POWER GENERATION THROUGH ENERGY FROM OCEAN WAVES

1.0 INTRODUCTION

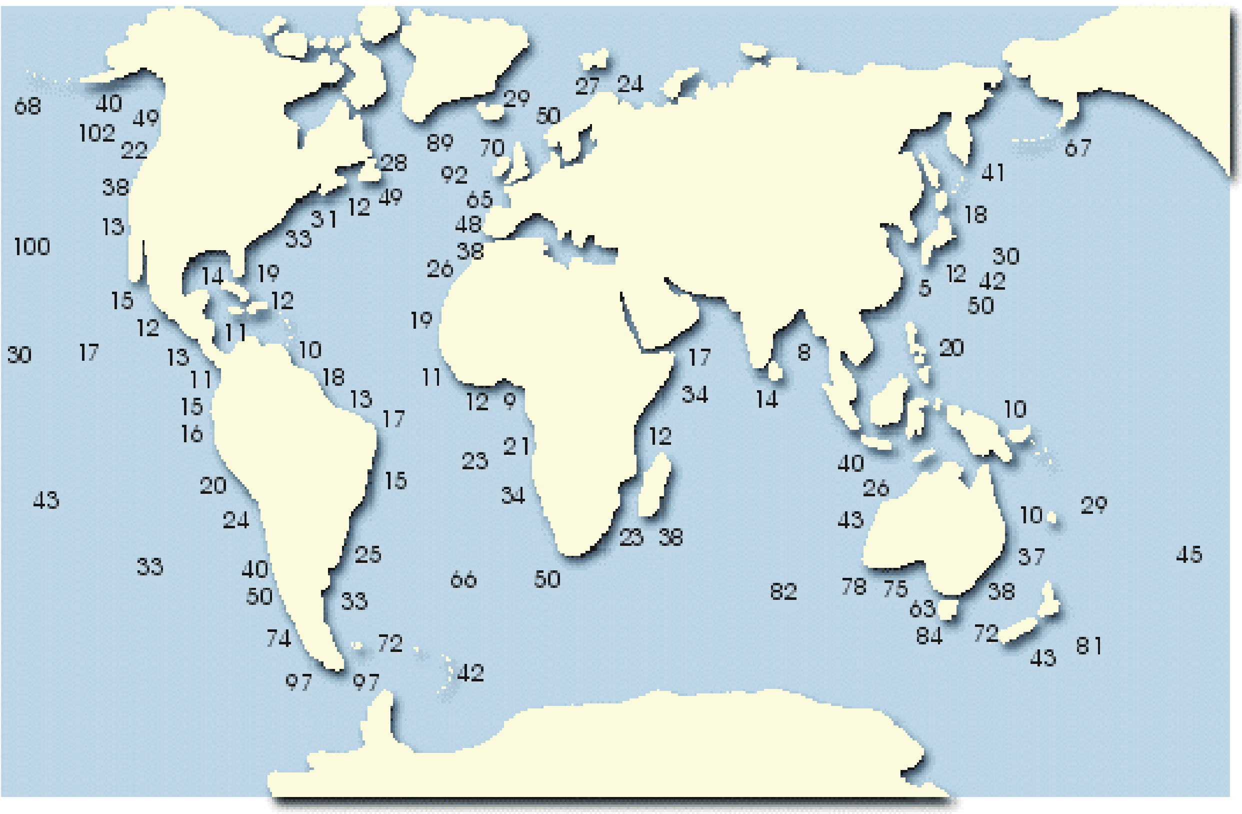
The growing demand for energy is fueling a drive for the extraction of sustainable sources. The oceans, which cover 70 per cent of the world, harbour a vast untapped source of renewable energy in the form of waves. According to the World Energy Council, the global energy available from wave energy conversion is 2000 TWh per year. Tapping just 0.2 per cent of this energy would satisfy the current global demand for electricity.

Waves are the most concentrated source of kinetic energy and are a free and sustainable energy resource, created by wind blowing over the ocean's surface. As the distance becomes greater, the waves become higher and longer. The energy is stored in this way until it reaches the shallows or beaches where the energy is released, sometimes with disastrous effects. New methods of utilizing this energy are now being explored and tested.

Mid to high latitude locations offer the best wave resource. The Pacific Ocean is the most consistent ocean for wave energy and offers an abundant source of power. Almost all of the wave energy is concentrated in the upper few meters of the ocean. This energy from the wave front is proportional to the square of the wave height. ($P=0.98\ H^2\ {}^*T$).

The ability to rapidly assess the resource potential is greatly enhanced by the use of satellite-derived wave measures and global ocean weather databases. Local geographic variations and physical site characteristics, including distance to end-users, are key criteria in developing economically livable projects. A main component in project costs is the transmission and connection of the energy to regional grids – sometimes out weighing the cost of construction of the wave energy conversion technology.

Annual average wave power in kilowatts per metre of crest width for various sites around the world



There are many promising sites around the world, any site on the map above with an average wave power level of over 15kW per metre has the potential to generate wave energy at competitive prices. Many countries recognise this potential and are seriously looking at how to exploit it.

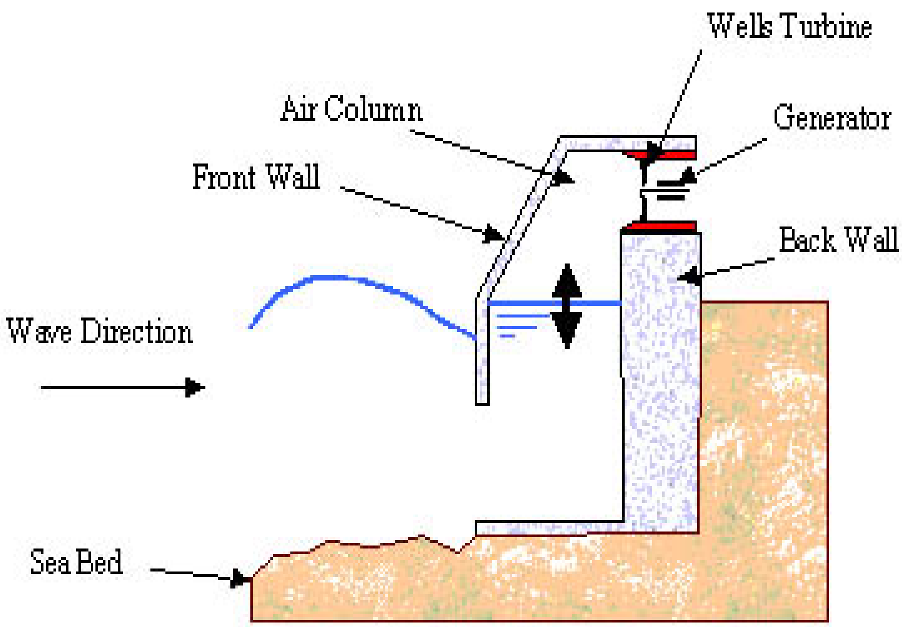
2.0 TECHNOLOGY OPTIONS

The technology for potential mainstream power generation is available today. Over 400 patents on wave energy devices have been filed. Although there are various designs, there are three basic ways of converting the oceans's kinetic energy.

- The first method is a tapered channel which focuses the wave energy into an elevated reservoir. A turbine is spun when the water returns to sea level. These systems can be located both onshore and off-shore. An onshore example is Tapchan, which operated in Norway from 1985 to 1988. An offshore example is the floating artificial beach called, 'Merrimack', coated by US Myriad Technologies.

- A second method of converting the wave energy is capturing the vertical motion of a float. Various 'heaving buoy' mechanisms have been advanced to capture the motion of the sea including hydraulic pumps, spring and piezoelectric polymers. An example is Sea Power & Associate's wave rider design that utilizes a special hydraulic pump to create hydraulic pressure as the buoy is accelerated by the passing wave.

- The third method utilizes an oscillating water column (OWC). Water rising in a cylinder forces air out through a simple turbine. The retreating water forces are back into the chamber again, passing through a turbine.



Principle of Oscillating Water Column (OWC)

<u>SHORELINE DEVICES</u>

Being constructed at the shoreline, these devices are the easiest to fabricate and maintain but they capture much less energy than offshore devices. Shoreline devices have the advantage of relatively easier maintenance and installation and do not require deep-water moorings and long underwater electrical cables. The less energetic wave climate at the shoreline can be partly compensated by the concentration of wave energy that occurs naturally at some locations by refraction and/or diffraction. The three major classes of shoreline devices are the oscillating water column (OWC), the convergent channel (TAPCHAN) and the Pendulor.

- The OWC comprises a partly submerged concrete or steel structure, which has an opening to the sea below the water line, thereby enclosing a column of air above a column of water. As waves impinge on the device, they cause the water column to rise and fall, which alternately compresses and depressurises the air column. This air is allowed to flow to and from the atmosphere through a turbine which drives an electric generator. Both conventional (i.e. unidirectional) and self- rectifying air turbines have been proposed. The axial-flow Wells turbine, invented in the 1970s, is the best known turbine for this kind of application and has the advantage of not requiring rectifying air valves. A number of OWC devices have been installed world-wide, with several of them being built into a breakwater to lower overall construction costs.

- The Tapchan comprises a gradually narrowing channel with wall heights typically 3 to 5 m above mean water level. The waves enter the wide end of the channel and, as they propagate down the narrowing channel, the wave height is amplified until the wave crests spill over the walls to a reservoir which provides a stable water supply to a conventional low head turbine. The requirements of low tidal range and suitable shoreline limit the world-wide replicability of this device.

- The Pendulor device consists of a rectangular box, which is open to the sea at one end. A pendulum flap is hinged over this opening, so that the action of the waves causes it to swing back and forth. This motion is then used to power a hydraulic pump and generator. World-wide, only small devices have been deployed.

3.0 TECHNOLOGY STATUS:

A number of shoreline oscillating water column (OWC) devices have been installed world-wide, with several of them being built into breakwaters to lower overall construction costs.

Studies for a European pilot OWC plant started in 1992 under the sponsorship of the European Commission. The construction of the plant, started in 1995 on the shoreline of the island of Pico, Azores. It will be which will be equipped with two 500 kW Wells turbo-generators, one of which will utilise variable pitch blades. The plant is expected to become operational in 1998-9.

Pioneered by the company WaveGen, their system known as Land-installed marine Power Energy Transformer or LIMPET, uses a highly-reliable simple air turbine and is designed in such a way that all electrical components are on land. Limpet has been developed to its current commercial stage as a collaborative project between Wavegen and Queens University, Belfast who have been involved in the research and development of wave power generation for over 20 years. The funding for the prototype was supported by the EU Joule programme. During this time they have been responsible for the development of a pilot plant on the Island of Islay, off the West coast of Scotland. This 75kW shoreline device started to generate electricity in 1991 and has been in successful operation for 10 years. This has provided valuable information regarding the performance of the system and its components and in the areas of design, hydrodynamics and grid integration.

A Limpet 500 shoreline module was installed in November, 2000. This supplies power to the Island grid. Limpet is located on the Isle of Islay in Scotland, UK, and is currently delivering 500kW of power to the national grid. The company evolved from a government-supported laboratory into a private company and has recently secured a 20-year power purchase contract with Scottish Power.

A 150 kW pilot OWC was built onto the breakwater of the Vizhinjam Fisheries Harbour, near Trivandrum in India in 1991. This has functioned successfully, providing data on the in-service performance of the Wells' turbine and the mechanical and electrical plant. After the initial tests, the plant has been used to test different types of generating equipment. This information has been used to produce new designs for a breakwater comprised of 10 OWC units with a total capacity of 1.1 MW.

A five chambered OWC was built as part of the harbour wall at Sakata Port in Japan. The device became operational in 1989 but, after a test programme, only three air chambers were used for energy production. A turbogenerator module of 60 kW has been installed and is being used as a power generator unit for demonstration and monitoring purposes. This is expected to be replaced later by a larger and more powerful turbine (possibly 200 kW).

In 1985, a 500 kW shoreline OWC was installed at Tofteshallen in Norway. This demonstration scheme functioned well until destroyed in a storm three years later.

In 1983 a 40 kW steel and concrete OWC was deployed on the shoreline structure at Sanze, Japan for research purposes. This functioned for several years and was then decommissioned and examined to investigate its resistance to corrosion and fatigue.

A scheme comprising 10 OWCs was installed in front of an existing breakwater at Kujukuri-Cho in Japan. The air emitted from each OWC was passed through a manifold into a pressurised reservoir and used to drive a 30 kW turbine.

A prototype 130 kW OWC was deployed at Haramachi, Japan in 1996. This uses rectifying valves to control the flow of air to and from the turbine, in order to produce a steady power output. Tests on this device will continue until 1998.

In 1989, an experimental 3 kW shoreline OWC was installed on Dawanshan Island (in the Pearl river estuary in China), which supplied electricity to the island community. This is being upgraded with a 20 kW turbine.

Nearly all the devices withstood the severe wave loadings imposed on them and demonstrated that wave energy can be harnessed to provide useful energy. However, all these devices can be considered as prototypes and, as such, they were not intended to be commercially competitive. In all cases, important lessons have been learned relating to wave loading, capture efficiency, energy conversion efficiency or design of mechanical and electrical plant for variable wave power inputs. However, there appear to have been few (if any) attempts to collate and build on this international experience.

<u>NEARSHORE DEVICES:</u>

Nearshore devices are situated in shallow waters (typically 10 to 25 m water depth). Again the OWC is the main type of device, with several designs having been deployed worldwide. There have been a number of shoreline wave energy devices installed world-wide, primarily oscillating water column designs.

- The OSPREY (Ocean Swell Powered Renewable EnergY) is a steel OWC, designed by ART Ltd (UK), which was built primarily with industrial funding. It was designed for bottom mounting in 14m water depth at Dounreay in the North of Scotland. When completed, it was expected to generate 2 MW of electric power from four Wells turbines. In addition, it can act as a support structure for a 1.5 MW wind turbine. The structure was built in a shipyard and launched from the River Clyde in August 1995. However, due to damage during launch and installation, the device structure (but not the equipment) was destroyed by bad weather before repairs could be carried out. It has been announced that a new OSPREY will be built in 1999.

- A 60 MW floating OWC (the Mighty Whale) is to be deployed in the seas to the east of Japan in the near future. If the device achieves its predicted performance and reliability, it is intended that this will be the start of a large, national deployment programme.

- A floating OWC known as the Backward Bent Duct Buoy was deployed in Japan in 1988. This is similar to a conventional OWC but the opening faces towards the shoreline. A prototype device was tested at sea.

Again, all these devices were prototypes and were deployed only to gain useful experimental data and operational experience. In contrast, several hundred, small-scale wave-powered navigation buoys have been deployed commercially by China.

OFFSHORE DEVICES:

Offshore devices are situated in deeper water, with typical depths of more than 40 m. Several different designs having been deployed world-wide, with many more still at the design stage. Offshore devices exploit the more powerful wave regimes available in deep water (typically more than 40 m water depth). In order to extract energy from the waves, the device needs to be at or near the water surface and requires flexible moorings and electrical transmission cables. Several methods have been proposed to convert the oscillating motion of the body into useful mechanical energy and prototypes of some of these concepts have been deployed. Some of the representative devices that have been deployed are listed below:

- **The Swedish Hosepump** has been under development since 1980. It consists of a specially reinforced elastomeric hose (whose internal volume decreases as it stretches), connected to a float which rides the waves. The rise and fall of the float stretches and relaxes the hose thereby pressurising sea water, which is fed (along with the output from other Hosepumps) through a non-return valve to a central turbine and generator unit. A system of five modules connected in parallel to a single turbine and generator was installed in Lake Lygnern. During 1983-4 a plant of three modules with turbine and generator was installed in the open sea at Vigna. There were losses of equipment in some severe storms but the tests proved the feasibility of this approach. Currently, there are plans for deployment of demonstration IPS/Hosepump schemes in several countries.

- **The McCabe Wave Pump** consists of three rectangular steel pontoons which move relative to each other in the waves. The key aspect of the scheme is the damper plate attached to the central pontoon, which ensures that it stays still as the fore and aft pontoons move relatively to the central pontoon by pitching about the hinges. Energy is extracted from the rotation about the hinge points by linear hydraulic pumps mounted between the central and two outer pontoons near the hinges. The device was developed to supply potable water (by reverse osmosis) but can also be used to generate electricity (via a hydraulic motor and generator). This has been under development since 1980. A 40 m long prototype was deployed off the coast of Kilbaha, County Clare, Ireland, with a further commercial-scale device is currently being built for deployment in 1999.

- **The floating wave power vessel** is a steel platform containing a sloping ramp, which gathers incoming waves into a raised internal basin. The water flows from this basin back into the sea through low-head turbines. In these respects it is similar to an offshore Tapchan but the device is not sensitive to tidal range. A 110 kW pilot floating prototype device was tested successfully off the western coast of Sweden in about 1991/2.

- **The Danish Wave Power float-pump** device uses a float which is attached to a seabed mounted piston pump; the rise and fall motion of the float causes the pump to operate driving a turbine and generator mounted on the pump. The flow of water through the turbine is maintained as uni-directional through the incorporation of a non-return valve. Danish Wave Power have been testing their design for a float-pump device at Hanstholm in Denmark since 1989.

- **The Pelamis**. The Pelamis device is composed of a number hollow, cylindrical sections linked by hinged joints. These sections point into the oncoming waves and move with respect to each other as the waves pass down their length. Again, energy is extracted by hydraulic rams at the joints, which drive electrical generators. Here the emphasis is on building the device with 100 % 'off the shelf' components. A device is being developed for deployment in Scotland, which is rated at 375kW and is 130 m long and 3.5 m in diameter.

- **The Archimedes Wave Swing**. This consists of a cylindrical, air filled chamber (the "Floater"), which can move vertically with respect to the cylindrical "Basement", which is fixed to the sea bed. The air within the 10m - 20m diameter Floater ensures buoyancy. However, a wave passing over the top of the device, alternatively pressurises and depressurises the air within the Floater, changing this buoyancy. This causes the Floater to move up and down with respect to the Basement and it is this relative motion that is used to produce energy. This is the most powerful device currently under construction: a 2 MW Pilot scheme is being built for Portugal.

An early study for the EC indicated that the Tapchan shoreline scheme was the most developed wave energy device. It utilises mature technology, with the only innovation being the design of the wave concentrating flume.

Some shoreline and nearshore OWC devices are nearing the end of the development stage, with several near full-sized plants having been deployed. However, these schemes have yet to prove their integrity and reliability in in-service conditions. Should it prove successful, the OSPREY might achieve commercial status in the next few years, with other designs of OWC (e.g. the Limpet) following shortly thereafter. Most of these devices have certain areas where the technology is still developing (e.g. improved hydrodynamic characteristics, Wells turbines). These have been areas where R&D has been supported by the JOULE programme.

There are many designs for offshore devices. Most of these are still at the R&D stage. All of them contain some novel technology, which has yet to be proven, for instance for the two devices closest to commercial demonstration:

The Swedish Hosepump requires that the long term reliability of the Hosepump and valving system be demonstrated.

The McCabe Wave Pump requires demonstration of both its theoretical capture efficiency and reliability.

Australian oceanographer, Tom Denniss, has taken the concept of the OWC one step further by focusing the on-coming waves with a parabolic wave reflector to concentrate and amplify the wave’s energy. His company, Energetech (Australia) has tested this system at 1:25 scale at the University of South Wales. The testing demonstrated a wave height enhancement of two to four fold. The company estimates that parabolic bays 40 meters by 20 meters would generate between 250kW to 1MW per day. A demonstration facility is underway in Port Kembla. The company is in discussions with independent power producers in Hawaii and the Pacific Northwest for future projects.

Several promising technologies in wave power are in the feasibility phase. Some governments have been very supportive efforts to develop renewable ocean-based technologies. For example, the Danish government is supporting the development of 40 new concepts in wave energy conversion. As government change policies directed toward inclusion of renewable energy systems, technologies to harness the oceans processes with their tremendous potential will need to be carefully considered.

List of some major wave energy projects:

Device	**Company**	**Location**	**Operational from**
Tapchan		Norway	1985-88
5kW Pendulor		Hokkaido, Japan	1983
Pendulor			1994
OWC 150 kW		Vizhinjam Fisheries Harbour, Trivandrum, India	1991
OWC 75 kW		Islay, Scotland	1991
LIMPET 500, a 500 kW oscillating water column	Wavegen	Islay, Western Scotland	November 2000
Two 375 kW Pelamis ('Sea Snake') Wave Energy Convertors	Ocean Power Delivery	off the West coast of Islay	mid-2002 (expected)
400 kW Floating Wave Power Vessel (FWPV)	Sea Power International	off the Shetland Islands	October 2002 (expected)

The successful deployment of any wave energy device represents a major engineering challenge. Not only must it effectively convert the kinetic energy of the water into electricity, but it must survive the extremely challenging environment of the sea or ocean. It must overcome such factors as:

- salt water corrosion;
- marine fouling (barnacles, seaweed, etc.);
- access difficulties; and
- storm damage.

Rough weather, in particular, has often been thought to rule out wave energy, especially offshore devices. However, devices have survived off the coast of Sweden and Japan for several years, and testing has been performed on a large number of prototypes.

Early attempts in installing wave energy converter (WEC) prototypes have met with, at best, partial success. Many of them have failed due to wave storms such as the multiphase oscillating water column in Norway and the Osprey in Scotland or due to economic problems such as the Tapchan in Norway or political reasons such as the previous UK wave programme. The result is a general lack of confidence in the technology. The main countries involved with the development of wave power have been Denmark, India, Ireland, Japan, Norway, Portugal, UK and USA.

4.0 TECHNO-ECONOMICS

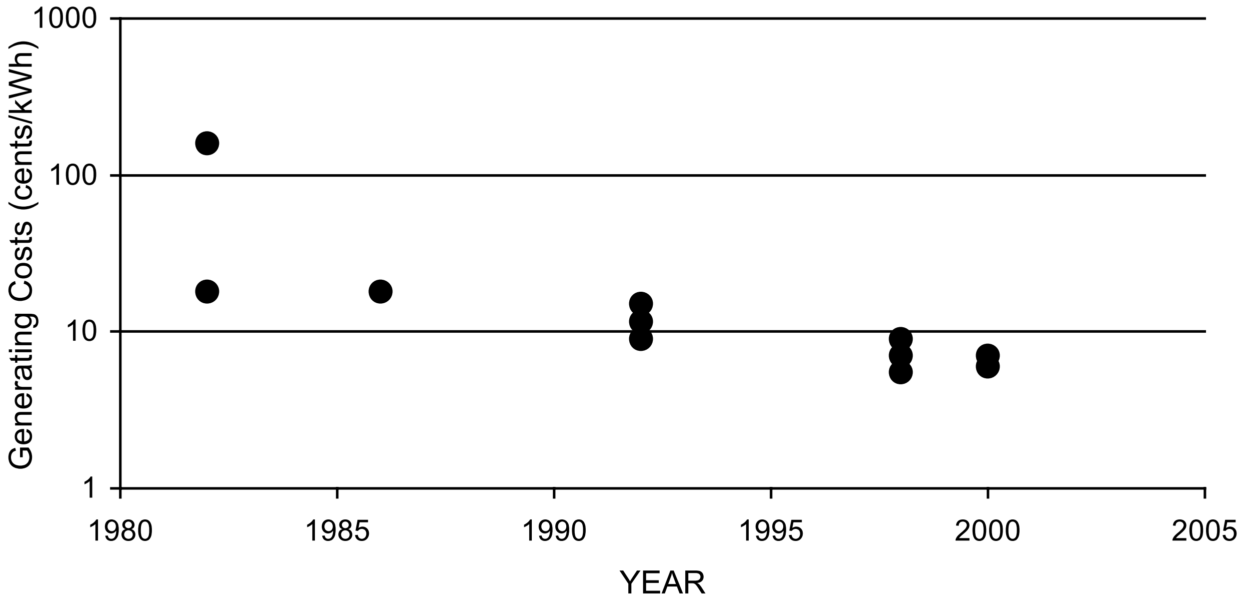
The economic viability of wave energy is the leading uncertainty in securing capital for development of concepts into commercial ventures. The cost of harnessing wave energy has declined dramatically over the past decade. Now, most developers are targeting <$0.10/kWh and moving toward $5.05/kWh for their next generation designs.

The main reason for the efficiencies is that redesigns have incorporated technology break through and utilize the greater computational facilities available today to design hydro dynamically efficient systems. By incorporating experience gained from earlier prototypes of wave energy devices and experiences gained as offshore oil and gas prospects move into deeper water, designers and engineers can build more efficient, reliable systems for the offshore wave conditions.

It has been stated that if the development programmes of companies engaged in this activity go forward, then the global contribution of wave power is over 2 TWh/yr. This represents over $200 billion in planned investment. While this estimate may be overly optimistic, any forecast toward commercialization must consider the political attitudes and energy industries attitudes.

At current costs of UK 4-8 p/kWh, wave energy is significantly more costly than electricity from an average fossil fuel power station (about 2 - 3 p/kWh). But it must be recalled that wave and tidal energy are both at an 'immature' stage of their development, and that a true picture of the cost of electricity from wave and tidal energy will only be available after large-scale devices have been operating for some time. Already, the cost of wave and tidal energy has fallen over the past 10 to 15 years and is competitive in niche markets, such as remote islands. As the technology develops, with more full-size demonstrators and economies of scale beginning to have an impact, it would be reasonable to expect the price to fall even lower.

Cost of Harnessing Wave Energy has declined dramatically over the past decade



5.0 FUTURE PROSPECTS

Oceans of energy await harnessing. Various companies, which have developed their own technology, are in the process of proving their technology at sea. Several demonstration projects are planned over the next several months including those by sea power & Associates (California), US Myriad Technologies (New jersey), Ocean Power Technology (New Jersey), S.D.E(Israel),and Ocean Power Delivery(UK), among others.

The European market will most likely dominate wave power over the next decade. The US energy market is turning toward hydrocarbons for their next generation of power plants. Other markets lack the level of investment and long-term support necessary to undertake the risk of wave energy conversion. The European market has access to long-term financial support abundant prospective purchasers, and extensive grid net-work and is aware of the increasing requirements for green energy to lead the way in developing this sector.

Recent forecasts report installed wave energy capacity will reach at least 50MW by the end of the decade. Shoreline-based technologies will account for about 40 per cent of this projection. As advances in offshore oil and gas technology in mooring and cabling gain access to the wave energy sector, offshore wave devices will gain momentum by 2010.

Along the pacific coast of Canada, the British Columbia utility, BC Hydro, is soliciting proposals for the development of wave energy demonstration projects (4 MW capacity) and expects to reach a goal of 100MW capacity from wave energy conversion systems in the near future. Concerns about extraction efficiency, cost of energy, and energy pricing will be addressed over the course of the demonstration project.

Because wave energy is a highly reliable, predictable source of energy, systems could be designed to enhance grid stability and maintain grid voltage. Imagine a series of wave buoy forms off the pacific coast from British Columbia to Baja California, all connected to the grid providing voltage control along the West Coast cor5ridor from BC Hydro to Washington State and the Bonneville power Authority and hooked to California’s Edison’s systems.

The commitment of countries to take steps to reduce emissions of carbon dioxide and other greenhouse gases will spur commercialization of these technologies. Renewable energy systems from the ocean exist and will be developed further as energy demand escalates

TECHNICAL DETAILS OF SOME WAVE ENERGY CONVERTORS

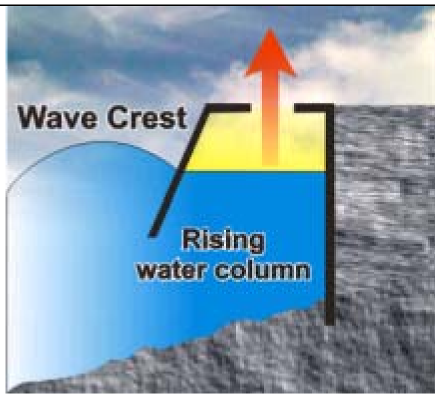
WAVEGEN PRODUCTS:

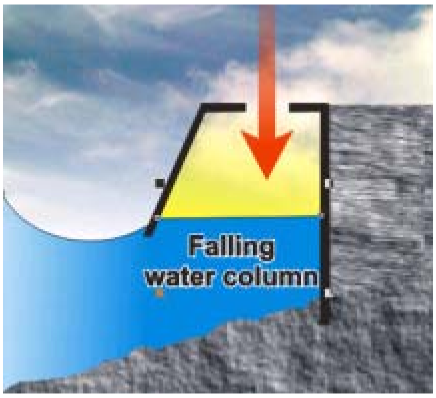
The LIMPET 500 0.5MW shoreline wave power station designed to operate on exposed shores for local or island power generation and port development.

The OSPREY 2000 2MW near shore gravity anchored wave station designed for regional power generation and coastal protection.

The WOSP 3500 3.5MW near shore combined wave and wind station.

The Collector and Oscillating Water Column (OWC)
The wave energy collectors used in Wavegen’s Limpet and Osprey modules are in the form of a partially submerged shell into which seawater is free to enter and leave. As the water enters or leaves, the level of water in the chamber rises or falls in sympathy. A column of air, contained above the water level, is alternately compressed and decompressed by this movement to generate an alternating stream of high velocity air in an exit blowhole. If this air stream is allowed to flow to and from the atmosphere via a pneumatic turbine, energy can be extracted from the system and used to generate electricity.
Power Off Take – The Turbo Generator Wells turbines are used to power the electricity generators. Wells turbines have the unique property of turning in the same direction regardless of which way the air is flowing across the turbine blades. Thus, the turbines continue turning on both the rise and fall of wave levels within the collector chamber. The turbine drives the generator, which converts this power into electricity.





Limpet 500 Technical Specification

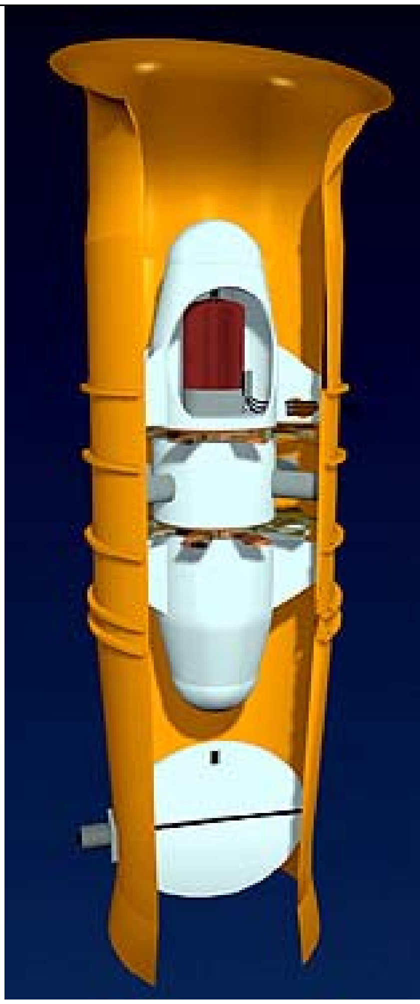
The Limpet shoreline wave energy concept has many similarities with the Osprey 2000 near shore unit. In particular it employs the same oscillating water column principle, and uses a combination of Wells turbines and induction generators in order to convert the pneumatic power captured into electricity. Whilst the Osprey is designed to be free standing in the near shore, the Limpet is based upon a very different structural concept and is built into the existing shoreline, relying on the existing cliff edge for support. Alternatively Limpet units may be incorporated within rubble mound or caisson breakwaters to provide self-financing coastal protection schemes.

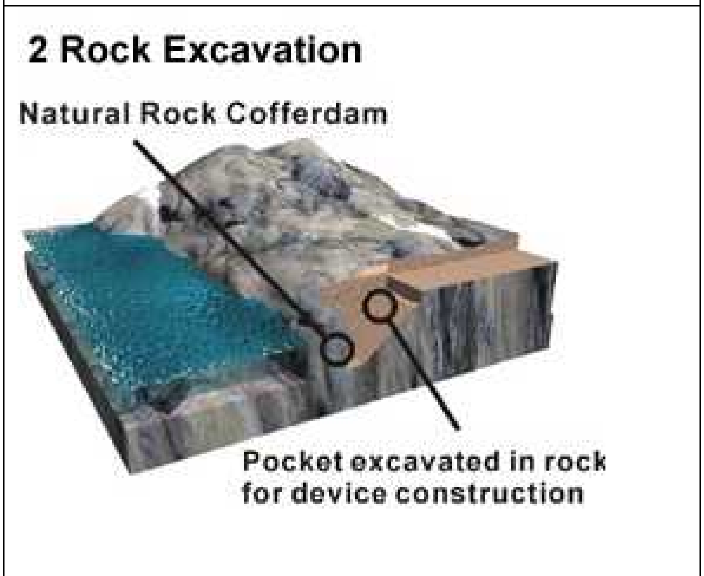
A standard Limpet unit comprises an inclined oscillating water column that couples well with the surge dominated wave field adjacent to the shore. The water depth at the entrance to the Oscillating Water Column is typically 7m and the water plane area is 170m2. The performance has been optimised for annual average wave intensities of between 15 and 25kW/m. The water column feeds a pair of counter-rotating Wells turbines each of which drives a 250kW generator, giving a nameplate rating of 500kW. The turbines are carefully sized to match the water column impedance to that of the power take off train, thereby maximising the power transfer from the water column.

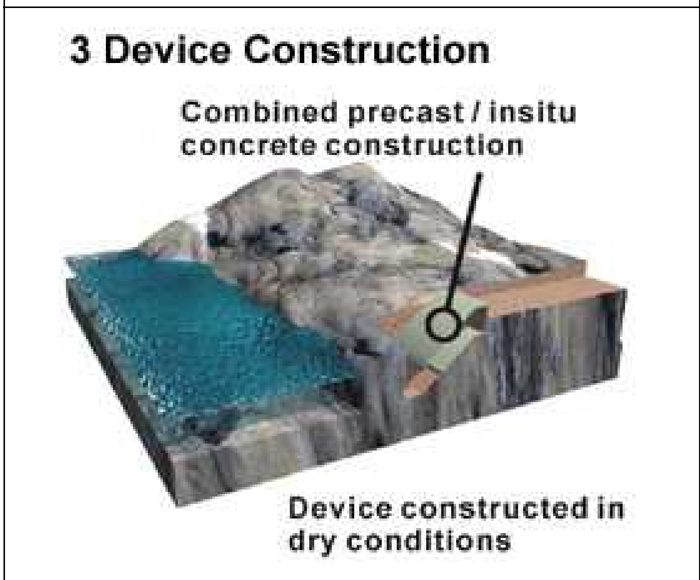
The Limpet design has been developed for ease of construction and installation with a minimal reliance on the existing coastline for suitable site selection. The low profile of the structure gives a low visibility so that in contrast to coastal wind energy schemes, Limpet does not create a significant visual intrusion.

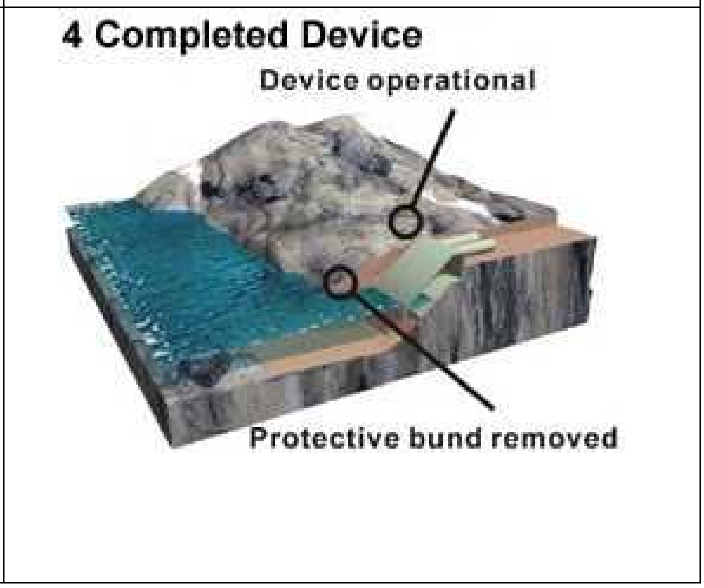
DESCRIPTION:

Wavegen's devices are comprised of two basic elements; a collector to capture the wave energy and a turbo generator to transform the wave power into electricity.









OSPREY 2000

OSPREY is an acronym for Ocean Swell Powered Renewable EnergY, and is a near shore wave powered station. It is designed to operate in 15m of water within 1km of the shore, generating up to 2MW of power for coastal consumers. Key innovative features of the near shore technology are:

- Modular low cost composite steel/concrete manufacture
- Rapid installation and decommissioning
- Minimal environmental impact.
- 60 Year structural design life with 20 year M&E plant upgrades

The experience of constructing, installing and decommissioning Osprey I has proved invaluable and has accelerated the design of subsequent devices. The new Osprey 2000 will be a composite construction with installation procedures designed to minimise the time required to install in open waters.

Following extensive technical and commercial evaluation by ETSU (Energy Technology Support Unit) on behalf of the Irish government, the company has been advised that it is the sole successful bidder for the AER III (Alternative Energy Requirement III) wave energy tender in the Republic of Ireland. It is anticipated that Osprey 2000 will now be installed in the Republic of Ireland, a country which enjoys one of Europe’s best wave climates with a near shore resource of 48TWhrs, yet which currently imports more than 90% of its energy requirements.

Technical Specification

The Osprey wave energy system developed by Wavegen is the world’s first commercially oriented approach to capturing power from ocean waves. Based on the Oscillating Water Column (OWC) principle, the Osprey pilot full-scale prototype plant represents a major advance in renewable energy technology and in the generation of electrical power by environmentally friendly and non-polluting means.

With a rating of 2MW the Osprey is an ideal unit for electrical power generation into an existing grid or, with a standby support, as a prime power source for remote island communities. The system is equally suited to powering desalination plant. The Osprey, which rests directly on the seabed is designed to operate in the near shore environment in a nominal mean water depth of 15m. Optimum performance will be achieved when driven by a long ocean swell generated over a fetch of more than 400km. Lesser seas may also produce satisfactory performance. In extreme storms the incoming power will be greater than the device capacity and the automatic control system will cap power generation at the maximum rating. The pneumatic power of the OWC is converted to electricity via self rectifying Wells turbines and specially designed induction generators. Power is brought ashore by sub-sea cable.

In addition to its role as fuel free power source, Osprey devices can be used singly or in an array to modify coastal wave regimes. Because they take power out of the waves, the sea to the landward side of the Osprey units is relatively calm. The "lagoon" created behind the Ospreys can contribute towards coastal defences and harbour developments or can be used to create a recreational area for water sports. Experience has shown that the presence of an Osprey structure constitutes an artificial reef, which is rapidly colonised by aquatic flora and fauna. This improves the area for both commercial and recreational fishermen. By these means Osprey offers environmental benefit, a stark contrast to conventional power generation.

The standard Osprey design relies on a concrete caisson structure that may be readily incorporated into caisson based breakwater structures. By substituting Osprey units for conventional breakwater caissons, breakwater schemes can become self-financing.

WOSP 3500

WOSP is an acronym for Wind and Ocean Swell Power, and is an integrated near shore wave and wind powered station. It is designed to operate much the same as the Osprey 2000 device, generating 3.5MW of power, and offers major advances in accessing multiple offshore renewable energy resources.

Benefits include:

- Greatly increases accessible renewable energy resource
- Substantial installation and infrastructure cost reductions
- Integrated project development reduces fixed costs
- Offshore siting minimises visual intrusion of wind turbines
- Combined wind and wave energy fluxes complement power output
- Wind turbines preinstalled before launch avoids costly offshore installation cranes

Wosp will demonstrate the ability to maximise the renewable resource available from the near shore environment. Adding 1.5MW of Wind generated capacity will bring the installed capacity up to 3.5MW for each device

Technical Specification:

The addition of a marinised wind turbine to an Osprey creates a Wosp unit. The extra structural loading from a wind turbine of up to 1.5MW is low compared to the wave loading for which the Osprey structure is designed and it is well within the capacity of the Osprey base to support a wind turbine. It is a logical extension of the Osprey concept to share the base between wind and wave generators to provide a combined 3.5MW nameplate capacity per device. The power generation of the wind and wave units is integrated through the on board power electronics and fed via a common cable to shore.

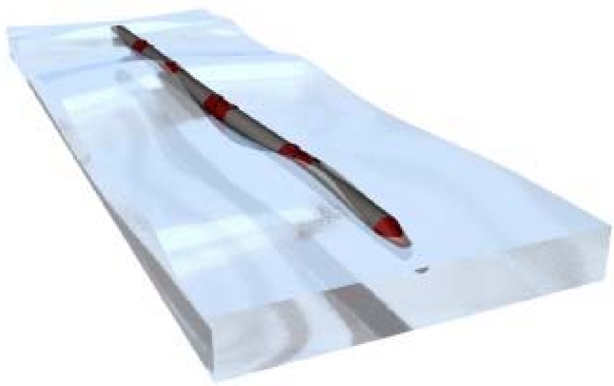
OCEAN POWER DELIVERY WAVE ENERGY CONVERTER: PELAMIS

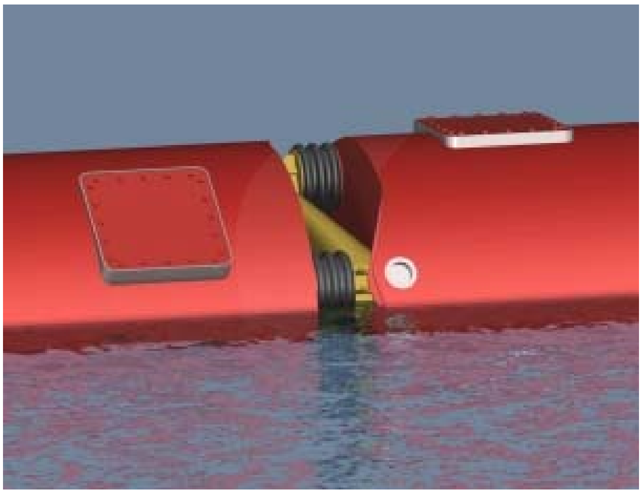
Ocean Power Delivery Ltd is developing a novel offshore wave energy converter called Pelamis. Building on technology developed for the offshore industry, the Pelamis has a similar output to a modern wind turbine. The first full-scale pre-production prototype will be built later this year and tested at the proposed UK Marine Energy Test Centre in Orkney. The company has won a bid for a 750kW project off Islay, Scotland under the Scottish Renewables Obligation and has recently signed a memorandum of understanding with BC Hydro to develop a 2 MW project off the coast of Vancouver Island, Canada.

It is anticipated that these and other projects will form the basis for larger, multi-machine 'wave-farms'. A typical 30MW installation would occupy a square kilometre of ocean and provide sufficient electricity for 20,000 homes. Twenty of these farms could power a city such as Edinburgh.

The Pelamis is a semi-submerged, articulated structure composed of cylindrical sections linked by hinged joints. The wave induced motion of these joints is resisted by hydraulic rams which pump high pressure oil through hydraulic motors via smoothing accumulators. The hydraulic motors drive electrical generators to produce electricity. Power from all the joints is fed down a single umbilical cable to a junction on the sea bed. Several devices can be connected together and linked to shore through a single seabed cable.

A novel joint configuration is used to induce a tuneable, cross-coupled resonant response which greatly increases power capture in small seas. Control of the restraint applied to the joints allows this resonant response to be 'turned-up' in small seas where capture efficiency must be maximised or 'turned-down' to limit loads and motions in survival conditions. The complete device is flexibly moored so as to swing head-on to the incoming waves and derives its 'reference' from spanning successive wave crests. A 750 kW device will be 150m long and 3.5m in diameter.





Source:

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