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System Level Design, Performance and Costs - San Francisco California Energetech Offshore Wave Power Plant

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1. Introduction and Summary

This document describes the results of the system level conceptual design, performance and cost study of both a feasibility demonstration-scale and a commercial-scale wave power plant installed off the coast of San Francisco, California. For purposes of this point design study, the selected demonstration deployment site is within the boundaries of an exclusion zone at a water depth of 15m, the commercial plant deployment is expected to be located in water depths of 15m-40m. These three assumptions should be reevaluated during the detailed design phase of the project. This conceptual design study was carried out using the methodology and standards established in the Design Methodology Report (Reference 1), the Power Production Methodology Report (Reference 2) and the Cost Estimate and Economics Assessment Methodology Report (Reference 3).

The San Francisco Public Utilities Commission (SFPUC) Water Pollution Control Division operates the Oceanside Wastewater Treatment Plant at 3500 Great Highway, San Francisco. The plant discharges treated wastewater effluent through an outfall pipe extending approximately four miles into the ocean on shoal-free sandy bottom. Because the outfall pipe is already owned and operated by the City and County of San Francisco, this scenario offers an ability to land the power transmission cable at a low cost. The location although surrounded by the Monterey Bay National Marine Sanctuary exists in an exclusion zone, which extends approximately six miles offshore and is not part of the Monterey Bay National Marine Sanctuary. The SFPUC Water Quality Bureau biology staff conducts regular environmental monitoring in the area including sediment and community analyses. Siting the offshore wave demonstration plant within the confines of the exclusion zone offers the potential for ease of permitting.

The Oceanside Facility National Pollution Discharge Elimination System permit requires ongoing marine biological surveys. The original Environmental Impact Report (EIR) for the Treatment Facility is available for review, and recent annual and five-year summary reports on the biological monitoring program are published on the www.sfwater.org web site. This level of ongoing research establishes a baseline for future EIR requirements and impact studies anticipated by the Offshore Wave project. This unique situation establishes a solid baseline for the assessment of the before and after control impact (BACI) which will be required to properly monitor the environmental impacts of such a demonstration plant

The Oceanside Facility is connected by a 12kV line to PG&E's Martin substation. This existing interconnection is sufficient for the interconnection of a wave power demonstration system. It is estimated, that the current connection will allow adding generation capacity of 8-10 MVA before a system build-out needs to be considered. A new 115 kV line would be required for the 100 MW commercial power plant. Net metering could be used to increase the revenues from a small demonstration wave farm. On site generation is provided by the SFPUC. PG&E has a service box adjacent to the Oceanside Facility allowing for a simple interconnection.

The yearly electrical energy produced and delivered to the grid interconnection by the single Energetech OWC unit is estimated to be 1131 MWh. Performance numbers were established using a measurement site further south in Montara in a representative water depth. While it is believed that the measurement site is representative for the Ocean Beach site, it needs to be clearly understood that wave power levels near-shore can vary strongly between locations as the wave resource is influenced by the local bathymetry. It is recommended that the city carries out a study to address these uncertainties and map out the local wave resource. The single unit wave power demonstration would cost $5.35 million (-27 to +35%) to build. This cost only reflects the capital needed to purchase a single Energetech device, the construction costs to build the plant and the cost to interconnect to the grid and does not include detailed design and permitting, yearly O&M and test and evaluation

A commercial-scale wave power plant was also evaluated to establish a base case from which cost comparisons to other renewable energy systems can be made. This commercial scale point design was established in deeper water to take advantage of the better wave resource. The yearly electrical energy produced is estimated to be 1,973 MWh for each Energetech OWC device. In order to meet the commercial plant target output of 300,000 MWh/year a total of 152 Energetech WEC devices are required. The elements of cost and economics (with cost in 2004$) are:

- Total Plant Investment = $238 million
- Annual O&M Cost = $10.6 million; 10-year Refit Cost = $14.7 million
- Levelized Cost of Electricity (COE)[1] = 9.2 (real), 11.1 (Nominal) cents/kWh

The COE for wind energy is about 3 cents/kWh ($2004). Therefore, the first wave energy plant, with essentially no learning experience, cannot be economically competitive with wind energy with today's 40,000 MW of cumulative production experience.

In order to compare offshore wave power economics to shore based wind, which reached a installed capacity base of about 40,000 MW in 2004, industry standard learning curves were applied to the commercial wave power plant design. The results indicate that even with worst-case assumptions in place, wave power compares favorable to wind power at any equivalent cumulative production ratio.

Offshore wave energy electricity generation is a new and emerging technology. The first time electricity was provided to the electrical grid from an offshore wave power plant occurred in early August, 2004 by the full scale preproduction OPD Pelamis prototype in the UK. The first full scale Energetech preproduction machine is being installed at this time at Port Kembla Australia and should be providing power to the grid very soon.

[1] For the first commercial-scale wave power plant assuming a regulated utility generator owner, 20 year plant life and other assumptions documented in Reference 3

Many important questions about the application of offshore wave energy to electricity generation remain to be answered, such as:

- There is not a single wave power technology. It is unclear at present what type of technology will yield optimal economics. It is also unclear at present at which size these technologies will yield optimal economics.
- Will the installed cost of wave energy conversion devices realize their potential of being much less expensive per COE than solar or wind?
- Will the performance, reliability and cost projections be realized in practice once wave energy devices are deployed and tested?

E2I EPRI Global makes the following specific recommendations to the San Francisco Electricity Stakeholders:

1. Coordinate efforts to attract a pilot feasibility demonstration wave energy system project to the San Francisco coast
2. Now that the Ocean Beach single unit Energetech plant project definition study is complete and a compelling case has been made for investing in wave energy in San Francisco, proceed to the next phase of the Project

If this recommendation cannot be implemented at this time (due to lack of funding or other reason), E2I EPRI Global recommends that the momentum built up in Phase 1 be sustained in order to bridge the gap until Phase II can start by funding what we will call Phase 1.5 with the following tasks:

a. Tracking potential funding sources
b. Tracking wave energy test and evaluation projects overseas (primarily in the UK, Portugal and Australia) and in Hawaii
c. Tracking status and efforts of the permitting process for new wave projects
d. Track and assess new wave energy devices
e. Establish a working group for the establishment of a permanent wave energy testing facility in the U.S.

3. Build collaboration with other states with common goals in offshore wave energy.

In order to stimulate the growth of ocean energy technology in the United States and to address and answer the techno-economic challenges, we recommend the following take place:

- Federal and state recognition of ocean energy as a renewable resource and that expansion of an ocean energy industry in the U.S. is a vital national priority
- Creation of an ocean energy program within the Department of Energy's Energy Efficiency and Renewable Energy division
- DOE works with the government of Canada on an integrated bi-lateral strategy.
- The process for licensing, leasing, and permitting renewable energy facilities in U.S. waters must be streamlined

- Provision of production tax credits, renewable energy credits, and other incentives to spur private investment in Ocean Energy technologies and projects.
- Provision of adequate federal funding for RD&D and demonstration projects.
- Ensuring that the public receives a fair return from the use of ocean energy resources and that development rights are allocated through an open, transparent process that takes into account state, local, and public concerns.

The techno-economic assessment forecast made by the Project Team is that wave energy will become commercially competitive with the current 40,000 MW installed land-based wind technology at a cumulative production volume of 10,000 – 20,000 MW. The size of a wave machine will be an order of magnitude smaller that an equivalent rated power wind machine and therefore is forecast to be less costly. The operations and maintenance (O&M) cost for a remotely located offshore wave machine in a somewhat hostile environment will, however, be higher than for a land based wind machine. The results of this study show that the lower cost machine outweighs the additional O&M cost on a cost of electricity basis. The challenge to the wave energy industry is to reduce the O&M cost of offshore wave energy to order to compete with onshore wind energy at large cumulative production volumes (> 40,000 MW).

In addition to the economics, there are other compelling arguments for investing in offshore wave energy. The first is that, with proper siting, converting ocean wave energy to electricity is believed to be one of the most environmentally benign ways of electricity generation. Second, offshore wave energy offers a way to avoid the 'Not In My Backyard' (NIMBY) issues that plague many energy infrastructure projects, from nuclear, coal and wind generation to transmission and distribution facilities. Because these devices have a very low profile and are located at a distance from the shore, they are generally not visible. Third, because wave energy is less intermittent and more predictable than other renewable technologies such as solar and wind, it offers the possibility of being dispatchable and earning a capacity payment (this needs to be explored – see recommendations in Section 13)

The key characteristic of wave energy that promises to enable it to be one of the lowest cost renewable technologies is its high power density. Solar and wind power systems use a very diffuse solar and wind energy source. Processes in the ocean tend to concentrate the solar and wind energy into ocean waves making it easier and cheaper to harvest.

Lastly, since a diversity of energy sources is the bedrock of a robust electricity system, to overlook wave energy is inconsistent with our national needs and goals. Wave energy is an energy source that is too important to overlook

2. Site Selection

The selected deployment site for the San Francisco Bay Area demonstration-scale wave power plant is about 6 miles offshore Ocean Beach. This site is within the boundaries of an exclusion zone in the Monterey Bay National Marine Sanctuary at a water depth of 15m, just south of the shipping lane used by oversea ship traffic, sitting on a sand bank. The presence of a wave power conversion device at this location will serve as a good navigational aid for the incoming ship traffic, preventing potentially dangerous run-ups of large oversea freighters on the particular sand bank. Sites for commercial plant deployment are located south of the proposed demonstration deployment site. The Energetech device can be located in water depths of 5m-50m. Figure 4 shows the area where deployments could potentially happen. Deployments sites will need to be re-considered after a detailed wave propagation study has been carried out. The complex local bathymetry suggests that there are likely a number of wave hot-spots which would yield a higher energy output. Wave hot spots are locations where the local bathymetry allows wave energy to be focused based on it's reflection and refraction characteristics. The location of these sites and that of two reference wave measurement buoys used to characterize offshore and near-shore wave climate are shown in figure 1. For the current study the near-shore wave measurement station off Montara was used as the site is similar water depth. A map showing the exclusion zone and environmental monitoring stations is shown in Figure 2.

The San Francisco Public Utilities Commission (SFPUC) Water Pollution Control Division operates the Oceanside Waste Water Treatment Plant at 3500 Great Highway, San Francisco. The plant discharges treated wastewater effluent through an outfall pipe extending approximately four miles into the ocean on shoal-free sandy bottom. The outfall pipe is an existing easement to land the power cable to shore, reducing cost and permitting requirements. The location although surrounded by the Monterey Bay National Marine Sanctuary exists in an exclusion zone that extends approximately six miles offshore and is not part of the Monterey Bay National Marine Sanctuary. The SFPUC Water Quality Bureau staff conducts regular environmental monitoring in the area, including sediment and community analyses

Based on data from the Oceanside Waste Water Treatment Plant offshore environmental monitoring studies. the ocean floor consists mostly of soft sediments, which is ideal for both cable burial and the deployment of the Pelamis mooring system. Detailed bathymetry and geotechnical assessments will need to be carried out in a detailed design and engineering phase. Special attention will need to be paid to identify potential obstacles such as large rock formations in the cable route and at the deployment location. This is accomplished by using a combination of side scan radar, sub-bottom profiler, local dives and sediment sampling. In addition consideration needs to be given to the fact that the Ocean Beach single unit deployment site does not have the typical deep water depths of 50m or more, which will affect the systems mooring configuration. Such issues can be addressed in a detailed design phase of the project.

Grid access is provided at the Oceanside Waste Water Treatment Plant or at the PG&E 12kV line box that services the plant. The existing connection provides enough capacity to interconnect a demonstration wave power plant. It is likely, that the maximum feed-in capacity is limited to 8-10 MVA, which would limit the build out of generation capacity at that point. To interconnect a commercial wave power plant with a installed capacity of more then 8 MVA, the transmission from the SF Wastewater Treatment Plant to Martin sub-station will need to be upgraded to accommodate additional load. At the scale of 90MW, a new 110kV transmission line will be needed. Such a new transmission will likely cost about $50 million. Such a transmission could accommodate up to 250 MVA. If generation of that magnitude would be added in form of offshore renewable resources (wind, tidal and wave), a new 110 kV line would be justified. Alternative options to allow for a gradual build out still remain to be addressed in a detailed engineering study.

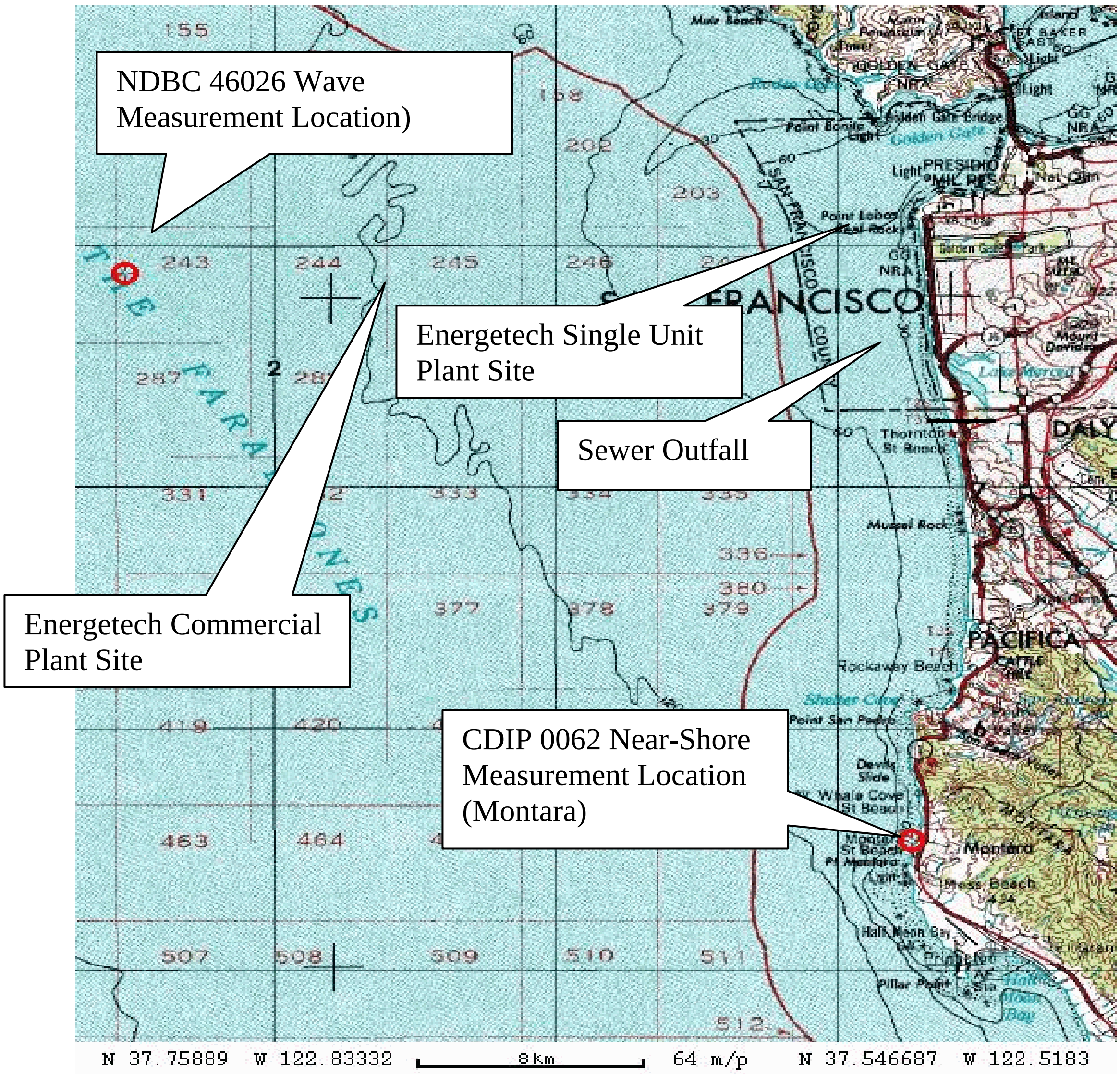

Figure 1: Site Map

The San Francisco Bay Area has ample marine engineering infrastructure (mooring, dock and crane facilities) to support the demonstration project as well as a notional commercial plant. For commercial plant implementation and O&M, facilities could be located in the Hunters Point Naval Shipyard facility now undergoing economic redevelopment.

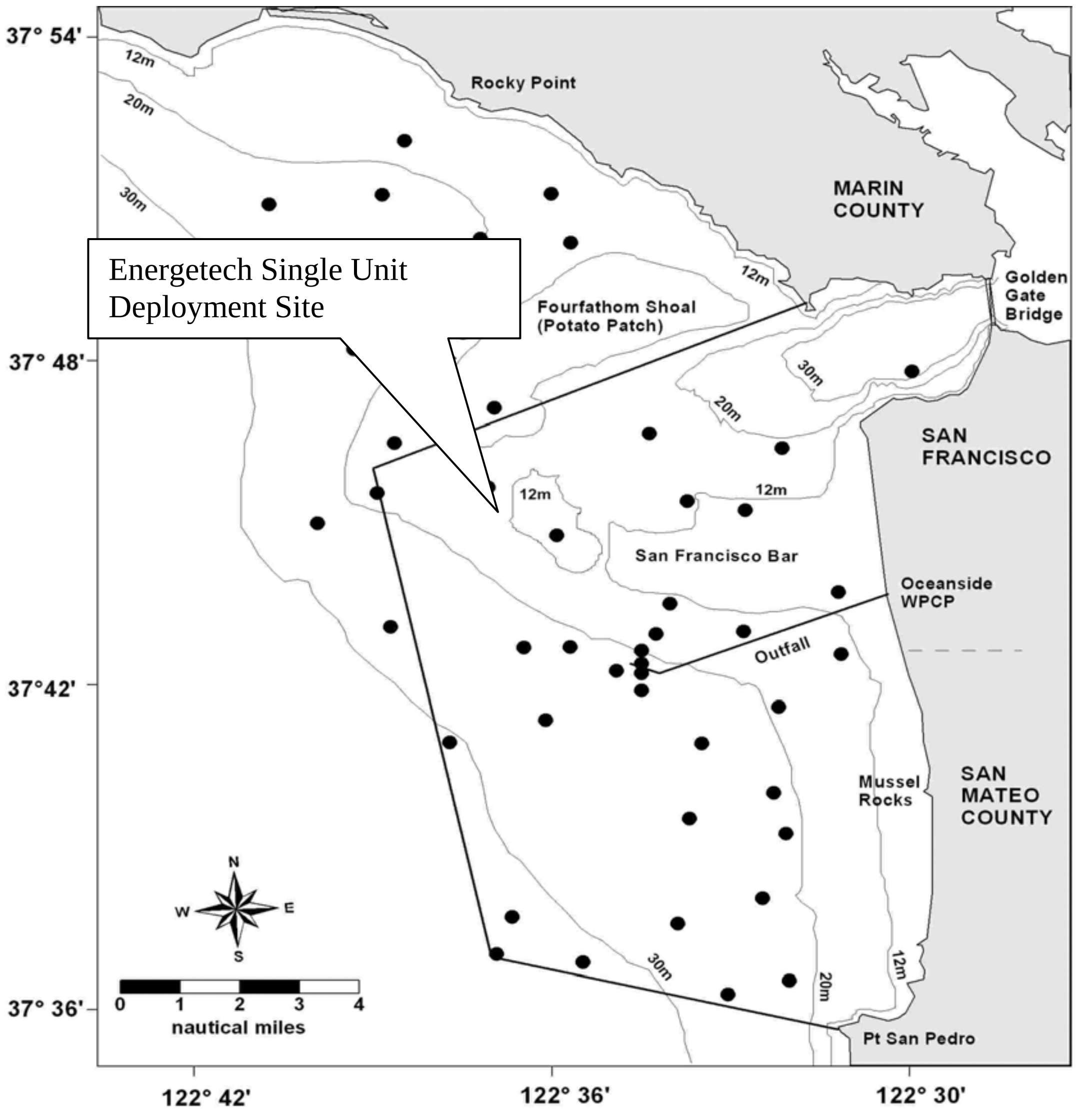

Figure 2: San Francisco exclusion zone, showing environmental monitoring stations and Proposed Energetech Demonstration site in 15m water depth.

Figure 2 shows the San Francisco exclusion zone from the Monterey Bay Marine Sanctuary and the deployment site for the single unit Energetech plant. A depth of 15 meters was desired to stay close to the depth of the current mooring design for the first pre prototype unit being installed at Port Kembla Australia. The northwest side of the little hill to the west of the San Francisco bar was selected as the least shadowed 15 meter depth location in the exclusionary zone in San Francisco County. The black dots indicate the locations of individual environmental monitoring stations. Figure 3 shows the bathymetry around the City of San Francisco. It shows that shallow waters extend relatively far off the coast close to San Francisco. The red-line shows the 50m water depth contour line, along which shows the limit in terms of water depth for a device of Energetechs type. The relatively shallow water, will allow the system to be located further offshore, significantly minimizing and/or eliminating visual impacts. The map also shows a complex local bathymetry, which can influence the viability of certain sites in the area. It will be of great importance to create a detailed map of the local wave conditions to identify potential hot-spots, where wave energy is naturally focused and therefore more concentrated. This applies especially for shallow water locations which are abundantly availably for the deployment of near-shore devices.

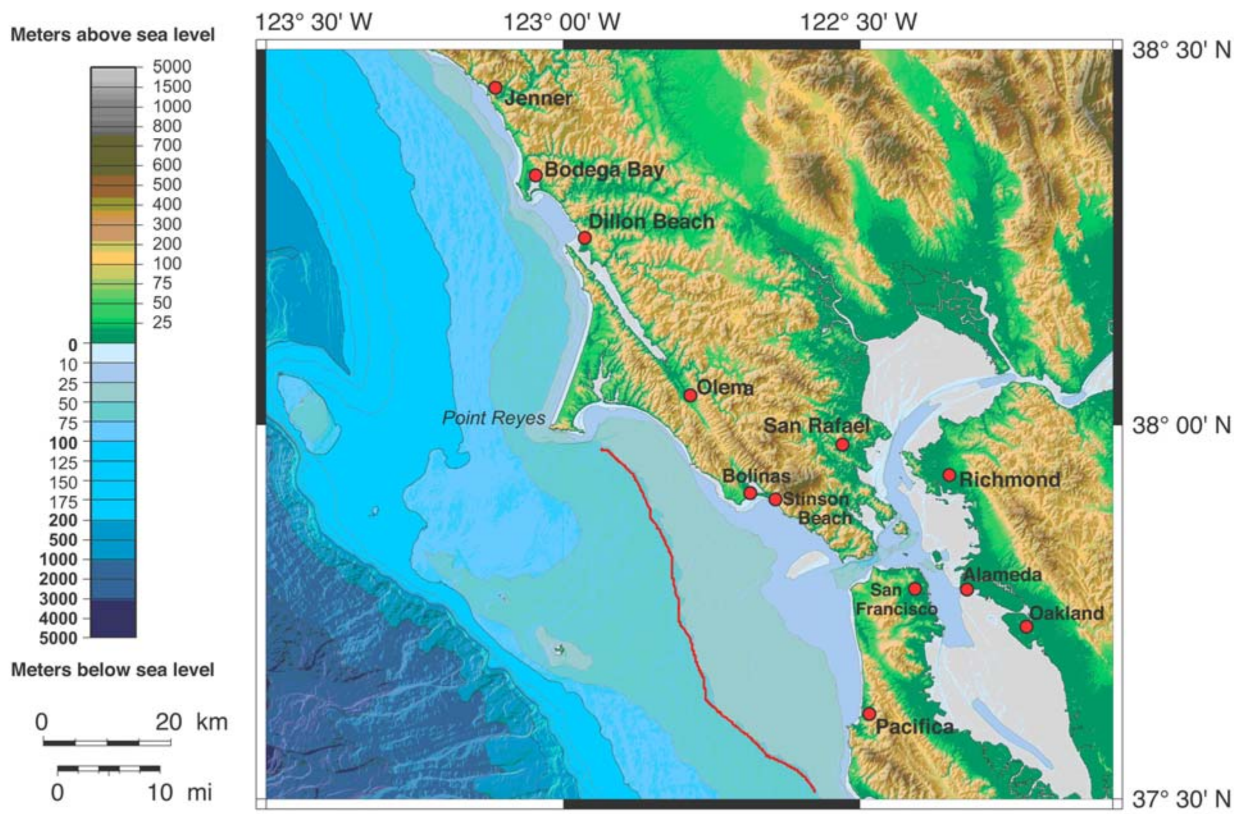

Figure 3: Bathymetry contours around San Francisco. Potential Deep water sites at 50m contour line shown in red.

The City and County of San Francisco is conducting an ocean monitoring program that has two main components: bacteria monitoring in shoreline waters to provide public health information and determine impacts from shoreline discharges; and offshore monitoring designed to evaluate impacts of treated wastewater on marine sediments and fauna. The monitoring program is a regulatory requirement mandated by the U.S. Environmental Protection Agency (U.S. EPA) and the San Francisco Bay Regional Water Quality Control

Board as a consequence of operating the southwest ocean outfall (SWOO) for the discharge of treated wastewater into the Pacific Ocean offshore of San Francisco.

This existing monitoring program provides a solid baseline for environmental impact assessments of such an offshore wave power demonstration. A before and after control impact study (BACI) will need to be a part of the test program. In addition, the existing data can be used in the permitting process and can potentially alleviate challenges.

In summary, the San Francisco demonstration power plant deployment site within the local exclusion zone has the following relevant site parameters which are used in later sections for site design and costing purposes of the prototype.

Water Depth at Deployment Site	15 m
Pipe Outfall to Deployment Site	7 km
Sewage Pipe length	6.5 km
Grid Interconnection Allowance	0.5 km
Total Cable Length Required	14 km
Ocean Floor Sediments	Soft Sediments
Transit Distance to Hunters Point Naval Shipyard	26 km
Estimated Transit Time	1.5 hours
Estimated Energetech Tow Time	4 hours

In summary, the San Francisco commercial deployment site was set at a deeper site further offshore for the project to benefit from the higher energy wave resource at that location. While optimal locations for a near-shore commercial plant are not known, the following parameters were assumed for this relevant commercial deployment site.

Water Depth at Deployment Site	40 m
Pipe Outfall to Deployment Site	16 km
Sewage Pipe length	6.5 km
Total Cable Distance	22.5 km
Ocean Floor Sediments	Soft Sediments
Transit Distance to Hunters Point Naval Shipyard	42 km
Estimated Transit Time	2 hours
Estimated Energetech Tow Time	6 hours

Although the SF Bay Area is not a place where low-cost manufacturing can be located, it offers plenty of facilities to carry out final assembly (staging) and operational activities of wave power conversion devices. Examples are the port of Oakland in the East Bay and the Hunters Point Naval Shipyard, which is undergoing economic development. For the purpose of this report, it was assumed, that the devices would be launched from the Hunters Point Shipyard and towed to the deployment site. Figure 4 shows an aerial view onto Hunters Point Shipyard.

Figure 4: Hunters Point Naval Shipyard

3. Wave Energy Resource Data

The San Francisco NDBC 46026 and the Montara CDIP 0062 wave measurement buoys, were chosen to characterize the wave resource at the proposed commercial and first unit deployment sites respectively. The buoy is sited at a water depth at which the first commercial unit is planned to be deployed. Uncertainties in respect to power levels at the actual deployment site remain to be addressed. This is especially important for near-shore deployments sites as power levels can vary significantly from location to location.

EPRI recommends that the City of San Francisco carry out a detailed wave modeling study, taking into consideration detailed bathymetry contours and based on deep water wave input compute power levels at the deployment site using refraction and diffraction characteristics of the waves as they travel towards the deployment site, as part of the next phase of work. Example of such computer models are RCPWAVE, REDDIR and STWAVE developed by the U.S. Army Corps of Engineers and SWAN developed by the US Navy. Given the complex bathymetry around the exclusion zone of the Monterey Bay National Marine Sanctuary, such a model could also reveal natural hot-spots for near-shore deployment sites which have the potential to provide superior economics. There is also a possibility, according to the U.S. Army Corps of Engineer Coastline Engineering Manual (Reference Part II, Chap 3, page II-3-3) that physical modeling may be required due to the strong currents which traverse the wave field. There is a possibility of the Corps at the Tidal Model Basin in Sausilito being involved in the project.

Below are some key results of the reference measurement station and characterization of the wave climate. The deep water measurement buoy is in close proximity to the proposed commercial deep water deployment site. As a result, the measurements are very representative of the wave climate that the commercial plant will experience. Figure 5 shows the average monthly wave energy power flux (in kW/meter) Scatter tables for the wave energy resource were created for each month and used to estimate the power production of Energetech as described in Section 6. The monthly scatter diagrams are contained in Appendix A of this report.

Measurement buoy:	NDBC 46026
Station Name:	San Francisco
Water depth:	52m
Coordinates:	37° 45’ 32” N 122° 50’ 00” W
Data availability:	21 years (1982 – 2003)
Maximum Significant Wave Height (Hs):	7.9 m
Maximum Significant Wave Period (Tp):	16.7 s
Estimated Single Wave Extreme Event:	15.8 m
Average Wave Power:	20 kW/m

A second nearby measurement buoy (see Figure 1), CDIP 0062 with a 5 year data set, provides wave energy data at a depth of only 15 meters.

Measurement buoy:	CDIP 0062
Station Name:	Montara
Water depth:	15m
Coordinates:	37° 32.8' N 122° 31.1' W
Data availability:	5 years (1987 – 1992)
Maximum Significant Wave Height (Hs):	5.4m
Maximum Significant Wave Period (Tp):	13.5 s
Estimated Single Wave Extreme Event:	11m
Average Wave Power:	11.2 kW/m

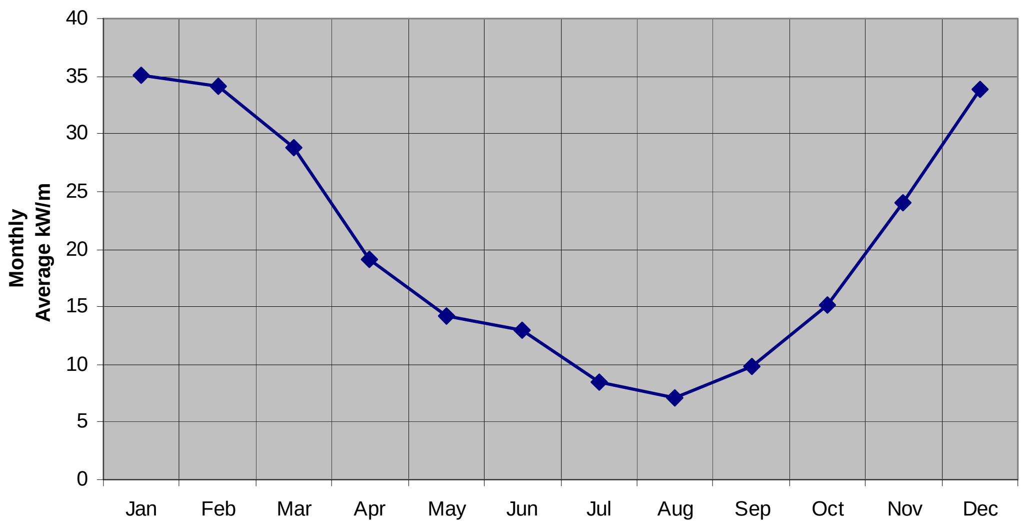

Figure 5: Monthly Average Wave Power Flux at NDBC 46026 (kW/m)

4. The Technologies

The WEC device chosen for this point design is the Energetech oscillating water column (OWC). The OWC functional principle is illustrated in Figure 6. An OWC uses an enclosed column of water as a piston to pump air . These structures can float, be fixed to the seabed, or mounted on the shoreline. An OWC device uses an air turbine to convert air flow into a high frequency rotational output required by the turbine machinery.

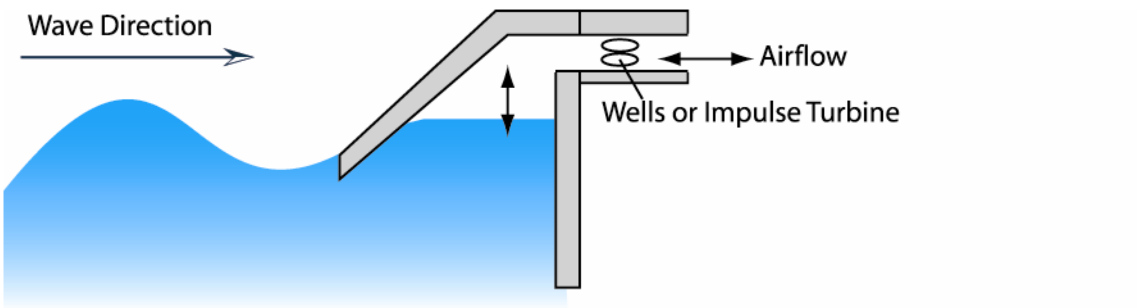

Figure 6: OWC function principle

Much of the wave power community's research has focused on OWC devices. OWC technology is one of the best established technologies and has traditionally focused on shore-based devices. Recent examples of full-scale deployments are the deployment of the LIMPET on Islay, Scotland and the OWC deployment by a recent European Union (EU) project in the Azores. Energetech's OWC device features three key improvements over previous developments. They are:

-Parabolic wall to increase the devices capture width
-Improved Air turbine increasing power conversion efficiency
-An improved mooring system

An OWC device's width and its related energy output is limited by the wave length. Therefore, the scalability of a device is limited. Energetech has overcome this problem by adding focusing walls to their device, focusing ocean waves from a broader width onto the central oscillation chamber. This feature allows the device capacity to be increased, enabling economies of scale which are critical for offshore renewable power systems.

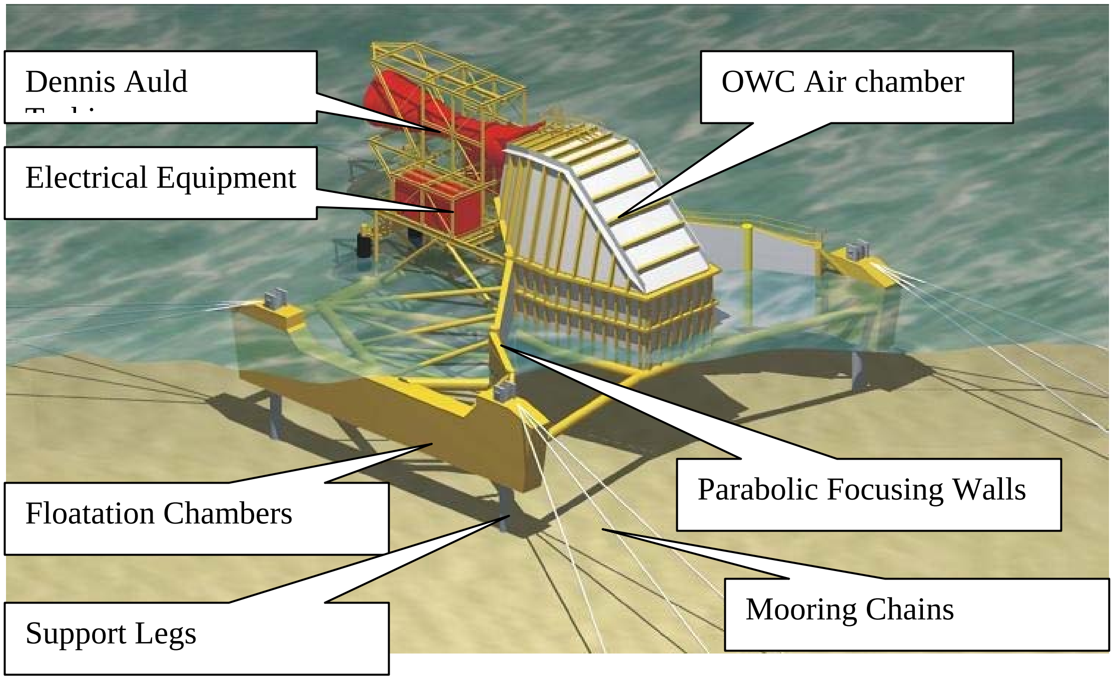

Figure 7: Energetech's OWC device

Figure 7 shows a rendered drawing of the device. The device is standing on 4 support legs. The length of these legs depends on the water depth at the deployment site. Mooring chains hold the structure in place and are attached to steel piles on the other side, providing good anchoring capabilities.

The structure is towed to the deployment site using two floatation chambers as shown in the above illustration. If filled with air, the structure starts to float and can be easily towed with a standard offshore tug.

At the time this report is being written, Energetech has completed the construction of the device, which will be deployed with operation commencing in early 2005 at Port Kembla in Australia. Figure 8 shows the steel structure being towed.

Figure 8: Energetech OWC being towed after offloading at Port Kembla

The Dennis Auld variable pitch air-turbine shows better performance over a broad bandwidth than the previous fixed bladed Wells turbine, which has traditionally been used in the industry. Figure 9 shows the turbines variable pitch mechanism (left) and the performance comparison of a Wells turbine with a 8 Blade Dennis Auld turbine.

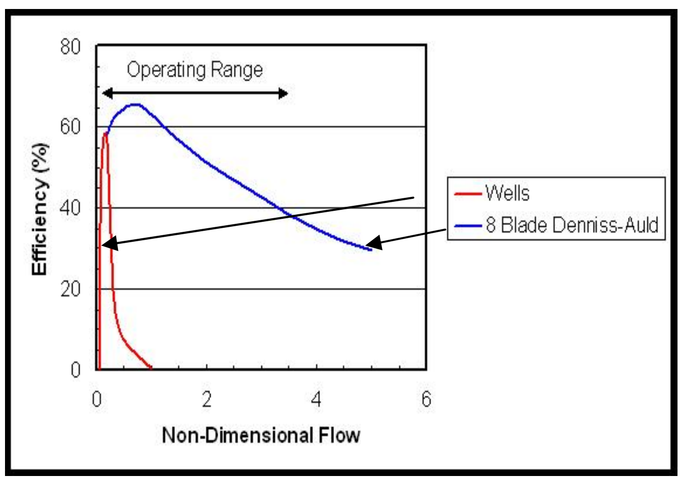

Figure 9 Turbine variable pitch mechanism (left) Performance comparison (right)

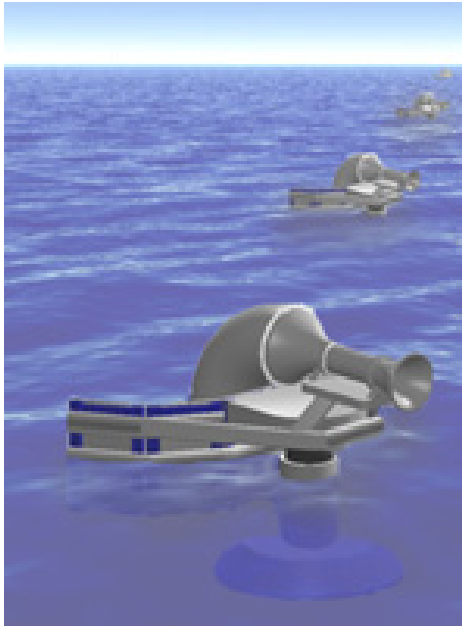

Figure 10: Artist Illustration of an Energetech Wave Farm

Figure 10 shows an illustration of a wave farm consisting of Energetech devices. It shows an alternate mooring arrangement, which would eliminate some of the chains used in the first prototype device.

Table 1: Device Specifications of Port Kembla Device

Structure	
Device Width	35 m
Highest point above water line	11.75 m
Device Length	24.5 m
Total Steel Weight	485 tons
Power Conversion	
Power Take Off	Variable pitch, variable speed Air Turbine
Generator Capacity (cooled)	1000 kVA
Power Generation	
Rated Power	1000 kVA
Generator Type	Asynchronous
System Voltage	3-phase / 415V 12-pole squirrel cage induction gen.
Power Conversion/Conditioning	AC/DC/AC Converter
Transformer	step up to required interconnection voltage
Site Mooring	
Water depths	5 – 50m

Mooring System

Energetech's OWC standing on its 4 legs and is moored by chains to driven piles which act as anchors. Once in place, the chains are getting tensioned to the appropriate level by special rigging equipment on the device itself. The tension of these chains will need to be readjusted from time to time to make sure they stay at appropriate levels. For the San Francisco deployment, the piles can be driven into sand using a vibratory hammer. The mooring arrangement of Energetech's OWC needs to be designed specifically for the site conditions. Similar to a wind turbine foundation, which needs to be type approved, the mooring system needs to be designed by Energetech and adapted to specific site conditions. Survival conditions, maximum current velocity, water depth, seafloor soil densities and other factors will need to be considered in a detailed design phase. This is especially important as the Energetech device is a bottom standing device.

Electrical Interconnection & Communication

Each Energetech OWC houses a step-up transformer to increase the voltage from generator voltage to a suitable wave farm interconnection voltage. The choice of the voltage level is driven by the grid interconnection requirements and the wave farm electrical interconnection design but is typically 12, 26 or 33kV. A riser cable is connecting the Energetech OWC to a junction box, sitting on the ocean floor. If multiple devices are connected together, they can be daisy-chained by a jumper cable which runs from one device to the next. Only at certain strong-points the electrical cable is then brought to the ocean floor. This approach reduces the number of riser cables required and makes the cabling more accessible for maintenance from the surface. Because the device is bottom standing and allows a cable to be fixed to the structure (or even running inside the structure), cyclic loadings on cable connections is not as much of an issue as it is for freely floating devices. The cables used are 3-phase cables with a fiber core. This fiber core is used to establish reliable communication between the devices and a shore-based supervisory system. Remote diagnostic and device management features are important from an O&M stand-point as it allows to pin-point specific issues or failures on each unit, reducing the physical intervention requirements on the device and optimizing operational activities. Operational activities offshore are expensive and minimizing such interventions is a critical component of any operational strategy in this harsh environment. A wireless link is used as a back-up in case primary communication fails.

Subsea Cabling

Umbilical cables to connect offshore wave farms (or wind farms) to shore are being used in the offshore oil & gas industry and for the inter-connection of different locations or entire islands. In order to make them suitable for in-ocean use, they are equipped with water-tight insulation and additional armor, which protects the cables from the harsh ocean environment and the high stress levels experienced during the cable laying operation. Submersible power cables are vulnerable to damage and need to be buried into soft sediments on the ocean floor. While traditionally, sub-sea cables have been oil-insulated, recent offshore wind projects in Europe, showed that the environmental risks prohibit the use of such cables in the sensitive coastal environment. XLPE insulations have proven to be an excellent alternative, having no such potential hazards associated with its operation. Figure 11 shows the cross-sections of armored XLPE insulated submersible cables.

Figure 11: Armored submarine cables

For this project, 3 phase cables with double armor and a fiber core are being used. The fiber core allows data transmission between the units and an operator station on shore. In order to protect the cable properly from damage such as an anchor of a fishing boat, the cable is buried into soft sediments along a predetermined route. If there are ocean floor portions with a hard bottom, the cable will have to be protected by sections of protective steel pipe, which is secured by rock bolts.

An important part of bringing power back to shore is the cable landing. Existing easements should be used wherever possible to drive down costs and avoid permitting issues. If they do not exist, directional drilling is the method with the least impact on the environment. Directional drilling is a well established method to land such cables from the shoreline into the ocean and has been used quite extensively to land fiber optic cables on shore.

Onshore Cabling and Grid Interconnection

Traditional overland transmission is used to transmit power from the shoreline to a suitable grid interconnection point. Grid interconnection requirements are driven by local utility requirements. At the very least, breaker circuits need to be installed to protect the grid infrastructure from system faults.

Procurement and Manufacturing

For the single-module pilot plant, it was assumed that the Power Take Off is procured from Energetech and is shipped from Australia to California and that the structural steel elements are built locally in an appropriate shipyard. Manufacturing facilities, which are capable of constructing the larger steel sections do exist in California and Oregon.

Mooring components such as chain and steel piles will be purchased from local manufacturers and assembled in a local staging site before deployment. Sub-sea cables, circuit breakers etc. will also be purchased from US based manufacturers.

At the commercial scale envisioned, it will make economic sense to establish local manufacturing facilities for the Dennis Auld Turbine. This will allow for a large amount of US content in the devices and bring benefits to the local economy.

San Francisco's Hunter's Point Naval Shipyard could be used as a base to carry out installation and operational tasks. This shipyard has adequate capacity and initial discussions with city officials showed that part of the facility could be converted and optimized to carry out operation and/or manufacturing of such devices.

Installation Activities

Installation and operational offshore activities require special equipment. In order to understand the offshore installation and removal activities and their impacts on cost, detailed process outlines were created to be able to estimate associated resource requirements. Results were verified with Energetech who is in the final stages of deploying a prototype device and local offshore operators in San Francisco. The major installation activities for both pilot demonstration plant and commercial wave farm are:

1. Install cable landing and grid interconnection
2. Installation of sub-sea cables
3. Installation of Mooring System (driven Piles)
4. Commissioning and Deployment of OWC units

Offshore handling requirements were established based on technical specifications supplied by Energetech. All operation can be carried out using locally available barges and offshore tugs. For the commercial plant, it proved to be cost effective to include a customized tug in the project cost and hire dedicated staff to carry out operational activities.

Operational stand-by time was included in form of a weather allowance. Weather allowances depend on many factors such as vessel capabilities, and deployment and recovery processes. Comparable numbers from the North Sea offshore oil & gas industry were adapted to local conditions, based on feedback from local offshore operators.

Operational Activities

Sophisticated remote monitoring capabilities allow the operator to monitor the device and, in case of a failure, isolate the fault to determine the exact problem and if required schedule physical intervention.

The devices maintenance strategy is to carry out most of the O&M activities on the device itself. Removal of the device is only required if the device suffers structural damage. This allows for the usage of small boats to transfer equipment and personnel.

Every 10 years, the device will be recovered for a complete overhaul and refit. For that purpose, it will need to be completely recovered to land. It is likely that only some touch-up painting will be required and the exchange of some of the power take-off elements, such as variable pitch mechanism. The device will also need to be inspected at that time by the American Bureau of Shipping (ABS) or a related agency.

5. System Design – Pilot Plant

The outline below (Figure 12) shows the electrical setup of the demonstration pilot plant. A single WEC device is moored in a water depth of 15m. A riser cable is connecting the absorber unit to a junction box on the ocean floor. From this junction box, a double armored 3 phase cable is buried into the soft ocean floor sediments and brought to the sewer pipe outfall, which extends 6km out from the shoreline. The cable landing site for the demonstration site is at the San Francisco Oceanside water treatment facility. The water treatment facility is connected by a 12kV distribution line to the nearest substation, which can be used to feed power into the grid.

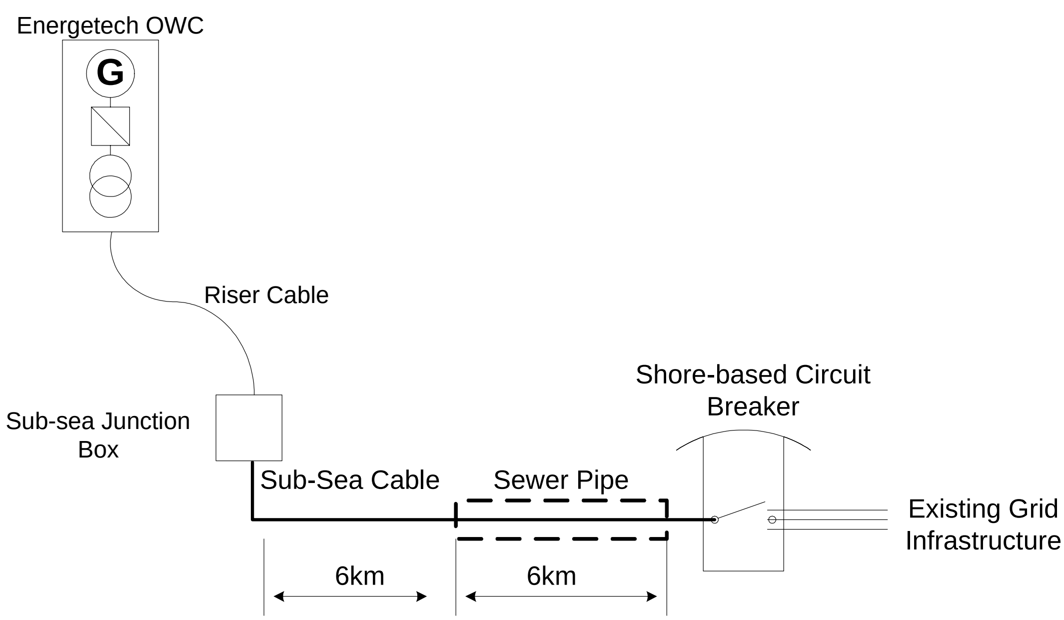

Figure 12: Electrical Interconnection of a single unit Pilot Plant

6. System Design - Commercial Scale Wave Power Plant

Whereas the conceptual design of the demonstration plant system focused on finding existing easements, allowing the installation of a small demonstration system in a cost effective manner, the commercial scale wave plant design focused on establishing a solid costing base case, and assessing manufacturing and true operational costs for a commercial-scale plant. The commercial scale cost numbers were used to compare energy costs to commercial wind farms to come to a conclusion on the cost competitiveness of wave power in this particular location.

While the demonstration plant lying within the SF exclusion zone provides an excellent demonstration opportunity as the site is in close proximity to shore and will likely encounter few permitting hurdles, a location further offshore will yield better economics for the commercial plant as the wave power level is higher. The following subsections outline the electrical system setup, the physical layout and the operational and maintenance requirements of such a deployment.

Electrical Interconnection and Physical Layout

Figure 13 illustrates the commercial system with a total of 4 clusters, each one containing 38 units (152 devices total), connected to sub-sea cables. All devices are aligned in a single row. The spacing between each individual unit is 35m and each unit is 35m wide. Based on this spacing, the width of each cluster is 2660m. The 4 clusters will spread over roughly 10.6km. The electrical interconnection of the devices is accomplished with flexible jumper cables, connecting the units in mid-water. The introduction of four independent sub-sea cables and the interconnection on the surface will provide some redundancy in the wave farm arrangement.

It is unclear at present what the device spacing should be, but the above mentioned 35m is reasonable, given the fact that the devices are fixed to the seabed and will not experience much lateral movement. Wave farm and grid interconnection voltage was set at 26kV.

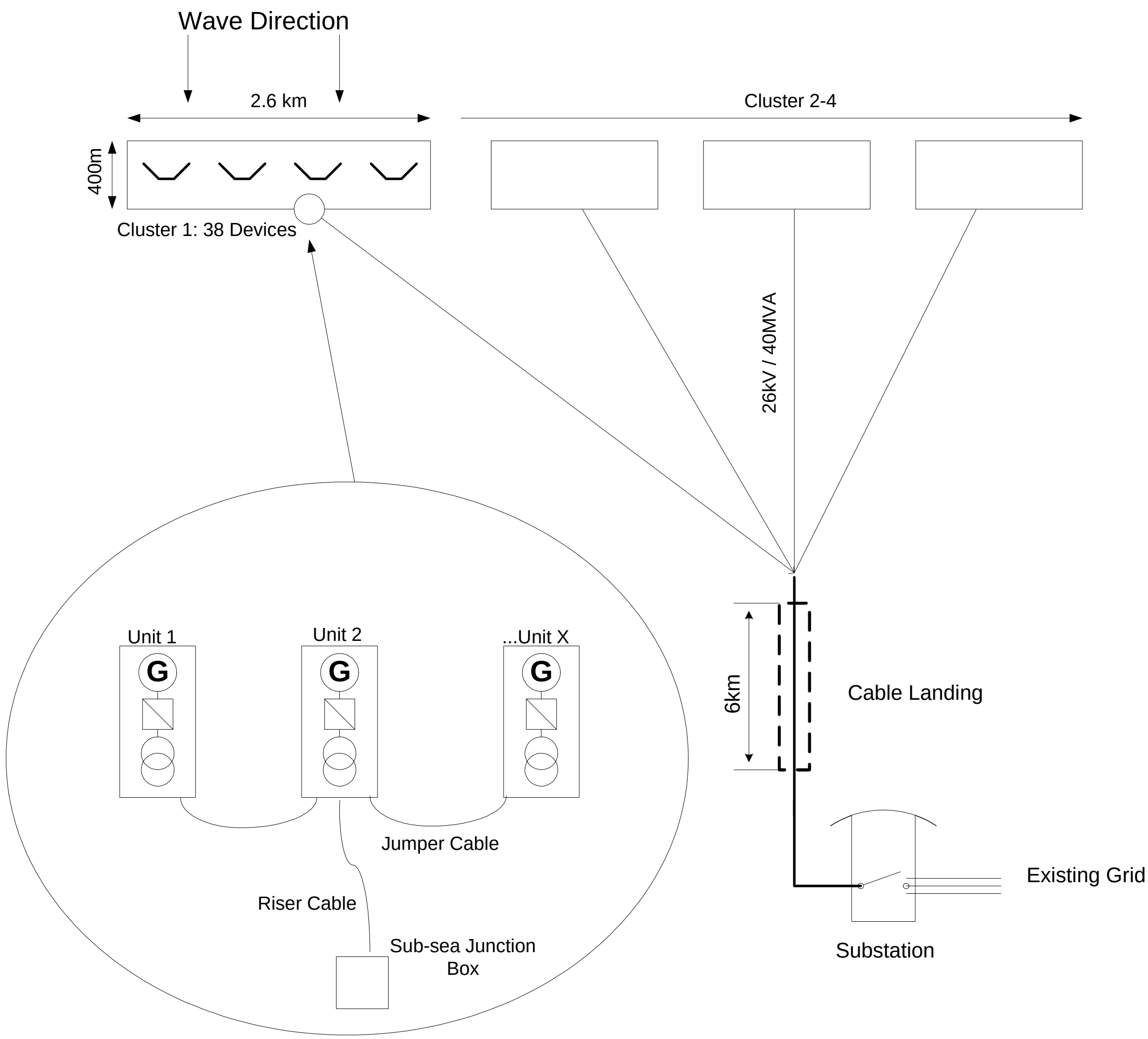

Figure 13: Overall System Layout and Electrical Connections

Operational and Maintenance Requirements

General operational activities are outlined in a previous section. It made economic sense for this wave farm to include the vessel cost in the capital cost of the project. Based on the workload, the vessels will be at 100% capacity during the installation phase of the project and then it's usage will drop to less then 50% to operate the wave farm.

O&M outlines showed that the vessels would need to be operated only during daytime. Based on the work loads involved with O&M and 10-year refit operation a total full-time crew of 9 is required. This includes onshore personnel to carry out annual maintenance activities and 10-year refits.

O&M activities can be carried out at a suitable pier side at the Hunters Point Naval Shipyard, with the device remaining in the water. For the 10-year refit, the device will need to be recovered to land onto a rail-type system on which these activities can be carried out. While some of these facilities are available at the Hunters Point Naval Shipyard, budget allowance was given to accommodate improvement to streamline such operational tasks.

7. Device Performance

The device performance was assessed based on the wave climate described in Section 3 and on the performance data supplied by Energetech. While the choices of deployment locations for the first unit is limited to the San Francisco Exclusion zone, because of permitting easements in place, a build-out to larger capacity levels could happen anywhere between the shoreline and the 50m water depth contour line. It is unclear at present what the optimal economic trade-offs between water depth and wave power resource are for the current design. In addition, visual impacts could be minimized by siting devices further offshore. Some of the sites which could be used for the deployment of Energetech's OWC are as far as 20miles from the coast. Siting devices this far offshore would result in a negligible visual impact from shore, making it difficult to see the devices from shore with bare eyes. The availability of shallow water sites in San Francisco so far from shore is a unique feature on the US west coast and could very well be a driver to consider shallow water wave power conversion device such as Energetech's OWC in San Francisco. A detailed mapping of the wave resource for the San Francisco bay area will be crucial to determine where optimal sites are located.

Since it is unclear at present what the performance at an optimal location would look like, the performance was assessed for the 2 measurement locations, where wave data is available. These 2 performance figures will show the upper and lower boundaries for the devices performance in this wave regime.

The upper limit of performance was assessed by applying the deep water wave regime to the Energetech device performance data. The monthly averages delivered to bus bar are shown below.

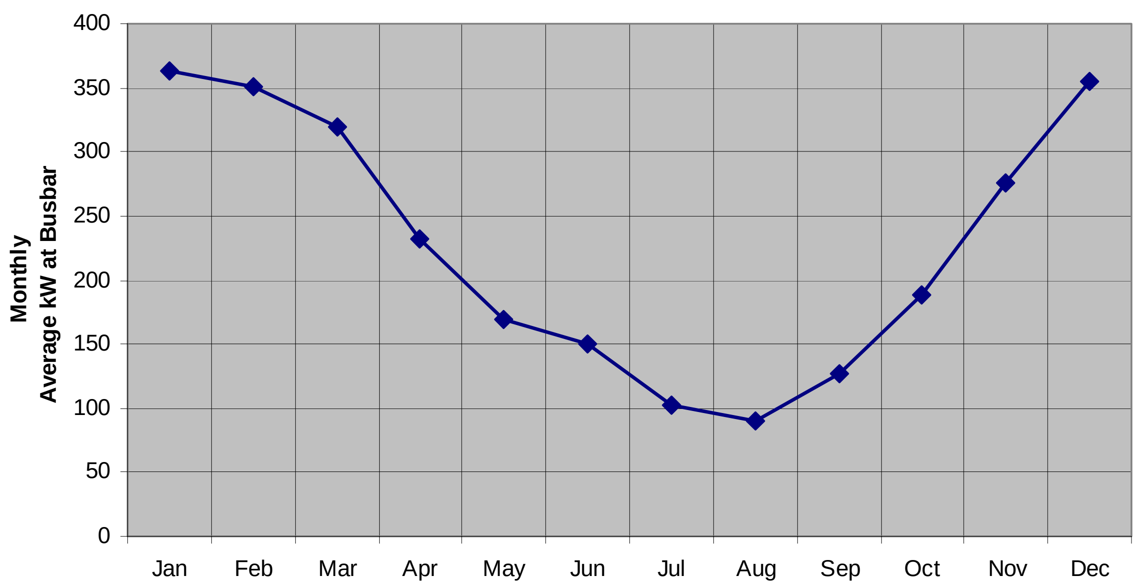

Figure 14: Monthly average power delivered to bus bar – Deep water site

Scatter diagrams of the annual and monthly wave energy was developed using long-term statistics from the San Francisco NDBC 46026 wave measurement buoy. The scatter diagram for the annual energy is shown in Table 2. Scatter diagrams for each month are contained in Appendix A. The Energetech wave energy absorption performance for each cell in the scatter diagram is shown in Table 3

Table 2: NDBC 46026 Annual occurrence of hours per sea-state (deep water site)

CDIP 0034		Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	
Makapuu Point		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	Total hours
Hs and Tp bin boundaries			Tp (sec)													
Lower Hs	Upper Hs	Hs (m)	3	4	5	6	7	8	9	10	11	12	14	17	20	
9.75	10.25	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.25	9.75	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.75	9.25	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.25	8.75	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.75	8.25	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.25	7.75	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.75	7.25	7	0	0	0	0	0	0	0	0	0	0	0	1	0	1
6.25	6.75	6.5	0	0	0	0	0	0	0	0	0	0	0	2	1	3
5.75	6.25	6	0	0	0	0	0	0	0	0	0	0	1	2	1	5
5.25	5.75	5.5	0	0	0	0	0	0	1	1	0	1	4	6	1	14
4.75	5.25	5	0	0	0	0	0	1	1	2	2	2	8	13	3	31
4.25	4.75	4.5	0	0	0	0	0	3	2	3	4	6	14	19	4	54
3.75	4.25	4	0	0	0	0	1	6	6	5	7	13	38	32	8	117
3.25	3.75	3.5	0	0	0	0	5	21	16	17	18	38	85	53	12	265
2.75	3.25	3	0	0	0	3	13	62	39	36	47	97	161	76	23	556
2.25	2.75	2.5	0	0	0	12	47	139	82	82	110	200	253	105	38	1,068
1.75	2.25	2	0	0	4	41	126	272	165	168	226	325	302	132	51	1,811
1.25	1.75	1.5	0	3	21	127	212	367	263	292	301	338	308	195	52	2,478
0.75	1.25	1	2	18	35	97	117	255	224	210	213	246	387	264	37	2,103
0.25	0.75	0.5	2	4	3	7	11	37	26	25	22	37	62	20	1	257
0	0.25	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		8,766	4	25	63	288	532	1,164	825	840	950	1,301	1,623	919	232	8,766

Table 3: Energetech Wave Energy Conversion System Performance (kW) in each sea-state (includes Absorption and Power Take Off Efficiecy) for deep water site

Hs (m) \ Tp (s)	3	4	5	6	7	8	9	10	11	12	14	17	20
10	50	113	161	214	255	301	367	459	578	711	881	932	1,000
9.5	53	121	172	228	272	321	392	489	617	759	939	994	1,000
9	57	129	183	243	290	343	418	522	658	809	1,000	1,000	1,000
8.5	60	137	195	259	308	364	444	555	700	860	1,000	1,000	1,000
8	64	146	207	275	327	387	471	589	742	913	1,000	1,000	1,000
7.5	67	154	218	290	345	409	498	622	784	965	1,000	1,000	1,000
7	71	162	229	305	363	429	523	653	824	1,000	1,000	1,000	1,000
6.5	74	168	239	317	378	447	544	680	857	1,000	1,000	1,000	1,000
6	76	173	246	326	388	459	560	699	882	1,000	1,000	1,000	1,000
5.5	76	174	248	329	393	464	566	708	891	1,000	1,000	1,000	1,000
5	78	174	247	327	389	462	561	699	885	1,000	1,000	1,000	1,000
4.5	91	171	244	315	375	448	548	674	864	1,000	1,000	1,000	1,000
4	133	170	229	304	360	422	511	643	814	988	1,000	1,000	1,000
3.5	100	165	232	293	340	401	486	601	754	916	1,000	1,000	1,000
3	120	179	230	268	303	344	411	509	643	781	911	926	1,000
2.5	73	118	163	198	231	269	325	401	500	596	699	652	929
2	58	93	125	151	173	199	237	285	348	413	455	444	776
1.5	44	67	86	101	110	120	132	164	183	226	317	332	234
1	25	37	47	53	50	57	64	105	132	140	152	122	3
0.5	12	16	18	23	11	15	24	4	7	8	23	10	13
0.125	0	1	2	3	4	5	6	7	8	9	10	11	12

By multiplying each cell in the hours of reoccurrence scatter diagram (Table 2) by each corresponding cell of the Energetech performance scatter diagram (Table 3), the total energy in each sea state was calculated. By summing up the two tables, the annual output (MWh/year) per WEC device was derived. First unit performance numbers are summarized below.

For the shallow water site, the same procedure was used except that no monthly statistics were generated. The table below shows the energy distribution at the shallow water site.

Table 4: CDIP062 Shallow water measurement site (15.5m water depth)

CDIP 0062		Upper Tp:	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	18.5	20.5	
Montara 15.5 m		Lower Tp:	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	19.5	*Total*
Hs and Tp bin boundaries			Tp (sec)													*annual*
Lower Hs	Upper Hs	Hs (m)	5	6	7	8	9	10	11	12	13	14	15	17	20	*hours*
9.75	10.25	**10**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
9.25	9.75	**9.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
8.75	9.25	**9**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
8.25	8.75	**8.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
7.75	8.25	**8**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
7.25	7.75	**7.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
6.75	7.25	**7**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
6.25	6.75	**6.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
5.75	6.25	**6**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
5.25	5.75	**5.5**	0	0	0	0	0	0	0	0	1	0	1	1	0	*3*
4.75	5.25	**5**	0	0	0	0	0	0	0	0	0	1	1	1	0	*3*
4.25	4.75	**4.5**	0	0	0	0	0	0	0	0	0	1	1	0	1	*3*
3.75	4.25	**4**	0	0	0	0	0	1	0	0	2	4	4	10	2	*25*
3.25	3.75	**3.5**	0	0	0	0	0	1	0	4	9	2	15	32	1	*65*
2.75	3.25	**3**	0	0	1	2	6	2	6	20	35	29	23	38	0	*162*
2.25	2.75	**2.5**	0	1	1	12	22	22	32	76	117	54	54	67	2	*461*
1.75	2.25	**2**	0	6	22	49	87	58	113	192	229	120	79	112	7	*1,073*
1.25	1.75	**1.5**	4	21	97	179	239	179	232	381	415	155	142	187	11	*2,243*
0.75	1.25	**1**	17	149	227	341	479	276	316	380	333	192	190	254	8	*3,160*
0.25	0.75	**0.5**	42	37	69	135	205	99	145	175	208	137	144	165	4	*1,568*
0	0.25	**0.125**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
			64	*213*	*418*	*718*	*1,039*	*639*	*844*	*1,229*	*1,349*	*696*	*654*	*867*	*37*	***8,766***

The table below summarizes the device performance at the shallow water and the deep water site. Deep water performance was used for cost of energy projection of a 300,000 MWh/yr equivalent wave power plant, while the shallow water performance data is used to estimate power production of the first installed unit.

Table 4: Device Performance at shallow and deep water sites

	Shallow Water (First Unit)	**Shallow Water**	**Deep Water Com'l Unit)**
Device Rated Capacity	1000 kW	1000 kW	1000 kW
Annual Energy Converted (mechanical energy at turbine shaft)	1643 MWh/yr	1643 MWh/yr	2714 MWh/yr
Device Availability	85%	95%	95%
Directionality Factor	90%	90%	85%
Power Conversion Efficiency (Electrical)	90%	90%	90%
Annual Generation at bus bar	1131 MWh/year	1264 MWh/year	1973 MWh/year
Average Power Output at bus bar	129 kW	144 kW	225 kW

Because the device is oriented in a single direction, a 85% directionality factor was applied. In shallow water the wave energy resource tends to be less directional, then in deep water.

8. Cost Assessment – Demonstration Plant

The cost assessment for the first unit was carried out using a assessment of each cost center. Installation activities were outlined in detail and hourly breakdowns of offshore operational activity created to properly understand the processes and associated cost implications. Wherever possible, manufacturing estimates were obtained from local manufacturers. An uncertainty range was associated to each costing element and a Monte Carlo Simulation was run to determine the uncertainty of capital cost. Operational cost was not assessed in detail for the Pilot plant. This is a task that is scheduled for subsequent project phases. Cost centers were validated by Energetech, based on their production experience of their first full scale prototype machine, which will be deployed in 2005.

Based on the above assumptions the following results in constant year 2004$ are presented:

Table 6: Cost Summary Table rounded to the nearest $1000

Cost Element	Demo Plant	Basis
Onshore Transmission & Grid Interconnection	$140,000	(1)
Subsea Cables	$1,218,000	(2)
Power Take Off	$747,000	(3)
Manufactured Steel Sections	$1,501,000	(4)
Mooring (Piles, Chain etc.)	$409,000	(5)
Installation	$850,000	(6)
Construction Mgmt and Commissioning (10% of cost)	$487,000	(7)
Total	**$5,352,000**	
2-Device Energetech Plant	**$7,748,000**	
4-Device Energetech Plant	**$11,678,000**	
8-Device Energetech Plant	**$18,122,000**	

1) Cost includes a breaker circuit and and allowance for cabling from the effluent outlet at the SF Wastewater treatment facility to the 12kV interconnection point at the facility.

2) Subsea cable cost is based on quotes from Olex cables. It includes a sub-sea, pressure compensated junction box, to connect the riser cable. The sub-sea cable consists of two pieces. The 4km offshore piece, connecting the offshore wave farm to the sewer pipe outfall and the 6.5km cable running through the sewer pipe and interconnecting at the SF Wastewater Treatment Facility a 0.5km allowance is also included for a total cable length of 11km.

3) Based on estimate by Energetech. Shipping cost is included from Australia to San Francisco, Ca, based on quote by Menlo International for the shipment of 2 containers.

4) Recently rising costs in raw steel has led to uncertainties in estimating costs for steel production. Energetech recently completed the building of the structure for a total of $1.26 million and estimates that the next structure would only cost $1.07 million to build because of important lessons learned. This turns out to approximately $2500 per ton of steel. It is important to understand, that the structure was built in Indonesia, where labor cost is lower then in the US. It was assumed, that manufacturing of a steel structure of Energetech's complexity would be about $3500 in the US for a single unit. Energetech estimates a reduction in steel by 15% over previous units. Reduction in steel weight by up to 75% for their next generation design was not considered for this first unit. Cost for test out, assembly and transport is included in this cost center.

5) Based on Energetech experience with their pre-production prototype. Cross checks were performed using local construction management feedback.

6) Installation cost was estimated by a rigorous assessment of vessel handling requirements, breakdown of installation tasks, quotes from local operators for vessel cost, fuel and crew, and allowance for weather downtime.

7) Based on the Project Team experience managing similar construction projects and commissioning to owner acceptance.

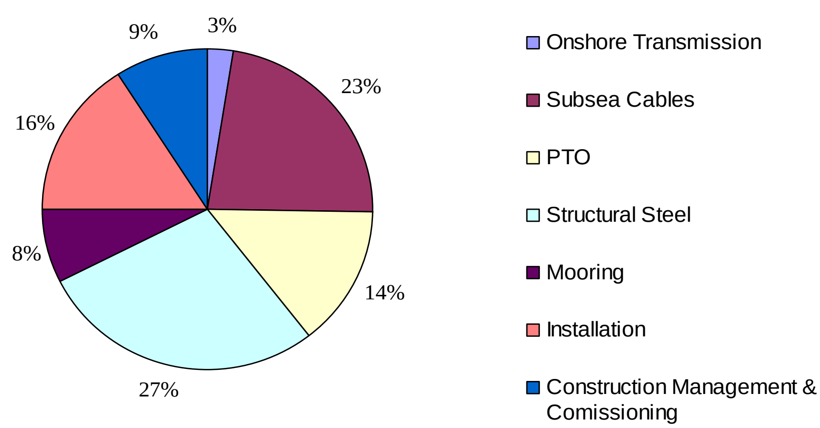

Figure 15: Pie Chart of cost centers for single unit installation

Cost uncertainties were estimated for each cost component and a Monte Carlo simulation was used to determine the likely capital uncertainty of the project. Figure 16 shows the cost as a function of cost certainty as an S-curve. A steep slope indicates a small amount of uncertainty, while a flat slope indicates a large amount of uncertainty. It shows that the cost accuracy is within -27% to +35%. This bottom-up approach to uncertainty estimation compares to an initially estimated accuracy of -25% to +30% for a pilot scale plant based on a preliminary cost estimate rating (from the top-down EPRI model described in Ref 3). This is important for budget estimate purposes as the range of values falls within the range of $3.9million and $7.2million.

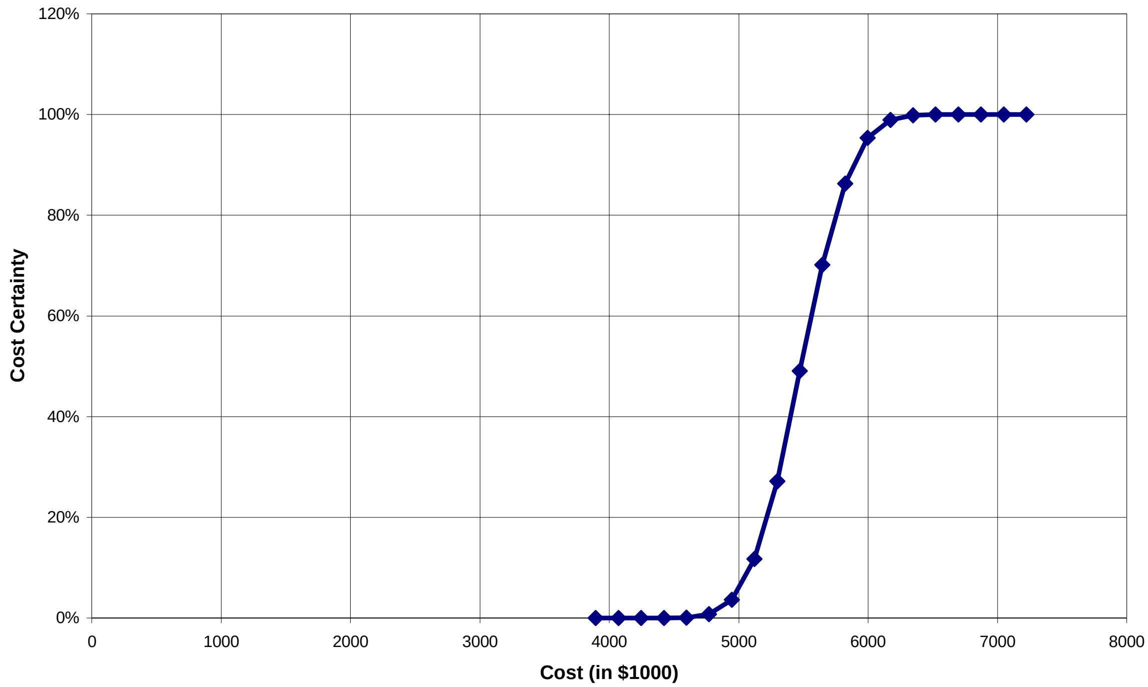

Figure 16: Cost Uncertainty based on Monte Carlo Simulation

9. Cost Assessment – Commercial Scale Plant

The cost assessment for the commercial wave power plant followed a assessment of each cost center. Instead of simply applying learning curves, a point design for the commercial plant using 152 devices was outlined and its cost estimated. Energetech's next generation device was looked at to come up with costing parameters for this device. The key difference is the mooring system, which allows the system to avoid large waves and as a result the peak loads on the device structure is reduced by about 75%. This has significant impacts on mooring and structural cost. Installation activities were outlined in detail and hourly breakdowns of offshore operational activities created to properly understand their impacts on cost and resources. Cost centers were validated by Energetech, based on their production experience of their first full scale prototype machine, which is planned to be deployed in early 2005. Operational tasks and outlines were validated by local operators.

Table 7: Installed Cost Breakdown for Commercial Scale Plant

Cost Element	**176-Energetech Units**		**Basis**
Constant Dollar Year	2004	In %	
Installed Cost			
Onshore Transmission & Grid Interconnection	$3,360,000	1.5%	(1)
Subsea Cables	$10,050,000	3.9%	(2)
152 x Mooring Systems	$19,762,000	9.2%	(3)
152 x Power Take Off	$66,821,000	31.2%	(4)
152 x Absorber Structure	$76,055,000	35.5%	(5)
Facilities	$15,000,000	6.5%	(6)
Installation	$16,784,000	7.8%	(7)
Construction Mgmt and Commissioning (5% of cost)	$9,552,000	4.4%	(8)
Total Plant Cost	**$217,385,000**	**100%**	
Construction Financing Cost	$20,653,000		
Total Plant Investment	**$238,038,000**		
Yearly O&M			
Labor	$1,936,000	17.6%	(9)
Parts (2%)	$4,348,000	41.2%	(10)
Insurance (2%)	$4,348,000	41.2%	(11)
Total	**$10,631,000**	**100%**	
10-year Refit			
Operation	$4,713,000	30.9%	(9)
Parts	$9,999,000	69.1%	(9)
Total	**$14,712,000**	**100%**	

(1) The current 12kV line limits transmission capabilities to about 8MVA. For a large scale deployment details on how to optimally interconnect such a power plant

would need to be studied in detail. From preliminary discussions with PG&E and internal assessments, the options are:

1. Build a new underground 110kV transmission line from the Waste water treatment plant at Ocean Beach to the Martin Substation. This option would require about 8 miles of new underground transmission at $6million per mile and would add about $50million to the project. Transmission capacity of a 110kV line would be about twice the requirements for the plant outlined for this point design. Electrical interconnection cost should be kept below 10% of total project cost to avoid significant impacts on electricity cost. Transmission capability could be shared with other offshore renewable generation sources, such as tidal and wind power, making a build-out an economically valid option.

2. Interconnect in Pacifica or Half Moon Bay. Grid Interconnection in Pacifica would cost only about $4million. The current substation could be adapted to handle the projected 100MVA load. Excellent wave resources exist in both of these areas and grid interconnection could be addressed in form of a regional development plan.

Alternative options to bring power to shore closed to Ocean Beach exist, but a detailed techno-economic assessment of different options would need to be carried out to properly understand limitations and opportunities and their impact on cost. It would make sense for the City of San Francisco to address these transmission limitations with a view of a comprehensive strategy to tap into it's vast offshore resources which are wind, wave and tidal. For this point design $4million (including installation) was added to the project cost.

(2) Includes a total of 4 sub sea cables connecting the offshore wave power clusters to the Wastewater treatment facility. Cables are buried in soft sediments and the existing pipe outfall is used to land the cables to shore.

(3) The mooring consists of 8 steel piles driven into soft sediments. A moderate cost reduction of 30% was assumed (as compared to the prototype). This cost reduction can easily be achieved by purchasing in larger quantities.

(4) The Power Take off consists of the Dennis Auld Air Turbine, electrical generator AC-DC-AC converter and a step transformer.

(5) Wave loads on Energetech's structure are reduced by as much as 75% in their next generation design. A reduction in steel weight by 66% was found to be reasonable. Steel manufacturing costs at these quantities was assumed to be $2000 per ton of

steel. Allowances for transport, ABS inspection and ancillary equipment was made.

(6) Includes tugs and allowances for dock modifications to launch and recover the device.

(7) Installation cost was estimated by a rigorous assessment of vessel handling requirements, breakdown of installation tasks, quotes from local operators for vessel cost, fuel and crew and allowance for weather downtime.

(8) Construction management and commissioning cost was estimated at 5% of the plant cost based on discussions with experienced construction management organizations.

(9) An outline of operational tasks was created to estimate the impact on costs. It showed, that a total of 9 crew is required to operate and maintain the wave farm of 152 devices.

(10) It is unclear at present what the failure rate of components and sub-systems are. Operational experience will be required with this specific technology to draw any conclusions. An allowance of 2% of Capital cost was included.

(11) 2% is a typical insurance rate for offshore projects using mature technology.

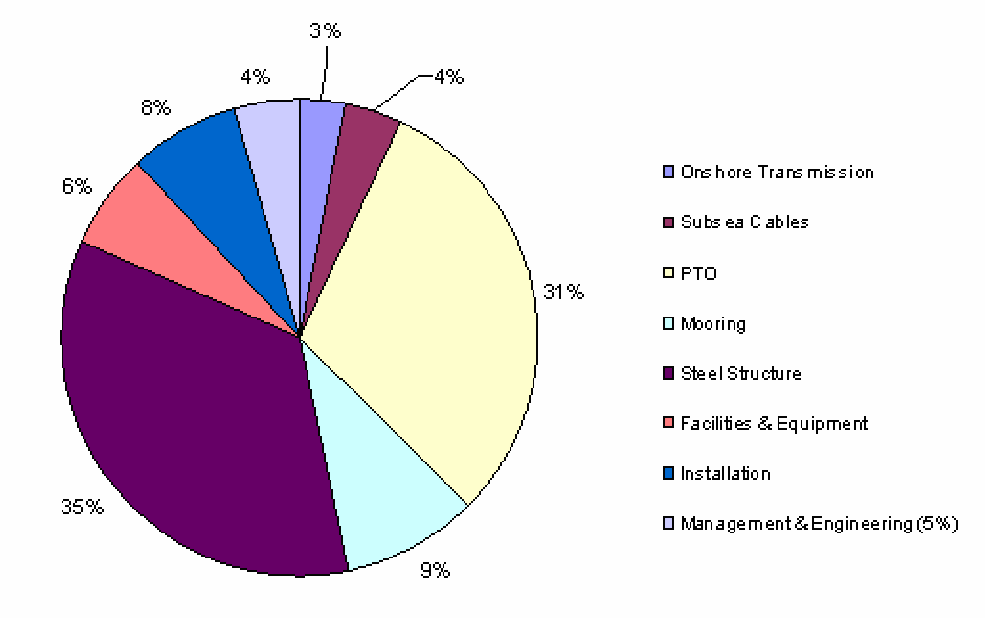

Figure 17: Installed Cost Breakdown for commercial scale plant

Cost uncertainties were estimated for each cost component and a Monte Carlo simulation was run to determine the likely capital uncertainty of the project. Figure 17 below shows the cost as a function of cost certainty as an S-curve. A steep slope indicates little uncertainty, while a flat slope indicates a large amount of uncertainty. The uncertainty for a large-scale project is bigger at this stage because it is unclear at present how well cost reductions could be achieved. These cost uncertainties were estimated for each cost center analyzed.

It shows that the cost accuracy is -26% to + 30%. This bottom-up approach to uncertainty estimation compares to an initially estimated accuracy of -25% to +30% (from the top-down EPRI model described in Reference 2). The reason, why the projections to a commercial plant have a higher uncertainty, then for a single unit demonstration plant is because certain cost centers include cost reduction measures, which are not well understood at present.

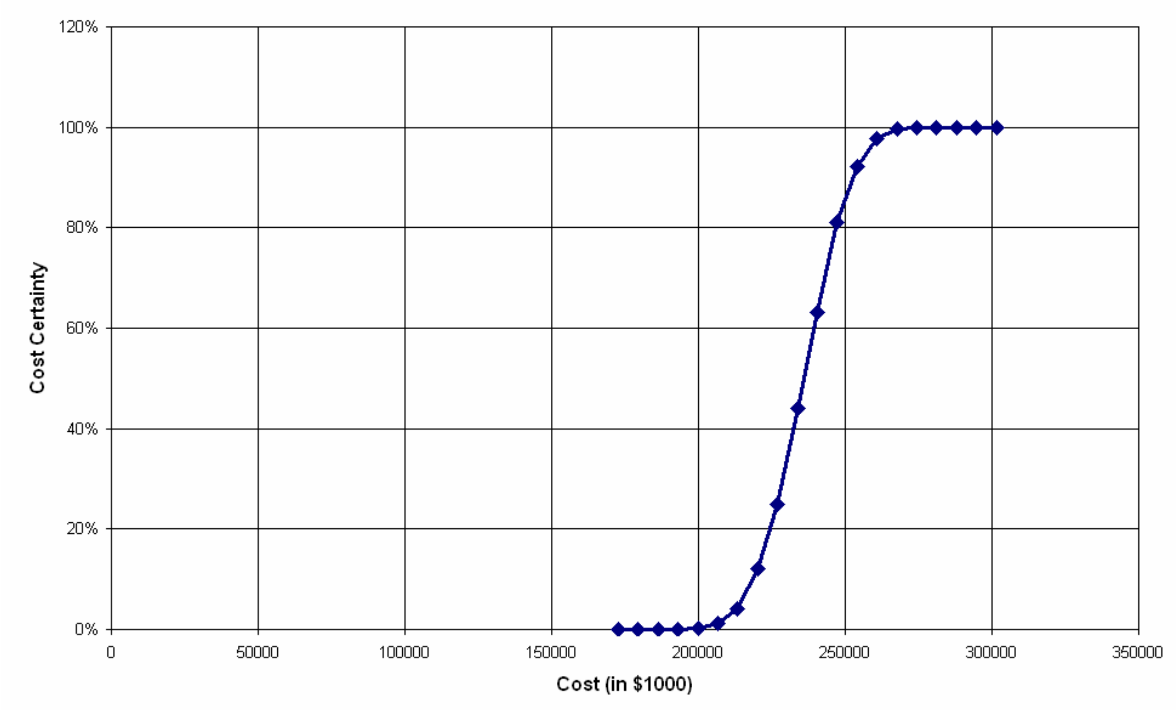

Figure 17: Installed Cost uncertainty S-curve

10. Cost of Electricity/Internal Rate of Return Assessment – Commercial Scale Plant

The Utility Generators (UG) cost of electricity (COE) and the Non-Utility Generator (NUG) internal rate of return (IRR) was assessed based on previously developed methodologies described in reference 3. In order to calculate the COE and IRR, underlying assumptions such as applicable tax rates, tax incentives, depreciation schedules and electricity price forecasts were identified based on the states applicable regulatory environment. Spreadsheet solutions were created for both Utility and Non-Utility Generators and results are outlined in this section.

Table 8: COE Assumptions for the State of California

	UG	NUG
Year Constant Dollar	2004	2004
Number of Devices	213	213
Annual Electrical Plant Output	300,000 MWh/yr	300,000 MWh/yr
Book Life	20 years	20 years
Taxation		
Federal Tax Rate	35%	35%
State Tax Rate (California)	8.844%	8.84%
Composite Tax Rate	40.7%	40.7%
Financing		
Common Equity Financing Share	52%	30%
Preferred Equity Financing Share	13%	
Debt Financing Share	35%	70%
Nominal Common Equity Financing Rate	13%	17%
Nominal Preferred Equity Financing Rate	10.5%	
Nominal Debt Financing Rate	7.5%	8%
Constant $ Discount Rate before Tax	9.25%	10.83%
Constant $ Discount Rate after Tax	5.77%	8.47%
Inflation rate	3%	3%
Renewable Credits & Incentives		
Federal Investment Tax Credit	10% of TPI	10% of TPI
Federal Production Tax Credit	1.8 cents/kWh (first 10 years)	1.8 cents/kWh (first 10 years)
State Investment Tax Credit	6%	6%
State Production Tax Credit		

Depreciation	MACR Accelerated 5 years	MACR Accelerated 5 years
Industrial Electricity Price (2002$) and	N/A	10.8 cents/kWh
Avoided Cost of Electricity (2004$)	N/A	5.4 cents/kWh[2]
Industrial Electricity Price Forecast (2002$) – The closest we could get to the electricity price as sold by a merchant plant to the grid operator	N/A	8% decline from 2002 to 2008, stable through 2011 and then a constant escalation rate of 0.3%

In terms of definition, the Internal Rate of Return (IRR) is the discount rate that sets the present value of the net cash flows over the life of the plant to the equity investment at the commercial operating date. The net present value represents the present value of profit or returns using the time value of money. This calculation results from discounting the net cash flows at the 'discount rate.' The economics analysis for this first commercial offshore wave power plant is described in detail in Appendix C

The capital, O&M and 10-Year Refit cost and their uncertainty was previously estimated in section 8. Table 9 shows the translation of those numbers into a levelized cost of electricity (COE) using the methodology described in Reference 3. The details of this economic analysis are contained in Appendix B.

Table 9 Major Cost elements and their Impacts on Cost of Electricity for Utility Generators (2004 constant year $)

Cost Element	Low	Best	High
Total Plant Investment	$176,852,000	$238,038,000	$308,832,000
Annual O&M Cost	$8,505,000	$10,631,000	$15,946,000
10-year Refit Cost (1 time cost)	$10,364,000	$14,712,000	$19,896,000
Fixed Charge rate (Nominal)	8.6	9.2	9.5
Cost of Electricity (c/kWh) (Nominal)	**8.1**	**11.1**	**15.5**
Fixed Charge rate (Real)	6.4	6.8	7.1
Cost of Electricity (c/kWh) (Real)	**6.8**	**9.2**	**13.0**

O&M costs have a significant effect on COE. It is a cost center with potential for significant improvements and is also the cost center with the most uncertainty at present because there is little experience with operating such wave farms which could be used to validate any of the numbers. Currently standard offshore oil & gas industry practices and rates were applied to derive appropriate operational costs. The offshore oil & gas industry is well known for it's high operational overhead and steep cost profiles. In order to reduce this cost center, the industry needs to learn by doing, by operating small wave farms. Cost

[2] Energy and Environmental Economics (E3), www.ethree.com/avoidedcosts.html, California PUC

reductions can be expected by improving the reliability of the deployed devices as well as improving the operational strategies.

Table 10 and 11 shows the translation of capital, O&M and 10-Year Refit cost and their uncertainty into a an internal rate of return (IRR) using the methodology described in Reference 3 for two electricity selling price assumptions:

1) A 2002 industrial price of 10.8 cents/kWh (source is the EIA)
2) A 2002 avoided price of electricity of 5.4 cents/kWh (source is E3 and Ca PUC)

Table 10: Major Cost elements and their impacts on IRR for Non Utility Generators (2008 initial operation – 20 year life – current year $ - 2002 Industrial price of 10.8 cents/kWh))

Cost Element	Lowest Estimate	Best Estimate	High Estimate
Total Plant Investment (2004)	$177,887,000	$239,432,000	$310,640,000
Annual O&M Cost (2004$)	$8,505,000	$10,631,000	$15,946,000
10-year Refit Cost (2004$)	$10,364,000	$14,712,000	$19,896,000
Internal Rate of Return	45.1%	29.8%	No IRR

Table 10 shows that the first commercial plant owned by a NUG provides a positive rate of return greater than the hurdle rate of 16% for both the best and low cost estimates cases..

Figure 19 shows the cumulative cash in current year dollars for the 20 year life of the project and Figure 20 shows the net cash flow.

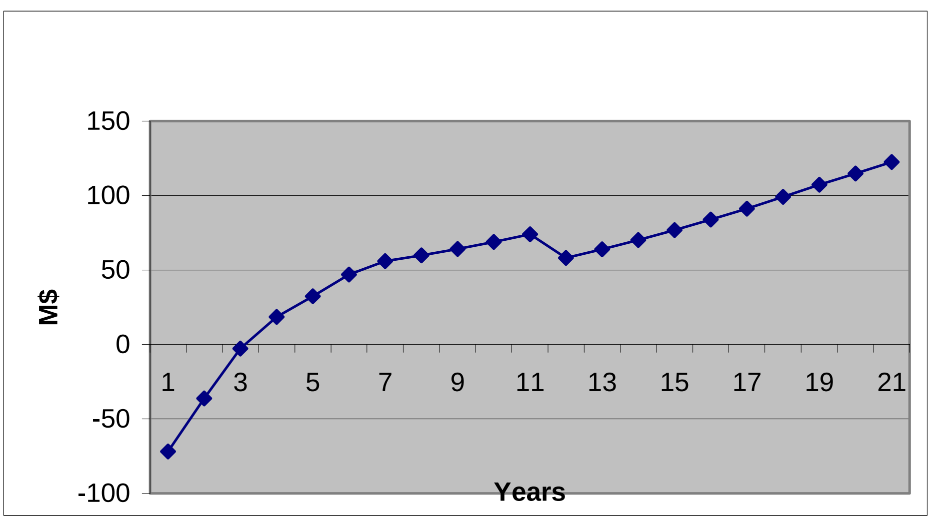

Figure 19: Cumulative Cash Flow Over 20 Year Project Life

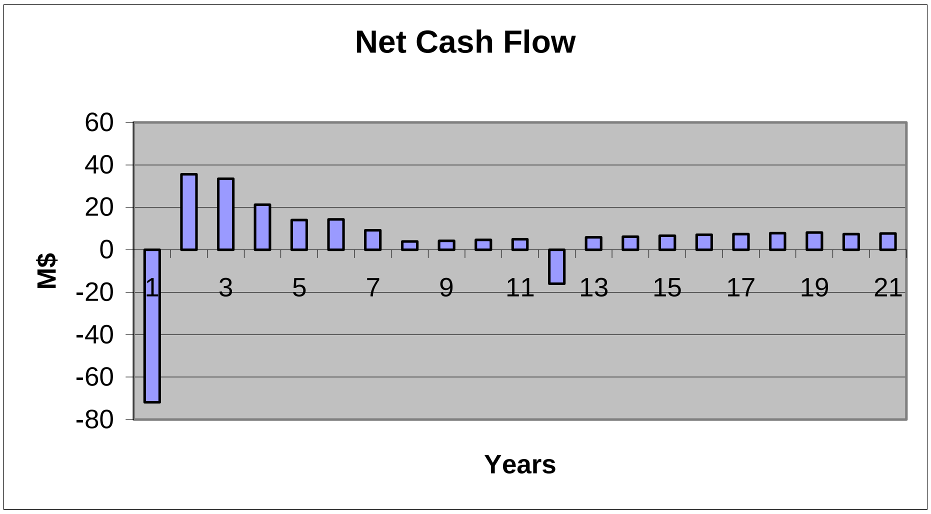

Figure 20: Net Cash Flow Over 20 Year Project Life

If the price at which the NUG can sell the electricity is the 5.4 cents/kWh of avoided cost in Northern California rather than the 10.8 cents/kWh industrial price, the economics change and are shown in Table 11.

Table 11: Major Cost elements and their impacts on IRR for Non Utility Generators (2008 initial operation – 20 year life – current year $ - 2004 selling price of 5.4 cents/kWh)

Cost Element	Lowest Estimate	Best Estimate	High Estimate
Total Plant Investment (2004)	$177,887,000	$239,432,000	$310,640,000
Annual O&M Cost (2004$)	$8,505,000	$10,631,000	$15,946,000
10-year Refit Cost (2004$)	$10,364,000	$14,712,000	$19,896,000
Internal Rate of Return	No IRR	No IRR	No IRR

Table 11 shows that a private investor does not make a return on this, the first commercial-scale offshore wave power plant under the scenario of a selling price equal to the avoided cost of electricity.

The next two sections describe learning curves and the reduction in cost associated with the learning experience

11. Learning Curves

Operating in competitive markets makes enterprises do better. This fact is at the core of the learning curve phenomenon. Learning through production experience reduces prices for energy technologies and these reductions influence the dynamic competition among technologies. In addition, learning curves are used by Government policymakers to design measures to stimulate the production of new technologies to where they become commercially competitive.

In order to make available environmentally effective technologies (or technologies that have characteristics that are deemed to be of societal benefit), which are price competitive, governments support these technologies through funding of RD&D and through price subsidies or other forms of deployment policy. Crucial questions concern how much support a technology needs to become competitive and how much of this support has to come from government budgets. Learning curves make it possible to answer such questions because they provide a simple, quantitative relationship between price and the cumulative production or use of a technology. There is overwhelming empirical support for such a price-experience relationship forms all fields of industrial activity, including the production of equipment that transfers or uses energy.

As explained in reference 3, cost reduction goes hand-in-hand with cumulative production experience and follows logarithmic relations such that for each doubling of the cumulative production volume, there is a corresponding percentage drop in cost. An 82% learning curve is the curve to use for wave technology based on experience in the wind, photovoltaic and offshore oil and gas platform industry.

How a learning curve is used to show the deployment investment necessary to make a technology, such as wave energy, competitive with an existing technology, such as wind energy is illustrated in Figure 24. It does not, however, forecast when the technologies will break-even. The time of break-even depends on the deployment rates, which the decision-maker can influence through policy.

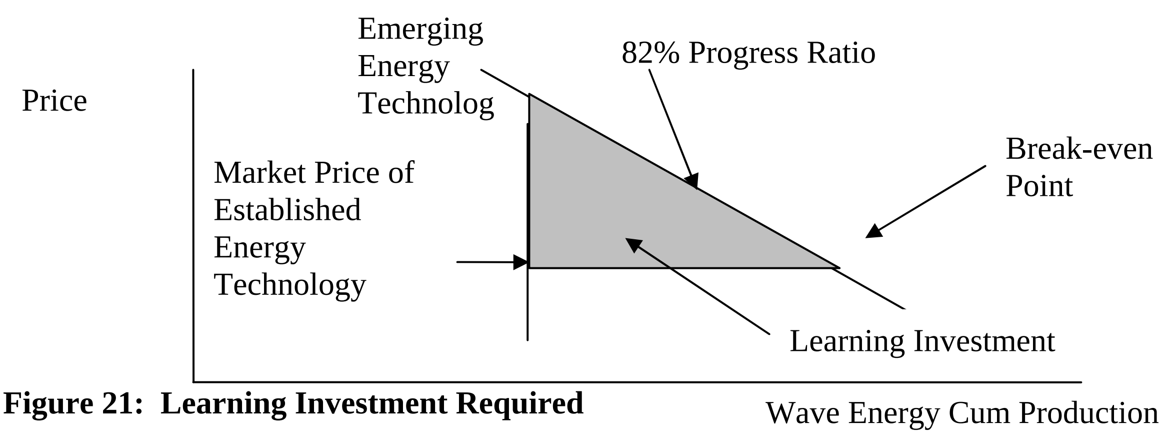

Figure 21: Learning Investment Required

12. Comparison with Commercial Scale Wind Power Plant

The costs (in 2004$) of a pilot offshore WEC device are described in Section 7 using the production experience gained by Energetech from building the first prototype machine. The costs (in 2004$) of a commercial scale offshore wave energy power plant are described in Section 8 and are an extension of the costs of the pilot plant with cost reductions estimated for each major component, i.e., on an individual basis and not using an overall learning curve effect.

In this section, we apply learning cost reductions discussed in the previous section to wave power systems using the cost of the commercial plant as the entry point to the learning curve process. The purpose is to enable the comparison of the cost of an offshore commercial scale wave farm versus the cost of an equivalent wind farm assuming the same level of production experience for both technologies.

For wind power plants and as reported by the National Wind Coordinating Council (NWCC), the installed capital cost has decreased from more than $2,500/kW in the early eighties to the 1997 range of $900/kW to $1,200/kW in 1997$[3]. The actual cost for a given installation depends on the size of the installation, the difficulty of construction, and the sophistication of the equipment and supporting infrastructure. “Total installed cumulative production volume topped 39,000 MW in 2003 and was about 10,000 MW in 1997”[4]. Based on the above numbers, the wind industry shows a progress ratio of 82%.

It turns out that the comparison of installed cost per unit of maximum or rated power as a function of cumulative installed capacity is not a meaningful comparison because of the effect of overrated or de-rated energy conversion devices. The 152 device Energetech 1st commercial plant system has a rating of 152 MW, however, it could be overrated or de-rated by the manufacturer without much of a change in the annual energy production. Therefore, the wave energy learning curve can be moved up or down in this chart at will and therefore has no useful meaning for the economic competitiveness to other renewable technologies. This is illustrated in Figure 25 which shows the learning curves for a 500kW and 750kW Energetech device in comparison to wind.

[3] “Wind Energy Costs” NWCC Wind Energy Series, Jan 1997, No 11
[4] “Wind Energy Industry Grows at Steady Pace, Adds Over 8,000 MW in 2003” American Wind Energy Association

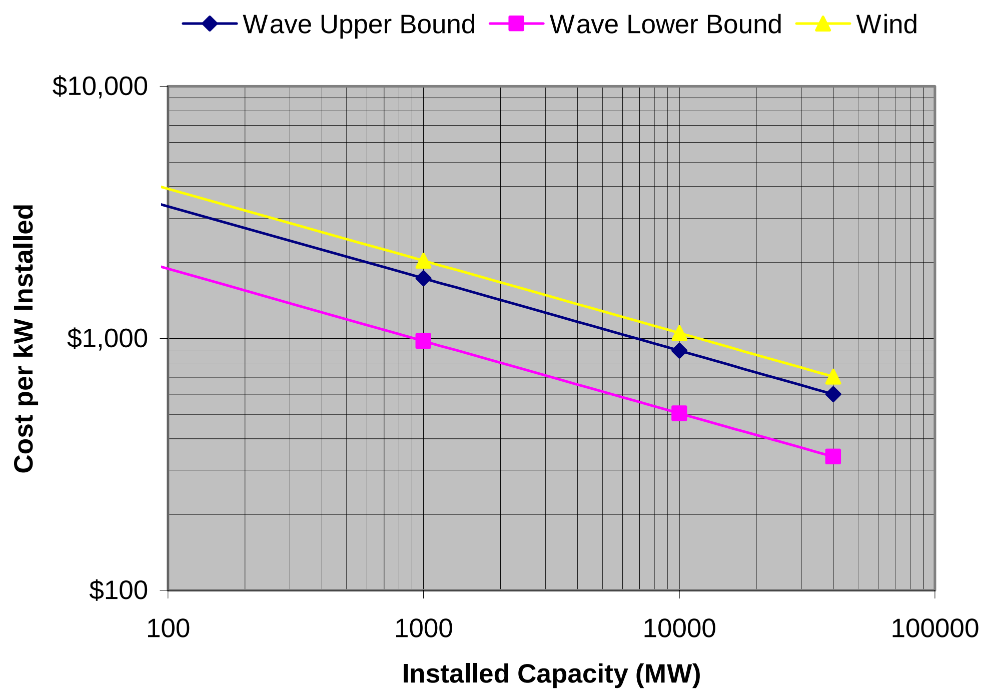

Figure 22: Installed Cost per kW installed as a Function of Installed Capacity

In order to make a meaningful comparison between wind and wave, a levelized comparison using COE numbers is required. In order to predict the cost of electricity for wave, a forecast of O&M cost is required. The following facts were considered in coming up with a conclusion:

- Offshore systems are more difficult to access then onshore systems and it is likely that it will always be more expensive to operate them then onshore systems
- Reliability will be similar to modern wind turbines Today (assuming the same cumulative production volume)
- Improvement in O&M costs can be made by paying greater attention to operational aspects in the design of the device

Based on numerous discussions, it was found a reasonable assumption for O&M cost for mature wave power technology to be 50% higher then shore based wind at a cumulative installed capacity of 40,000 MW. Using the O&M cost quoted by WCC of 1.29 cents/kWh, wave would have 1.9 cents/kWh at the equivalent cumulative installed capacity. Based on this assumption, COE costing curves are presented as a function of installed capacity and compared to wind. Optimistic and pessimistic scenarios are presented based on the uncertainty in opening Total Plant Investment and O&M costs of the commercial plant outlined in earlier sections of this report.

The NWCC (footnote 3) also provides data on O&M costs (in 1997$) as follows:

Management, Insurance, Land use and Property Taxes	0.39 cents/kWh
Unscheduled Maintenance	0.68 cents/kWh
Preventative Maintenance	0.18 cents/kWh
Major Overhaul	0.04 cents/kWh
Total	**1.29 cents/kWh**

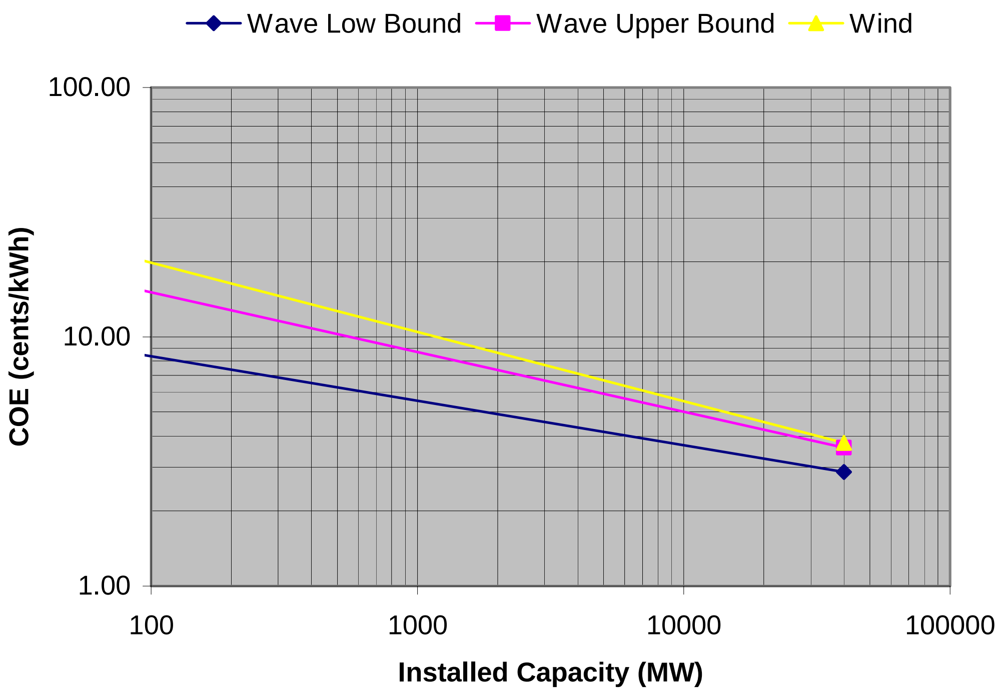

Figure 23: Levelized COE comparison to wind

Figure 23 shows that even under pessimistic assumptions, wave energy could become a viable option in the state of California and measure up to shore-based wind which is at present the most economic source of renewable energy.

The results in Figure 23 show that, even under pessimistic cost estimating assumptions for the wave energy technology plant, its economics is about equal to wind energy technology when both technologies are at an equivalent cumulative production level of 40,000 MW. Furthermore, this figure shows the magnitude of the O&M component of COE (the deviation from a straight line 82% learning curve) for wave energy. The wave energy industry must drive down O&M costs to compete with wind energy at very high cumulative production levels. Based on these results, we conclude that had wave energy been subsidized by the Government as it subsidized wind energy, wave energy would be the preferred renewable energy option by private investors today.

13. Conclusions

Offshore Demonstration Wave Power Plant

Ocean Beach California is a very good area for locating an offshore wave power plant for a lot of reasons, including but not limited to;

- Good wave climate
- Nearby harbor facilities offering marine engineering and local infrastructure
- Forward looking city leaders with a renewable energy vision
- Supportive public who voted for a bond measure to implement renewable energy by a large percentage
- Existing outflow pipe reducing the cost of landing the transmission cable and reducing the difficulty of permitting
- Existing marine sanctuary exclusion zone useful for demonstration plant with minimum permitting issues
- Existing environmental monitoring program provides the capability of determining before and after effects of the demonstration plant in a controlled test situation

The next steps forward towards implementing a wave energy pilot plant in the San Francisco Bay Area following this Phase I Project Definition Study are 1) create a detailed characterization of the near-shore wave climate off ocean beach to assess potential impacts on performance, 3) to analyze site-specific environmental effects and 4) to develop a detailed implementation plan for a Phase II (Detailed Design, Environmental Impact Statement, Permitting , Construction Financing and Detailed Implementation Planning for Construction, and Operational Test and Evaluation).

Commercial Scale Offshore Wave Power Plants

The San Francisco commercial scale power plant design, performance and cost results show that an offshore wave power plant, if learning investments are made to achieve the same degree of learning as today's wind technology, will provide favorable economics compared to wind technology in terms of both COE for a UG and in terms of IRR for a NUG.

As a new and emerging technology, offshore wave power has essentially no production experience and therefore its costs, uncertainties and risks are relatively high compared to existing commercially available technologies such as wind power with a cumulative production experience of about 40,000 MW installed. Private energy investors most probably will not select offshore wave technology when developing new generation because the cost, uncertainties and risk are too high at this point in time.

Government subsidy learning investments in wave energy technology, both RD&D and deployment are needed to ride down the experience curve to bring prices down to the break even point with wind energy technology. The market will then be transformed and offshore wave energy technology will be able to compete in the market place without further government subsidy (or at a subsidy equal to the wind energy subsidy). The learning effect irreversibly binds tomorrow's options to today's actions. Successful market implementation sets up a positive price-growth cycle; market growth provides learning and reduces price, which makes the product more attractive, supporting further growth which further reduces price. Conversely, a technology which cannot enter the market because it is too expensive will be denied the learning necessary to overcome the cost barrier and therefore the technology will be locked-out from the market.

The learning-curve phenomenon presents the Government policy-maker with both risks and benefits. The risks involve the lock-out of potentially low-cost and environmentally benign technologies. The benefits lie in the creation of new technology options by exploiting the learning effect. However, there is also the risk that expected benefits will not materialize. Learning opportunities in the market and learning investments are both scarce resources. Policy decisions to support market learning for a technology must therefore be based on assessments of the future markets for the technology and its value to the energy system

In a market where price reflects all present and future externalities, we expect the integrated action of the actors to produce an efficient balance of the technology options. The risk of climate change and the social and health costs of some electricity generation options, however, pose an externality which might be very substantial and costly to internalize through price alone. Intervening in the market to support a climate-friendly technology that may otherwise risk lock-out is a legitimate way for the Government policy-maker to manage the externality.

We conclude that offshore wave technology requires a Federal Government learning investment subsidy in order for it to be able to compete with available electricity generation technologies. All electricity generation technologies commercially available today have received Federal Government subsidies in the past. Subsidy of beneficial societal energy options has traditionally not been handled by State Governments.

Techno-Economic Challenges

Offshore wave energy electricity generation is a new and emerging technology application. The first time electricity was provided to the electrical grid from an offshore wave power plant occurred in early August, 2004 by the full scale preproduction OPD Pelamis prototype in the UK. Many important questions about the application of offshore wave energy to electricity generation remain to be answered. Some of the key issues which remain to be addressed are:

- There is not a single wave power technology. Rather we are talking about a wide range of wave power technologies and power conversion machines which are currently under development. It is unclear at present what type of technology will yield optimal economics.

- It is also unclear at present at which size these technologies will yield optimal economics. Wave Power devices are typically tuned to prevailing wave conditions. As such optimization is largely driven by the wave climate at the deployment site. Very few existing designs have been optimized for the US wave climate. Wind turbines for example have grown in size from less then 100kW per unit to over 3MW in order to drive down cost.

- Given a certain device type and rating, what capacity factor is optimal for a given site? Ocean waves have a vast range of power levels and optimal power ratings can be only determined using sophisticated techno-economic optimization procedures.

- Will the low intermittency (relative to solar and wind) and the better predictability of wave energy (relative to solar and wind) earn capacity payments for its ability to be dispatched for electricity generation?

- Will the installed cost of wave energy conversion devices realize their potential of being much less expensive per COE than solar or wind (because a wave machine is converting a much more concentrated form of energy than a solar or wind machine and is therefore smaller in size)?

- Will the performance, reliability and cost projections be realized in practice once wave energy devices are deployed and tested?

14. Recommendations

Offshore Demonstration Wave Power Plant

E2I EPRI Global makes the following specific recommendations to the San Francisco Bay Area Electricity Stakeholders relative to the Ocean Beach demonstration plant:

Now that the project definition study is complete, proceed to the next steps of assessing local public support, local infrastructure interest (marine engineering companies and fabricators), analyzing site-specific environmental effects and developing a detailed implantation plan for a Phase II (Detailed Design, Environmental Impact Statement, Permitting , Construction Financing and Detailed Implementation Planning for Construction, and Operational test and Evaluation) with a eye towards the Phase III construction phase and the Phase IV Operations and Test Evaluation phase

Build collaboration with other city governments in the Bay Area, with other states with interest and common goals in offshore wave energy and with the U.S. Department of Energy for the future.

Commercial Scale Offshore Wave Power Plants

E2I EPRI Global makes the following specific recommendations to the San Francisco State Electricity Stakeholders relative to a Ocean Beach San Francisco California commercial scale offshore wave power plant

Understand the implications of Government subsidy of wave energy technology, the use of learning curves to assist in subsidy decision-making and the potential for lock-out of the technology if the Government decides to withhold subsidy from this technology.

If after gaining this understanding, you advocate Government subsidy of offshore wave energy technology:

Encourage Department of Energy leaders to initiate an ocean energy RD&D program.

Encourage DOE leaders to participate in the development of offshore wave energy technology (standards, national offshore wave test center, etc).

Technology Application

In order to stimulate the growth of ocean energy technology in the United States and to address and answer the techno-economic challenges listed in Section 13, we recommend the following take place:

- Federal recognition of ocean energy as a renewable resource, and public recognition by Congress that expansion of an ocean energy industry in the U.S. is a vital national priority.
- Creation of an ocean energy program within the Department of Energy's Energy Efficiency and Renewable Energy division.
- DOE works with the government of Canada on an integrated bi-lateral ocean energy strategy.
- The process for licensing, leasing, and permitting renewable energy facilities in U.S. waters must be streamlined
- Provision of production tax credits, renewable energy credits, and other incentives to spur private investment in Ocean Energy technologies and projects.
- Provision of adequate federal funding for ocean energy R&D and demonstration projects.
- Ensuring that the public receives a fair return from the use of ocean energy resources and that development rights are allocated through an open, transparent process that takes into account state, local, and public concerns.

15. References

1. E2I EPRI WP US 005 "Methodology for Conceptual Level Design of Offshore Wave Power Plants" Mirko Previsic and Roger Bedard, June 9, 2004

2. E2I EPRI WP US 001 "Guidelines for Preliminary Estimation of Power Production by Offshore Wave Energy Conversion Devices" George Hagerman and Roger Bedard, December 22, 2003

3. E2I EPRI WP US 003 "Economic Assessment Methodology for Offshore Wave Energy Power Plants" Rev 2. Mirko Previsic and Roger Bedard, August 16, 2004

4. E2I EPRI WP US 004 "E2I EPRI Assessment Offshore Wave Energy Devices" Rev 1, Mirko Previsic, Roger Bedard and George Hagerman, June 16, 2004

5. Coastline Engineering Manual, U.S. Army Corps of Engineers EM 1110-2-1100 Part II, 30 April 2002

Appendix A – Monthly Wave Energy Resource Scatter Diagrams

Table A-1: Scatter diagram San Francisco January

NDBC 46026		Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	744
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	Total
Hs and Tp bin boundaries			Tp (sec)													annual
Lower Hs	Upper Hs	Hs (m)	3	4	5	6	7	8	9	10	11	12	14	17	20	hours
9.75	10.25	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.25	9.75	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.75	9.25	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.25	8.75	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.75	8.25	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.25	7.75	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.75	7.25	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.25	6.75	6.5	0	0	0	0	0	0	0	0	0	0	0	1	0	1
5.75	6.25	6	0	0	0	0	0	0	0	0	0	0	0	1	1	1
5.25	5.75	5.5	0	0	0	0	0	0	0	0	0	0	1	2	0	4
4.75	5.25	5	0	0	0	0	0	1	0	0	0	0	2	2	1	7
4.25	4.75	4.5	0	0	0	0	0	1	0	0	1	1	3	5	2	13
3.75	4.25	4	0	0	0	0	0	1	0	0	1	3	9	9	4	26
3.25	3.75	3.5	0	0	0	0	1	2	0	0	1	8	19	13	4	49
2.75	3.25	3	0	0	0	1	2	4	2	2	5	19	33	18	6	92
2.25	2.75	2.5	0	0	0	2	2	5	4	5	12	29	48	20	7	135
1.75	2.25	2	0	0	0	1	3	10	6	7	18	42	50	26	10	174
1.25	1.75	1.5	0	1	1	2	4	7	7	11	24	49	40	19	6	168
0.75	1.25	1	0	0	0	0	1	5	4	6	12	18	14	5	3	69
0.25	0.75	0.5	0	0	0	0	0	0	0	0	1	1	3	0	0	6
0	0.25	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	1	1	6	12	35	25	33	75	170	221	120	46	744

Table A-2: Scatter Diagram San Francisco February

NDBC 46026		Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	678
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	Total
Hs and Tp bin boundaries			Tp (sec)													annual
Lower Hs	Upper Hs	Hs (m)	3	4	5	6	7	8	9	10	11	12	14	17	20	hours
9.75	10.25	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.25	9.75	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.75	9.25	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.25	8.75	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.75	8.25	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.25	7.75	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.75	7.25	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.25	6.75	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.75	6.25	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1
5.25	5.75	5.5	0	0	0	0	0	0	0	0	0	0	1	2	0	4
4.75	5.25	5	0	0	0	0	0	0	0	0	0	1	2	5	1	11
4.25	4.75	4.5	0	0	0	0	0	1	0	1	1	2	4	6	1	15
3.75	4.25	4	0	0	0	0	0	1	1	1	1	2	8	6	1	21
3.25	3.75	3.5	0	0	0	0	1	3	2	2	2	5	13	10	2	39
2.75	3.25	3	0	0	0	0	2	5	3	3	6	13	23	15	4	76
2.25	2.75	2.5	0	0	0	1	2	6	3	6	12	23	36	20	8	119
1.75	2.25	2	0	0	1	2	3	6	6	11	21	40	53	18	9	169
1.25	1.75	1.5	0	0	1	1	2	4	6	10	22	39	38	15	7	146
0.75	1.25	1	0	0	0	1	1	2	4	5	9	11	22	12	2	69
0.25	0.75	0.5	0	0	0	1	0	0	0	1	2	1	3	0	0	9
0	0.25	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	2	7	12	28	26	41	76	139	203	109	36	678

Table A-3: Scatter Diagram San Francisco March

NDBC	46026	Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	744
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	Total
Hs and Tp bin boundaries									Tp (sec)							annual
Lower Hs	Upper Hs	Hs (m)	3	4	5	6	7	8	9	10	11	12	14	17	20	hours
9.75	10.25	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.25	9.75	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.75	9.25	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.25	8.75	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.75	8.25	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.25	7.75	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.75	7.25	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.25	6.75	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.75	6.25	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.25	5.75	5.5	0	0	0	0	0	0	0	0	0	0	0	1	0	2
4.75	5.25	5	0	0	0	0	0	0	0	0	0	0	1	2	0	4
4.25	4.75	4.5	0	0	0	0	0	0	0	1	0	1	2	3	1	9
3.75	4.25	4	0	0	0	0	0	1	1	1	1	3	7	4	1	19
3.25	3.75	3.5	0	0	0	0	1	2	1	2	3	8	15	5	2	39
2.75	3.25	3	0	0	0	0	2	6	3	4	9	17	26	11	3	80
2.25	2.75	2.5	0	0	0	2	6	8	6	8	18	31	37	15	6	137
1.75	2.25	2	0	0	1	3	6	8	8	13	30	48	46	20	7	189
1.25	1.75	1.5	0	0	2	3	4	11	8	14	27	41	36	15	6	166
0.75	1.25	1	0	1	1	2	1	2	5	10	12	18	24	6	1	82
0.25	0.75	0.5	1	0	0	0	0	1	1	1	2	5	4	1	0	17
0	0.25	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			1	2	3	10	18	39	33	54	103	173	197	83	28	744

Table A-4: Scatter Diagram San Francisco April

NDBC	46026	Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	720
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	Total
Hs and Tp bin boundaries									Tp (sec)							annual
Lower Hs	Upper Hs	Hs (m)	3	4	5	6	7	8	9	10	11	12	14	17	20	hours
9.75	10.25	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.25	9.75	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.75	9.25	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.25	8.75	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.75	8.25	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.25	7.75	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.75	7.25	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.25	6.75	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.75	6.25	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.25	5.75	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.75	5.25	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.25	4.75	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3.75	4.25	4	0	0	0	0	0	0	1	1	1	1	1	1	0	5
3.25	3.75	3.5	0	0	0	0	0	3	2	3	3	2	5	2	1	22
2.75	3.25	3	0	0	0	0	1	7	5	6	6	9	15	6	3	58
2.25	2.75	2.5	0	0	0	1	6	14	8	9	12	23	21	7	2	104
1.75	2.25	2	0	0	0	5	12	20	15	20	31	39	22	9	1	174
1.25	1.75	1.5	0	0	2	8	10	18	20	31	33	32	26	16	3	198
0.75	1.25	1	0	1	2	3	3	13	11	17	22	26	28	19	2	146
0.25	0.75	0.5	0	0	0	0	1	1	0	1	1	2	3	1	0	10
0	0.25	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	1	4	18	33	76	62	87	109	134	123	62	11	720

Table A-5: Scatter Diagram San Francisco May

NDBC	46026	Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	744
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	Total
Hs and Tp bin boundaries									Tp (sec)							annual
Lower Hs	Upper Hs	Hs (m)	3	4	5	6	7	8	9	10	11	12	14	17	20	hours
9.75	10.25	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.25	9.75	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.75	9.25	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.25	8.75	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.75	8.25	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.25	7.75	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.75	7.25	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.25	6.75	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.75	6.25	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.25	5.75	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.75	5.25	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1
4.25	4.75	4.5	0	0	0	0	0	0	0	0	1	0	0	0	0	1
3.75	4.25	4	0	0	0	0	0	0	1	1	0	0	0	0	0	3
3.25	3.75	3.5	0	0	0	0	0	2	2	2	2	1	2	0	0	11
2.75	3.25	3	0	0	0	0	1	11	8	6	3	3	3	1	0	35
2.25	2.75	2.5	0	0	0	1	7	25	14	12	10	8	5	2	1	85
1.75	2.25	2	0	0	0	6	24	40	28	21	26	18	8	6	2	179
1.25	1.75	1.5	0	0	3	21	25	43	31	31	28	21	21	22	4	249
0.75	1.25	1	0	3	4	12	8	15	12	12	13	16	35	25	2	156
0.25	0.75	0.5	0	1	0	1	1	3	3	4	2	3	6	1	0	24
0	0.25	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	4	7	40	66	139	99	89	84	69	80	57	9	744

Table A-6: Scatter Diagram San Francisco June

NDBC	46026	Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	720
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	Total
Hs and Tp bin boundaries									Tp (sec)							annual
Lower Hs	Upper Hs	Hs (m)	3	4	5	6	7	8	9	10	11	12	14	17	20	hours
9.75	10.25	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.25	9.75	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.75	9.25	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.25	8.75	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.75	8.25	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.25	7.75	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.75	7.25	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.25	6.75	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.75	6.25	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.25	5.75	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.75	5.25	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.25	4.75	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.75	4.25	4	0	0	0	0	0	0	1	0	0	0	0	0	0	1
3.25	3.75	3.5	0	0	0	0	0	2	3	2	0	1	0	0	0	9
2.75	3.25	3	0	0	0	0	1	11	8	6	2	3	3	0	0	34
2.25	2.75	2.5	0	0	0	1	7	28	18	12	7	8	6	1	0	88
1.75	2.25	2	0	0	0	6	20	52	27	22	11	8	4	2	1	153
1.25	1.75	1.5	0	0	3	23	29	54	39	29	18	10	9	16	4	233
0.75	1.25	1	0	1	5	11	10	22	25	19	16	13	28	29	5	184
0.25	0.75	0.5	0	0	0	0	0	2	2	1	1	2	6	3	1	17
0	0.25	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	1	7	40	68	173	122	91	54	45	57	51	10	720

Table A-7: Scatter Diagram San Francisco July

NDBC	46026	Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	744
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	*Total*
Hs and Tp bin boundaries									Tp (sec)							*annual*
Lower Hs	Upper Hs	**Hs (m)**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**14**	**17**	**20**	*hours*
9.75	10.25	**10**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
9.25	9.75	**9.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
8.75	9.25	**9**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
8.25	8.75	**8.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
7.75	8.25	**8**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
7.25	7.75	**7.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
6.75	7.25	**7**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
6.25	6.75	**6.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
5.75	6.25	**6**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
5.25	5.75	**5.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
4.75	5.25	**5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
4.25	4.75	**4.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
3.75	4.25	**4**	0	0	0	0	0	0	0	0	0	0	0	0	0	*1*
3.25	3.75	**3.5**	0	0	0	0	0	0	1	1	0	0	0	0	0	*1*
2.75	3.25	**3**	0	0	0	0	0	3	2	1	0	0	0	0	0	*6*
2.25	2.75	**2.5**	0	0	0	0	3	18	8	4	1	0	0	0	0	*34*
1.75	2.25	**2**	0	0	0	2	20	52	24	15	3	0	0	0	0	*117*
1.25	1.75	**1.5**	0	0	2	23	47	77	43	33	11	3	5	19	2	*266*
0.75	1.25	**1**	0	4	8	16	24	57	39	26	12	14	45	35	3	*283*
0.25	0.75	**0.5**	0	1	1	1	1	7	4	1	1	3	12	4	0	*36*
0	0.25	**0.125**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
			0	*4*	*11*	*43*	*95*	*213*	*122*	*81*	*28*	*20*	*63*	*59*	*6*	***744***

Table A-8: Scatter Diagram San Francisco August

NDBC	46026	Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	744
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	*Total*
Hs and Tp bin boundaries									Tp (sec)							*annual*
Lower Hs	Upper Hs	**Hs (m)**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**14**	**17**	**20**	*hours*
9.75	10.25	**10**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
9.25	9.75	**9.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
8.75	9.25	**9**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
8.25	8.75	**8.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
7.75	8.25	**8**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
7.25	7.75	**7.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
6.75	7.25	**7**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
6.25	6.75	**6.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
5.75	6.25	**6**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
5.25	5.75	**5.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
4.75	5.25	**5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
4.25	4.75	**4.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
3.75	4.25	**4**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
3.25	3.75	**3.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
2.75	3.25	**3**	0	0	0	0	0	2	1	0	0	0	0	0	0	*3*
2.25	2.75	**2.5**	0	0	0	0	3	9	3	2	0	0	0	0	0	*17*
1.75	2.25	**2**	0	0	0	4	19	42	12	7	4	2	1	0	0	*90*
1.25	1.75	**1.5**	0	0	2	24	52	74	32	19	9	6	9	15	1	*245*
0.75	1.25	**1**	1	4	10	30	37	68	42	28	16	16	47	40	5	*344*
0.25	0.75	**0.5**	1	1	1	3	3	9	5	3	2	5	9	4	0	*45*
0	0.25	**0.125**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
			2	*6*	*14*	*60*	*114*	*203*	*95*	*59*	*31*	*29*	*66*	*59*	*6*	***744***

Table A-9: Scatter Diagram San Francisco September

NDBC	46026	Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	720
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	*Total*
Hs and Tp bin boundaries									Tp (sec)							*annual*
Lower Hs	Upper Hs	**Hs (m)**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**14**	**17**	**20**	*hours*
9.75	10.25	**10**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
9.25	9.75	**9.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
8.75	9.25	**9**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
8.25	8.75	**8.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
7.75	8.25	**8**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
7.25	7.75	**7.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
6.75	7.25	**7**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
6.25	6.75	**6.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
5.75	6.25	**6**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
5.25	5.75	**5.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
4.75	5.25	**5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
4.25	4.75	**4.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
3.75	4.25	**4**	0	0	0	0	0	0	0	0	0	0	0	0	0	*1*
3.25	3.75	**3.5**	0	0	0	0	0	0	0	0	0	0	0	1	0	*3*
2.75	3.25	**3**	0	0	0	0	0	1	1	0	1	0	1	1	0	*6*
2.25	2.75	**2.5**	0	0	0	0	2	5	3	3	3	4	3	3	1	*28*
1.75	2.25	**2**	0	0	0	2	5	17	16	17	11	11	10	6	2	*99*
1.25	1.75	**1.5**	0	0	2	10	21	41	37	50	31	22	19	15	6	*252*
0.75	1.25	**1**	0	2	3	15	17	37	40	34	29	25	50	36	6	*295*
0.25	0.75	**0.5**	0	0	0	1	1	5	3	7	6	5	7	2	0	*37*
0	0.25	**0.125**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
			0	*2*	*5*	*28*	*46*	*107*	*100*	*112*	*81*	*66*	*92*	*66*	*16*	***720***

Table A-10: Scatter Diagram San Francisco October

NDBC	46026	Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	744
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	*Total*
Hs and Tp bin boundaries									Tp (sec)							*annual*
Lower Hs	Upper Hs	**Hs (m)**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**14**	**17**	**20**	*hours*
9.75	10.25	**10**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
9.25	9.75	**9.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
8.75	9.25	**9**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
8.25	8.75	**8.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
7.75	8.25	**8**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
7.25	7.75	**7.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
6.75	7.25	**7**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
6.25	6.75	**6.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
5.75	6.25	**6**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
5.25	5.75	**5.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
4.75	5.25	**5**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
4.25	4.75	**4.5**	0	0	0	0	0	0	0	0	0	0	0	1	0	*1*
3.75	4.25	**4**	0	0	0	0	0	0	0	0	1	1	2	2	0	*5*
3.25	3.75	**3.5**	0	0	0	0	0	1	1	1	1	1	4	3	0	*13*
2.75	3.25	**3**	0	0	0	0	1	3	2	2	3	4	8	2	1	*26*
2.25	2.75	**2.5**	0	0	0	1	3	7	6	6	9	12	13	5	2	*64*
1.75	2.25	**2**	0	0	0	4	7	11	10	16	22	32	23	8	4	*138*
1.25	1.75	**1.5**	0	0	2	7	11	24	24	29	37	43	35	19	5	*236*
0.75	1.25	**1**	0	1	1	5	10	21	26	29	33	35	35	31	4	*232*
0.25	0.75	**0.5**	0	1	0	1	2	5	4	1	2	5	5	1	0	*27*
0	0.25	**0.125**	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*
			0	*2*	*3*	*18*	*32*	*73*	*73*	*85*	*109*	*133*	*127*	*72*	*17*	***744***

Table A-11: Scatter Diagram San Francisco November

NDBC	46026	Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	720
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	Total
Hs and Tp bin boundaries									Tp (sec)							annual
Lower Hs	Upper Hs	Hs (m)	3	4	5	6	7	8	9	10	11	12	14	17	20	hours
9.75	10.25	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.25	9.75	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.75	9.25	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.25	8.75	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.75	8.25	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.25	7.75	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.75	7.25	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.25	6.75	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.75	6.25	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.25	5.75	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1
4.75	5.25	5	0	0	0	0	0	0	0	0	0	0	1	2	0	4
4.25	4.75	4.5	0	0	0	0	0	0	0	0	0	0	2	3	0	6
3.75	4.25	4	0	0	0	0	0	0	0	0	0	1	5	5	0	13
3.25	3.75	3.5	0	0	0	0	1	2	1	1	2	5	9	6	0	26
2.75	3.25	3	0	0	0	0	2	4	2	2	5	11	17	8	1	53
2.25	2.75	2.5	0	0	0	1	4	7	4	8	14	31	38	12	3	123
1.75	2.25	2	0	0	1	2	4	9	8	11	29	45	41	14	5	168
1.25	1.75	1.5	0	0	2	4	6	10	10	21	39	39	28	9	5	172
0.75	1.25	1	0	1	1	2	5	9	12	14	21	26	29	14	2	136
0.25	0.75	0.5	0	0	0	0	1	3	2	2	2	3	3	1	0	17
0	0.25	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			1	1	3	10	23	45	39	59	113	161	172	74	18	720

Table A-12: Scatter Diagram San Francisco December

NDBC	46026	Upper Tp:	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	14.5	17.5	20.5	744
San Francisco 52 m		Lower Tp:	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	16.5	19.5	Total
Hs and Tp bin boundaries									Tp (sec)							annual
Lower Hs	Upper Hs	Hs (m)	3	4	5	6	7	8	9	10	11	12	14	17	20	hours
9.75	10.25	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.25	9.75	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.75	9.25	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.25	8.75	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.75	8.25	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.25	7.75	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.75	7.25	7	0	0	0	0	0	0	0	0	0	0	0	1	0	1
6.25	6.75	6.5	0	0	0	0	0	0	0	0	0	0	0	1	0	1
5.75	6.25	6	0	0	0	0	0	0	0	0	0	0	1	1	0	2
5.25	5.75	5.5	0	0	0	0	0	0	0	0	0	0	2	1	0	4
4.75	5.25	5	0	0	0	0	0	0	0	0	1	0	2	2	0	6
4.25	4.75	4.5	0	0	0	0	0	1	0	0	1	1	3	3	1	10
3.75	4.25	4	0	0	0	0	0	2	1	1	2	3	7	6	1	23
3.25	3.75	3.5	0	0	0	0	1	3	1	2	3	8	19	14	3	56
2.75	3.25	3	0	0	0	1	2	4	2	3	7	17	33	16	5	90
2.25	2.75	2.5	0	0	0	2	2	4	3	5	11	31	46	22	8	135
1.75	2.25	2	0	0	0	2	2	4	4	6	19	41	47	24	9	157
1.25	1.75	1.5	0	0	1	1	1	4	6	14	20	34	43	16	4	142
0.75	1.25	1	0	1	0	0	0	5	5	10	16	26	29	9	3	105
0.25	0.75	0.5	0	0	0	0	1	1	1	2	2	3	1	0	0	12
0	0.25	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	1	1	6	10	28	24	44	82	165	233	115	34	744

Appendix B Commercial Plant Cost Economics Worksheet – Regulated Utility

INSTRUCTIONS

Indicates Input Cell (either input or use default values)

Indicates a Calculated Cell (do not input any values)

Sheet 1. TPC/TPI (Total Plant Cost/Total Plant Investment)

a) Enter Component Unit Cost and No. of Units per System
b) Worksheet sums component costs to get TPC
c) Adds the value of the construction loan payments to get TPI

Sheet 2. AO&M (Annual operation and Maintenance Cost)

a) Enter Labor Hrs and Cost by O&M Type)
b) Enter Parts and Supplies Cost by O&M Type)
c) Worksheet Calculates Total Annual O&M Cost

Sheet 3. O&R (Overhaul and Replacement Cost)

a) Enter Year of Cost and O&R Cost per Item
b) Worksheets calculates the present value of the O&R costs

Sheet 4. Assumptions (Financial)

a) Enter project and financial assumptions or leave default values

Sheet 5. NPV (Net Present Value)

A Gross Book Value = TPI
B Annual Book Depreciation = Gross Book Value/Book Life
C Cumulative Depreciation
D MACRS 5 Year Depreciation Tax Schedule Assumption
E Deferred Taxes = (Gross Book Value X MACRS Rate - Annual Book Depreciation) X Debt Financing Rate
F Net Book Value = Previous Year Net Book Value - Annual Book Depreciation - Deferred Tax for that Year

Sheet 6. CRR (Capital Revenue Requirements)

A Net Book Value for Column F of NPV Worksheet
B Common Equity = Net Book X Common Equity Financing Share X Common Equity Financing Rate
C Preferred Equity = Net Book X Preferred Equity Financing Share X Preferred Equity Financing Rate
D Debt = Net Book X Debt Financing Share X Debt Financing Rate
E Annual Book Depreciation = Gross Book Value/Book Life
F Income Taxes = (Return on Common Equity+Return of Preferred Equity-Deferred Taxes- Book Depreciation + Deferred Taxes) X (Comp Tax Rate/(1-Comp Tax Rate))
G Property Taxes and Insurance Expense =
H Calculates Investment and Production Tax Credit Revenues
I Capital Revenue Req'ts = Sum of Columns B through G

Sheet 7. FCR (Fixed Charge Rate)

A Constant $ Capital Revenue Req'ts from Columnn H of Previous Worksheet
B Constant $ Present Worth Factor = 1 / (1 + After Tax Discount Rate)
C Constant $ Product of Columns A and B = A * B
D Real $ Capital Revenue Req'ts from Columnn H of Previous Worksheet
E Real $ Present Worth Factor = 1 / (1 + After Tax Discount Rate - Inflation Rate)
F Real $ Product of Columns A and B = A * B

Sheet 8. Calculates COE (Cost of Electricity)

COE = ((TPI * FCR) + AO&M + LO&R) / AEP
In other words…The Cost of Electricity =
The Sum of the Levelized Plant Investment + Annual O&M Cost + Levelized Overhaul and Replacement Cost Divided by the Annual Electric Energy Consumption

TOTAL PLANT COST (TPC) - 2004$

TPC Component	Unit	Unit Cost	Total Cost (2004$)	
Procurement				
Onshore Trans & Grid I/C	1	$3,360,000	$3,360,000	
Subsea Cables	1	$10,050,000	$10,050,000	
Mooring	152	$130,013	$19,761,976	
Power Take Off	152	$439,612	$66,821,024	
Absorber Structure	152	$500,362	$76,055,024	
Facilities	1	$15,000,000	$15,000,000	
Installation	1	$16,785,000	$16,785,000	
Construction Management	1	$9,552,419	$9,552,419	
TOTAL			$217,385,443	

TOTAL PLANT INVESTMENT (TPI) - 2004 $

End of Year	Total Cash Expended TPC (2004$)	Before Tax Construction Loan Cost at Debt Financing Rate	2004 Value of Construction Loan Payments	TOTAL PLANT INVESTMENT 2004$
2006	$108,692,722	$8,151,954	$7,360,681	$116,053,402
2007	$108,692,722	$8,151,954	$13,292,426	$121,985,148
Total	$217,385,443	$16,303,908	$20,653,107	$238,038,550

ANNUAL OPERATING AND MAINTENANCE COST (AO&M) - 2004$

Costs	Yrly Cost	Amount	
LABOR	$1,936,000	$1,936,000	
PARTS AND SUPPLIES (2%)	$4,348,000	$4,348,000	
INSURANCE (2%)	$4,348,000	$4,348,000	
Total		$10,632,000	

OVERHAUL AND REPLACEMENT COST (OAR) - 2004$

O&R Costs	Year of Cost	Cost in 2004$	
10 Year Retrofit			
Operation	10	$4,713,000	
Parts	10	$9,999,000	
Total		$14,712,000	

FINANCIAL ASSUMPTIONS

(default assumptions in pink background - without line numbers are calculated values)

1	Rated Plant Capacity ©	152	MW
2	Annual Electric Energy Production (AEP)	300,000	MWeh/yr
	Therefore, Capacity Factor	22.52	%
3	Year Constant Dollars	2004	Year
4	Federal Tax Rate	35	%
5	State	SF California	
6	State Tax Rate	8.84	%
	Composite Tax Rate (t)	0.40746	
	t/(1-t)	0.6876	
7	Book Life	20	Years
8	Construction Financing Rate	7.5	
9	Common Equity Financing Share	52	%
10	Preferred Equity Financing Share	13	%
11	Debt Financing Share	35	%
12	Common Equity Financing Rate	13	%
13	Preferred Equity Financing Rate	10.5	%
14	Debt Financing Rate	7.5	%
	Nominal Discount Rate Before-Tax	10.75	%
	Nominal Discount Rate After-Tax	9.68	%
15	Inflation Rate = 3%	3	%
	Real Discount Rate Before-Tax	7.52	%
	Real Discount Rate After-Tax	6.49	%
16	Federal Investment Tax Credit	10	% 1st year only
17	Federal Production Tax Credit	0.018	$/kWh for 1st 10 years
18	State Investment Tax Credit	6	% of TPI 1st yr only
20	State Production Tax Credit	0	

NET PRESENT VALUE (NPV) - 2004 $

TPI = $238,038,550

Year End	Gross Book Value	Book Depreciation Annual	Book Depreciation Accumulated	Renewable Resource MACRS Tax Depreciation Schedule	Deferred Taxes	Net Book Value
	A	B	C	D	E	F
2007	**238,038,550**					**238,038,550**
2008	238,038,550	11,901,927	11,901,927	0.2000	14,548,678	211,587,944
2009	238,038,550	11,901,927	23,803,855	0.3200	26,187,621	173,498,396
2010	238,038,550	11,901,927	35,705,782	0.1920	13,772,749	147,823,720
2011	238,038,550	11,901,927	47,607,710	0.1152	6,323,825	129,597,967
2012	238,038,550	11,901,927	59,509,637	0.1152	6,323,825	111,372,214
2013	238,038,550	11,901,927	71,411,565	0.0576	737,133	98,733,154
2014	238,038,550	11,901,927	83,313,492	0.0000	-4,849,559	91,680,786
2015	238,038,550	11,901,927	95,215,420	0.0000	-4,849,559	84,628,417
2016	238,038,550	11,901,927	107,117,347	0.0000	-4,849,559	77,576,049
2017	238,038,550	11,901,927	119,019,275	0.0000	-4,849,559	70,523,681
2018	238,038,550	11,901,927	130,921,202	0.0000	-4,849,559	63,471,313
2019	238,038,550	11,901,927	142,823,130	0.0000	-4,849,559	56,418,945
2020	238,038,550	11,901,927	154,725,057	0.0000	-4,849,559	49,366,577
2021	238,038,550	11,901,927	166,626,985	0.0000	-4,849,559	42,314,209
2022	238,038,550	11,901,927	178,528,912	0.0000	-4,849,559	35,261,841
2023	238,038,550	11,901,927	190,430,840	0.0000	-4,849,559	28,209,472
2024	238,038,550	11,901,927	202,332,767	0.0000	-4,849,559	21,157,104
2025	238,038,550	11,901,927	214,234,695	0.0000	-4,849,559	14,104,736
2026	238,038,550	11,901,927	226,136,622	0.0000	-4,849,559	7,052,368
2027	238,038,550	11,901,927	238,038,550	0.0000	-4,849,559	0

CAPITAL REVENUE REQUIREMENTS

TPI = $238,038,550

End of Year	Net Book	Returns to Equity Common	Returns to Equity Pref	Interest on Debt	Book Dep	Income Tax on Equity Return	ITC and PTC	Capital Revenue Req'ts
	A	B	C	D	E	F	H	I
2008	211,587,944	14,303,345	2,888,175	5,554,184	11,901,927	18,006,807	43,486,168	9,168,271
2009	173,498,396	11,728,492	2,368,253	4,554,333	11,901,927	24,569,749	5,400,000	49,722,754
2010	147,823,720	9,992,883	2,017,794	3,880,373	11,901,927	15,061,630	5,400,000	37,454,607
2011	129,597,967	8,760,823	1,769,012	3,401,947	11,901,927	9,250,068	5,400,000	29,683,777
2012	111,372,214	7,528,762	1,520,231	2,923,521	11,901,927	8,560,756	5,400,000	27,035,197
2013	98,733,154	6,674,361	1,347,708	2,591,745	11,901,927	4,241,050	5,400,000	21,356,792
2014	91,680,786	6,197,621	1,251,443	2,406,621	11,901,927	132,637	5,400,000	16,490,248
2015	84,628,417	5,720,881	1,155,178	2,221,496	11,901,927	-134,089	5,400,000	15,465,393
2016	77,576,049	5,244,141	1,058,913	2,036,371	11,901,927	-400,815	5,400,000	14,440,538
2017	70,523,681	4,767,401	962,648	1,851,247	11,901,927	-667,541	5,400,000	13,415,682
2018	63,471,313	4,290,661	866,383	1,666,122	11,901,927	-934,267		17,790,827
2019	56,418,945	3,813,921	770,119	1,480,997	11,901,927	-1,200,992		16,765,972
2020	49,366,577	3,337,181	673,854	1,295,873	11,901,927	-1,467,718		15,741,116
2021	42,314,209	2,860,441	577,589	1,110,748	11,901,927	-1,734,444		14,716,261
2022	35,261,841	2,383,700	481,324	925,623	11,901,927	-2,001,170		13,691,406
2023	28,209,472	1,906,960	385,059	740,499	11,901,927	-2,267,895		12,666,550
2024	21,157,104	1,430,220	288,794	555,374	11,901,927	-2,534,621		11,641,695
2025	14,104,736	953,480	192,530	370,249	11,901,927	-2,801,347		10,616,840
2026	7,052,368	476,740	96,265	185,125	11,901,927	-3,068,073		9,591,984
2027	0	0	0	0	11,901,927	-3,334,798		8,567,129
Sum of Annual Capital Revenue Requirements								366,023,040

FIXED CHARGE RATE (FCR) - NOMINAL AND REAL LEVELIZED

TPI = $238,038,550

End of Year	Capital Revenue Req'ts Nominal A	Present Worth Factor Nominal B	Product of Columns A and B C	Capital Revenue Req'ts Real D	Present Worth Factor Real E	Product of Columns D and E F
2008	9,168,271	0.9117	8,359,077	8,390,267	0.9391	7,879,232
2009	49,722,754	0.8313	41,333,005	44,178,023	0.8819	38,960,322
2010	37,454,607	0.7579	28,386,900	32,308,673	0.8282	26,757,375
2011	29,683,777	0.6910	20,511,753	24,859,696	0.7777	19,334,294
2012	27,035,197	0.6300	17,032,722	21,982,089	0.7304	16,054,974
2013	21,356,792	0.5744	12,267,652	16,859,249	0.6859	11,563,438
2014	16,490,248	0.5237	8,636,217	12,638,402	0.6441	8,140,463
2015	15,465,393	0.4775	7,384,621	11,507,705	0.6049	6,960,713
2016	14,440,538	0.4353	6,286,682	10,432,152	0.5680	5,925,801
2017	13,415,682	0.3969	5,325,027	9,409,490	0.5334	5,019,349
2018	17,790,827	0.3619	6,438,372	12,114,688	0.5009	6,068,784
2019	16,765,972	0.3300	5,531,967	11,084,282	0.4704	5,214,410
2020	15,741,116	0.3008	4,735,407	10,103,624	0.4418	4,463,575
2021	14,716,261	0.2743	4,036,362	9,170,687	0.4149	3,804,659
2022	13,691,406	0.2501	3,423,825	8,283,526	0.3896	3,227,284
2023	12,666,550	0.2280	2,887,971	7,440,263	0.3659	2,722,190
2024	11,641,695	0.2079	2,420,035	6,639,096	0.3436	2,281,115
2025	10,616,840	0.1895	2,012,202	5,878,287	0.3227	1,896,693
2026	9,591,984	0.1728	1,657,508	5,156,164	0.3030	1,562,360
2027	8,567,129	0.1575	1,349,750	4,471,120	0.2846	1,272,269
	366,023,040		190,017,057	272,907,483		179,109,300

	Nominal $		Real $
1. The present value is at the beginning of 2006 and results from the sum of the products of the annual present value factors times the annual requirements	190,017,057		179,109,300
2. Escalation Rate	3%		3%
3. After Tax Discount Rate = i	9.68%		6.49%
4. Capital recovery factor value = i(1+i)"/(1+i)"-1 where book life = n and discount rate = i	0.114907902		0.090654358
5. The levelized annual charges (end of year) = Present Value (Item 1) * Capital Recovery Factor (Item 4)	21,834,461		16,237,039
6. Booked Cost	238,038,550		238,038,550
7. The levelized annual fixed charge rate (levelized annual charges divided by the booked cost)	**0.0917**		**0.0682**

LEVELIZED COST OF ELECTRICITY CALCULATION - UTILITY GENERATOR

COE = ((TPI * FCR) + AO&M + LO&R) / AEP
In other words…
The Cost of Electricity =
The Sum of the Levelized Plant Investment + Annual O&M Cost + Levelized Overhaul and Replacement Cost
Divided by the Annual Electric Energy Consumption

NOMINAL RATES

	Value	Units	From
TPI	$238,038,550	$	From TPI
FCR	9.17%	%	From FCR
AO&M	$10,632,000	$	From AO&M
LO&R = O&R/Life	$735,600	$	From LO&R
AEP =	300,000	MWeh/yr	From Assumptions
COE - TPI X FCR	7.28	cents/kWh	
COE - AO&M	3.54	cents/kWh	
COE - LO&R	0.25	cents/kWh	
COE	$0.1107	$/kWh	Calculated
COE	**11.07**	cents/kWh	Calculated

REAL RATES

	Value	Units	From
TPI	$238,038,550	$	From TPI
FCR	6.82%	%	From FCR
AO&M	$10,632,000	$	From AO&M
LO&R = O&R/Life	$735,600	$	From LO&R
AEP =	300,000	MWeh/yr	From Assumptions
COE - TPI X FCR	5.41	cents/kWh	
COE - AO&M	3.54	cents/kWh	
COE - LO&R	0.25	cents/kWh	
COE	$0.0920	$/kWh	Calculated
COE	**9.20**	cents/kWh	Calculated

Appendix C - Commercial Plant Cost Economics Worksheet – NUG

INSTRUCTIONS		
Fill in first four worksheets (or use default values) - the last two worksheets are automatically calculated. Refer to E2I EPRI Economic Methodology Report 004 Rev 2		
(pink cell)		Indicates Input Cell (either input or use default values)
(outlined cell)		Indicates a Calculated Cell (do not input any values)
Sheet 1.	**Total Plant Cost/Total Plant Investment (TPC/TPI) - 2004$**	
	1	Enter Component Unit Cost and No. of Units per System
	2	Worksheet sums component costs to get TPC
	3	Worksheet adds the value of the construction loan payments to get TPI
Sheet 2.	**AO&M (Annual Operation and Maintenance Cost) - 2004$**	
	1	Enter Labor Hrs and Cost by O&M Type)
	2	Enter Parts and Supplies Cost by O&M Type)
	3	Worksheet Calculates Total Annual O&M Cost
Sheet 3.	**O&R (Overhaul and Replacement Cost) - 2004$**	
	1	Enter Year of Cost and O&R Cost per Item
	2	Worksheet calculates inflation to the year of the cost of the O&R
Sheet 4.	**Assumptions (Project, Financial and Others)**	
	1	Enter project, financial and other assumptions or leave default values
Sheet 5.	**Income Statement - Assuming no capacity factor income - Current $**	
	1	2008 Energy payments(2002-2008) = AEP X 2002 wholesale price X 92% (to adjust price from 2002 to 2008 (an 8% decline) X Inflation from 2002 to 2008
		2009-2011 Energy payments = 2008 Energy Payment X Inflation
		2012-2027 Energy payments = 2011 Energy Price X 0.3% Price escalation X Inflation
	2	Calculates State Investment and Producint tax credit
	3	Calculates Federal Investment and Production Tax Credit
	4	Scheduled O&M from TPC worksheet with inflation
	5	Scheduled O&R from TPC worksheet with inflation
	8	Earnings before EBITDA = total revenues less total operating costs
	9	Tax Depreciation = Assumed MACRS rate X TPI
	10	Interest paid = Annual interest given assumed debt interest rate and life of loan
	11	Taxable earnings = Tax Depreciation + Interest Paid
	12	State Tax = Taxable Earnings x state tax rate
	13	Federal Tax = (Taxable earnings - State Tax) X Federal tax rate
	14	Total Tax Obligation = Total State + Federal Tax
Sheet 6.	**Cash Flow Statement - Current $**	
	1	EBITDA
	2	Taxes Paid
	3	Cash Flow From Operations = EBITDA - Taxes Paid
	4	Debt Service = Principal + Interest paid on the debt loan
	5	Net Cash Flow after Tax
		Year of Start of Ops minus 1 = Equity amount
		Year of Start of Ops = Cash flow from ops - debt service
		Year of Start of Ops Plus 1 to N = Cash flow from ops - debt service
	6	Cum Net Cash Flow After Taxes = previous year net cash flow + current year net cash flow
	7	Cum IRR on net cash Flow After Taxes = discount rate that sets the present worth of the net cash flows over the book life equal to the equity investment at the commercial operations

TOTAL PLANT COST (TPC) - 2004$

TPC Component	Unit	Unit Cost	Total Cost (2004$)	Notes and Assumptions
Procurement				
Onshore Trans & Grid I/C	1	$3,360,000	$3,360,000	
Subsea Cables	1	$10,050,000	$10,050,000	
Mooring	152	$130,013	$19,761,976	
Power Take Off	152	$439,612	$66,821,024	
Absorber Structure	152	$500,362	$76,055,024	
Facilities	1	$15,000,000	$15,000,000	
Installation	1	$16,785,000	$16,785,000	
Construction Management	1	$9,552,419	$9,552,419	
TOTAL			$217,385,443	

TOTAL PLANT INVESTMENT (TPI) - 2004 $

End of Year	Total Cash Expended TPC ($2004)	Before Tax Construction Loan Cost at Debt Financing Rate	2004 Value of Construction Loan Payments	TOTAL PLANT INVESTMENT (TPC + Loan Value) ($2004)
2006	$108,692,722	$8,695,418	$7,854,939	$116,547,661
2007	$108,692,722	$17,390,835	$14,191,399	$122,884,120
Total	$217,385,443	$26,086,253	$22,046,338	$239,431,781

ANNUAL OPERATING AND MAINTENANCE COST (AO&M) - 2004$

Costs	Yrly Cost	Amount
LABOR	$1,935,500	$1,935,500
PARTS AND SUPPLIES	$4,347,700	$4,347,700
INSURANCE	$4,347,700	$4,347,700
Total		$10,630,900

OVERHAUL AND REPLACEMENT COST (LOAR) -

O&R Costs	Year of Cost	Cost in 2004$	Cost Inflated to 2018$
10 Year Retrofit			
Operation	10	$4,712,600	$7,128,230
Parts	10	$9,999,000	$15,124,385
Total		$14,711,600	$22,252,615

FINANCIAL ASSUMPTIONS

(default assumptions in pink background - without line numbers are calculated values)

1	Rated Plant Capacity ©	152	MW
2	Annual Electric Energy Production (AEP)	300,000	MWeh/yr
	Therefore, Capacity Factor	22.52	%
3	Year Constant Dollars	2004	Year
4	Federal Tax Rate	35	%
5	State	SF California	
6	State Tax Rate	8.84	%
	Composite Tax Rate (t)	0.40746	%
	t/(1-t)	0.6876	
7	Book Life	20	Years
8	Construction Financing Rate	8	
9	Common Equity Financing Share	30	%
10	Preferred Equity Financing Share	0	%
11	Debt Financing Share	70	%
12	Common Equity Financing Rate	17	%
13	Preferred Equity Financing Rate	0	%
14	Debt Financing Rate	8	%
	Current $ Discount Rate Before-Tax	10.7	%
	Current $ Discount Rate After-Tax	8.42	%
15	Inflation rate	3	%
16	Federal Investment Tax Credit	10	% 1st year only
17	Federal Production Tax Credit	0	$/kWh for 1st 10 yrs
18	State Investment Tax Credit	6	% 1st year only
19	State Production Tax Credit	0	
20	Industrial electricity price - 2002$	0.108	$/kWh
21	Decline in wholesale elec. price from 2002 to 2008	8	%
23	MACRS Year 1	0.2000	
24	MACRS Year 2	0.3200	
25	MACRS Year 3	0.1920	
26	MACRS Year 4	0.1152	
27	MACRS Year 5	0.1152	
28	MACRS Year 6	0.0576	

INCOME STATEMENT ($) **CURRENT DOLLARS**

Description/Year	2008	2009	2010	2011	2012	2013	2014	2015
REVENUES								
Energy Payments	35,592,311	36,660,080	37,759,883	38,892,679	40,179,638	41,509,182	42,882,721	44,301,710
State ITC and PTC	6							
Federal ITC and PTC	23,943,178	0	0	0	0	0	0	0
TOTAL REVENUES	59,535,495	36,660,080	37,759,883	38,892,679	40,179,638	41,509,182	42,882,721	44,301,710
AVG $/KWH	0.198	0.122	0.126	0.130	0.134	0.138	0.143	0.148
OPERATING COSTS								
Scheduled and Unscheduled O&M	11,965,172	12,324,127	12,693,851	13,074,666	13,466,906	13,870,913	14,287,041	14,715,652
Scheduled O&R	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0
TOTAL	11,965,172	12,324,127	12,693,851	13,074,666	13,466,906	13,870,913	14,287,041	14,715,652
EBITDA	47,570,323	24,335,953	25,066,032	25,818,013	26,712,732	27,638,269	28,595,680	29,586,058
Tax Depreciation	47,886,356	76,618,170	45,970,902	27,582,541	27,582,541	13,791,271	0	0
Interest Paid	13,408,180	13,115,181	12,798,743	12,456,990	12,087,896	11,689,275	11,258,765	10,793,813
TAXABLE EARNINGS	-13,724,213	-65,397,398	-33,703,613	-14,221,518	-12,957,706	2,157,723	17,336,916	18,792,245
State Tax	-1,213,220	-5,781,130	-2,979,399	-1,257,182	-1,145,461	190,743	1,532,583	1,661,234
Federal Tax	-4,378,847	-20,865,694	-10,753,475	-4,537,518	-4,134,286	688,443	5,531,516	5,995,854
TOTAL TAX OBLIGATIONS	-5,592,068	-26,646,824	-13,732,874	-5,794,700	-5,279,747	879,186	7,064,100	7,657,088

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
45,767,654	47,282,105	48,846,670	50,463,007	52,132,827	53,857,903	55,640,061	57,481,190	59,383,243	61,348,234	61,348,234	63,378,247
0	0										
45,767,654	47,282,105	48,846,670	50,463,007	52,132,827	53,857,903	55,640,061	57,481,190	59,383,243	61,348,234	61,348,234	63,378,247
0.153	0.158	0.163	0.168	0.174	0.180	0.185	0.192	0.198	0.204	0.204	0.211
15,157,121	15,611,835	16,080,190	16,562,596	17,059,474	17,571,258	18,098,396	18,641,347	19,200,588	19,776,606	20,369,904	20,981,001
0	0	33,659,077	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
15,157,121	15,611,835	49,739,267	16,562,596	17,059,474	17,571,258	18,098,396	18,641,347	19,200,588	19,776,606	20,369,904	20,981,001
30,610,532	31,670,270	-892,597	33,900,411	35,073,354	36,286,645	37,541,665	38,839,843	40,182,655	41,571,629	40,978,331	42,397,247
0	0	0	0	0	0	0	0	0	0	0	0
10,291,665	9,749,346	9,163,641	8,531,079	7,847,913	7,110,093	6,313,248	5,452,655	4,523,215	3,519,420	2,435,320	1,264,493
20,318,867	21,920,924	-10,056,238	25,369,331	27,225,441	29,176,551	31,228,417	33,387,187	35,659,440	38,052,209	38,543,010	41,132,753
1,796,188	1,937,810	-888,971	2,242,649	2,406,729	2,579,207	2,760,592	2,951,427	3,152,294	3,363,815	3,407,202	3,636,135
6,482,938	6,994,090	-3,208,543	8,094,339	8,686,549	9,309,070	9,963,739	10,652,516	11,377,501	12,140,938	12,297,533	13,123,816
8,279,125	8,931,900	-4,097,515	10,336,988	11,093,278	11,888,278	12,724,331	13,603,943	14,529,795	15,504,753	15,704,735	16,759,952

CASH FLOW STATEMENT

Description/Year	2006	2007	2008	2009	2010	2011
EBITDA			47,570,323	24,335,953	25,066,032	25,818,013
Taxes Paid			-5,592,068	-26,646,824	-13,732,874	-5,794,700
CASH FLOW FROM OPS			53,162,391	50,982,777	38,798,906	31,612,713
Debt Service			-17,070,659	-17,070,659	-17,070,659	-17,070,659
NET CASH FLOW AFTER TAX		-71,829,534	36,091,732	33,912,118	21,728,247	14,542,054
CUM NET CASH FLOW		-71,829,534	-35,737,802	-1,825,684	19,902,563	34,444,617
IRR ON NET CASH FLOW AFTER TAX						

Description/Year	2012	2013	2014	2015	2016	2017	2018	2019
EBITDA	26,712,732	27,638,269	28,595,680	29,586,058	30,610,532	31,670,270	-892,597	33,900,411
Taxes Paid	-5,279,747	879,186	7,064,100	7,657,088	8,279,125	8,931,900	-4,097,515	10,336,988
CASH FLOW FROM OPS	31,992,479	26,759,083	21,531,581	21,928,970	22,331,407	22,738,370	3,204,918	23,563,423
Debt Service	-17,070,659	-17,070,659	-17,070,659	-17,070,659	-17,070,659	-17,070,659	-17,070,659	-17,070,659
NET CASH FLOW AFTER TAX	14,921,820	9,688,424	4,460,922	4,858,311	5,260,748	5,667,711	-13,865,741	6,492,764
CUM NET CASH FLOW	49,366,436	59,054,860	63,515,782	68,374,093	73,634,841	79,302,552	65,436,811	71,929,575

Description/Year	2020	2021	2022	2023	2024	2025	2026	2027
EBITDA	35,073,354	36,286,645	37,541,665	38,839,843	40,182,655	41,571,629	40,978,331	42,397,247
Taxes Paid	11,093,278	11,888,278	12,724,331	13,603,943	14,529,795	15,504,753	15,704,735	16,759,952
CASH FLOW FROM OPS	23,980,076	24,398,367	24,817,334	25,235,899	25,652,860	26,066,876	25,273,596	25,637,295
Debt Service	-17,070,659	-17,070,659	-17,070,659	-17,070,659	-17,070,659	-17,070,659	-17,070,659	-17,070,659
NET CASH FLOW AFTER TAX	6,909,417	7,327,708	7,746,675	8,165,240	8,582,201	8,996,217	8,202,937	8,566,636
CUM NET CASH FLOW	78,838,992	86,166,700	93,913,375	102,078,615	110,660,816	119,657,032	127,859,969	136,426,605
IRR ON NET CASH FLOW AFTER TAX								29.8%