to manufacture than most buoy concepts.</td></tr>
<tr><td><u>Key Statistics:</u>
<u>Generation capacity:</u> 200 kW.
<u>Size:</u> 14 m-45 ton model.
<u>Manufacturing cost:</u> $500000-$650000</td><td><u>Source:</u> http://www.waveplane.com/ [2007, 25 February].</td></tr>
</table>

2.37. CETO III



The shore based part of the CETO III 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:

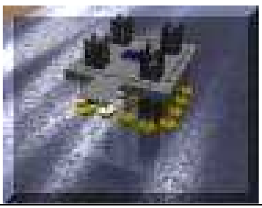
- Floating WEC with a water-pump as PTO.
- Point absorber.
- Max distance off shore: 10km.
- Development stage: CFD modeling (CETO III) and sea trails of CETO II.

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).

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

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



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.

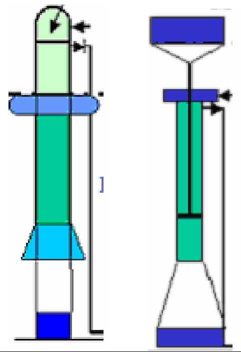
Classification:

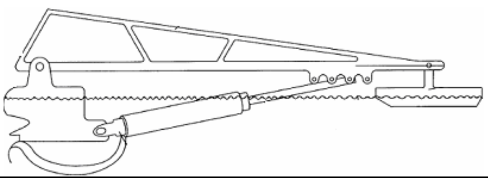
- Above waterline with a water pump as PTO.
- Point absorbing device.
- Development stage: Unknown.

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.

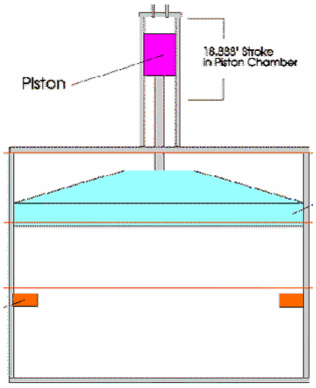
Key Statistics:
Rated power: 5-50 MW.

Developed by: Ocean Motion International
Source: http://www.oceanmotion.ws/ [2007, 1 July].

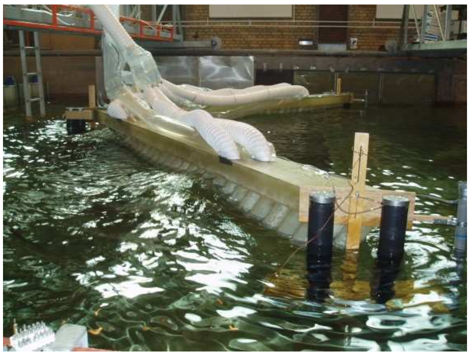
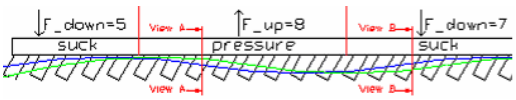
2.39. WAP and WWP 	The WAP has a capsule like structure with a flared open bottom and a sealed top. The WAP (wave air pump) is kept upright by a float that is situated below the waterline and it's anchored by cables. An air pocket is trapped inside the top of the device. The air will either be compressed 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.	**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.
Key Statistics: **Unit cost:** 0.02$/kWh	**Developed by:** Renewable Energy Pumps **Source:** http://www.renewableenergypumps.com/ [2007, 26 July].

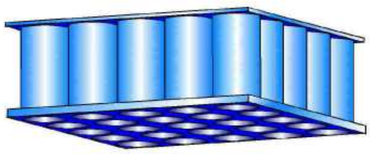
2.40. Waveberg 	A set of connected articulated floats flex when the waves pass under them. This bending motion is used to drive piston pumps witch pumps seawater under high pressure to the shore where it is used to drive a turbine. This turbine powers a generator. This system is very similar to no 1.
Classification: • Above waterline WEC with a water-pump as PTO. • Medium depth (50m) • Development stage: scale model testing.	**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).
Key Statistics: **Generation capacity:** 100 kW per unit. **Total cost:** $1 700 per kW. **Size:** 50m long. **Unit cost:** $0.02 per kWh	**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	**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.
Key Statistics: **Size:** 32 m diameter raft.	**Developed by:** South African inventor (name unknown). **Source:** http://www.engineeringnews.co.za [2007, 1 July].

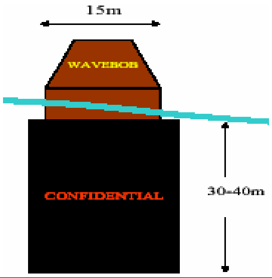
2.42. Seadog  	A buoyancy block, inside of a chamber, is used to drive a piston pump. The pump pumps seawater (under high pressure) to the shore where it is used to drive a hydroelectric system in order to generate electricity or to desalinate seawater. In a typical installation, several devices will 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.
Classification: • Above waterline WEC with a water-pump as PTO. • Point absorber. • Depth: 20m. • Development stage: prototype testing.	**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, witch is easy to use during manufacturing.

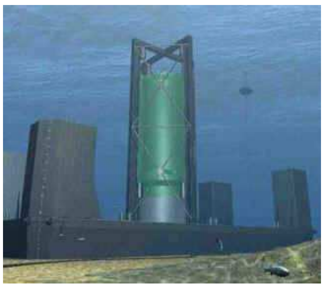
Key Statistics: **Generation capacity:** 55 l/min-82 l/min at a head of 34m-38m. **Size:** It is11m high and 7.8 tons. **Unit cost:** 2.08cents kWh. **Total cost:** $217 million for a 750 megawatt plant.	**Developed by:** Independent Natural Recourses Inc. **Source:** http://www.inri.us/pages/2/index.htm [2007, 11 March].

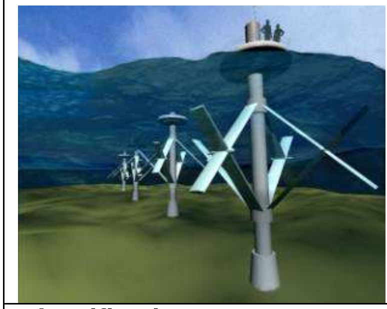
2.43. Leancon   	The system developed by Leancon works on the same principal as the SWEC. It uses a total of 60 tubes witch is situated in two rows and is connected to a v-shape (the v-shape allows it to align with the waves) structure. The crests compress the air, thereby forcing the high pressure valve open and allowing the air to flow into the high pressure collecting tube. This tube feeds the turbine witch 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.	**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.
Key Statistics: • Unknown	**Developed by:** Leancon **Source:** http://www.leancon.com [2007, 11 March].

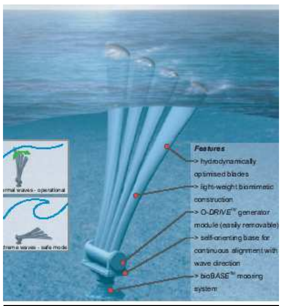
2.44. Pneumatically Stabilized Platform 	The pneumatically stabilized platform or PSP differs from conventional wecs because its primary purpose is to serve as a stable platform (oilrigs, airports, mobile offshore military base real estate ex) and not to generate electricity. The device is made of concrete and it consists of closely packet cylinders that are sealed at the top and open at the bottom with a trapped air pocket inside to keep it afloat. The passing waves cause a pressure difference between the cylinders. One of the considered ptos is to direct the pressurized air through a turbine (the turbine will power a generator) and into the low pressure cylinders.
Classification: • Above waterline WEC with a PTO that utilizes pressure difference. • Multiple point-absorbing WEC. • Multi absorbing WEC (MAWEC). • Development stage:	**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

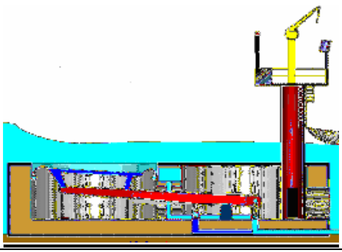
Model testing and computer simulating.	and then towed to the desired location where they will be assembled.
Key Statistics: • Unknown	**Developed by:** Float Incorporated **Source:** http://www.floatinc.com/ [2007, 1 July].

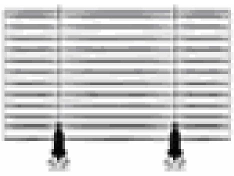
2.45. WaveBob  	The WaveBob is a free floating point absorber that uses a hydraulic system to convert the energy of the waves into electricity (there is very little available information about the system). The hydraulic system uses biodegradable fluids in order to prevent extensive pollution in case 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:** 1000 kW **Size:** 15m diameter **Weight:** 440 tons	**Developed by:** Wavebob **Source:** Bedard, R. & Hagerman, G. 2004. *Offshore Wave Energy Conversion Devices.* EPRI.

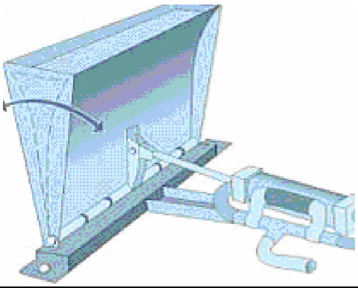
2.46. Archimedes Wave Swing 	It consists of two cylinders the lower one is fixed to the seabed and the upper one is allowed to move swell. An air pocket is trapped inside the upper cylinder; this pocket is compressed when the peak of the wave passes. This forces the float down, thereby compressing the 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 peace 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].

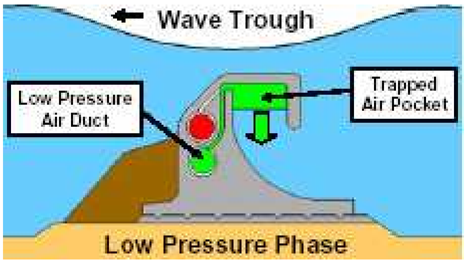
2.47. Wave Rotor 	The Wave Rotor uses two types of rotors, a Darius and a Wells rotor. These rotors are used to generate electricity from the up, down and circular currents in the ocean. The system uses the same principal as wind turbines to generate electricity. The system can achieve good efficiencies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

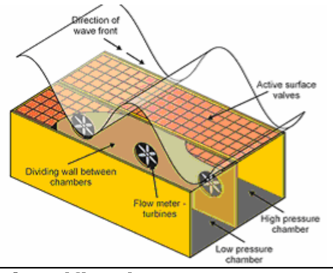
2.48. bioWAVE 	The device is said to move in the same way as an ocean plant if a wave passes. This swaying motion is converted into electricity by the specially developed O_DRIVE *TM* that is situated at the hinge point at the bottom of the device. The device will protect itself if a storm approaches 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. [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 PTO. • Medium depth, 20m. • Development stage: full scale testing.	**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 cables within witch 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.
Key Statistics: **Size:** 20.4m long and 4.6m high.	**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.	**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 (witch 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.
Key Statistics: **Rated power:** 300-600 kW per unit.	**Source:** http://www.aquamarinepower.com/ [2007, 25 July].

2.51. WaveRoller 	A plate (that is anchored to the see floor) uses the forward and backwards motion of the waves to drive a piston pump. The high pressure water is brought to shore by a pipeline where it is used to power a hydroelectric system or used for desalination. It's a modular system; hence its capacity can easily be increased by simply adding more units. The water can also be stored in a reservoir and used when the demand for electricity increases.
<u>Classification:</u> • Bottom mounted WEC with water-pump serving as PTO. • Near shore based (in the breaking waves).	**<u>Feasibility:</u>** **<u>Environmental impact</u>:** Medium. It will occupy a modest amount of space on the ocean bed, but it will have minimal impact on the beach. **<u>Maintenance:</u>** Medium. The pump is totally submerged, making access difficult, but the electricity generation system (witch is the most critical component) is on the shore. The units can also be serviced separately, allowing uninterrupted power generation. **<u>Manufacturability:</u>** Good. The system uses mostly proven technology and the newly developed parts are easy to manufacture.
<u>Key Statistics:</u> **<u>Generation capacity:</u>** Depends on the number of modules installed.	**<u>Developed by</u>:** AW-Energy **<u>Source</u>:** http://www.aw-energy.com [2007, 25 February].

2.52. SWEC (Stellenbosch wave energy converter)  	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).
<u>Classification:</u> • 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	**<u>Feasibility:</u>** **<u>Environmental impact</u>:** Medium. The device requires a relatively large structure that will occupy the seabed. However it has no moving parts that interfere with marine life. **<u>Maintenance:</u>** 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. **<u>Manufacturability:</u>** Medium. The device requires a lot of under water installation witch is quite expensive.
<u>Key Statistics:</u> **<u>Generation capacity:</u>** 5MW	**<u>Developed by</u>:** Mr. Muller from University of Stellenbosch **<u>Source:</u>** 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].

Abbreviations:
OWC oscillation water column