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System Level Design, Performance and Costs for San Francisco California Pelamis Offshore Wave Power Plant

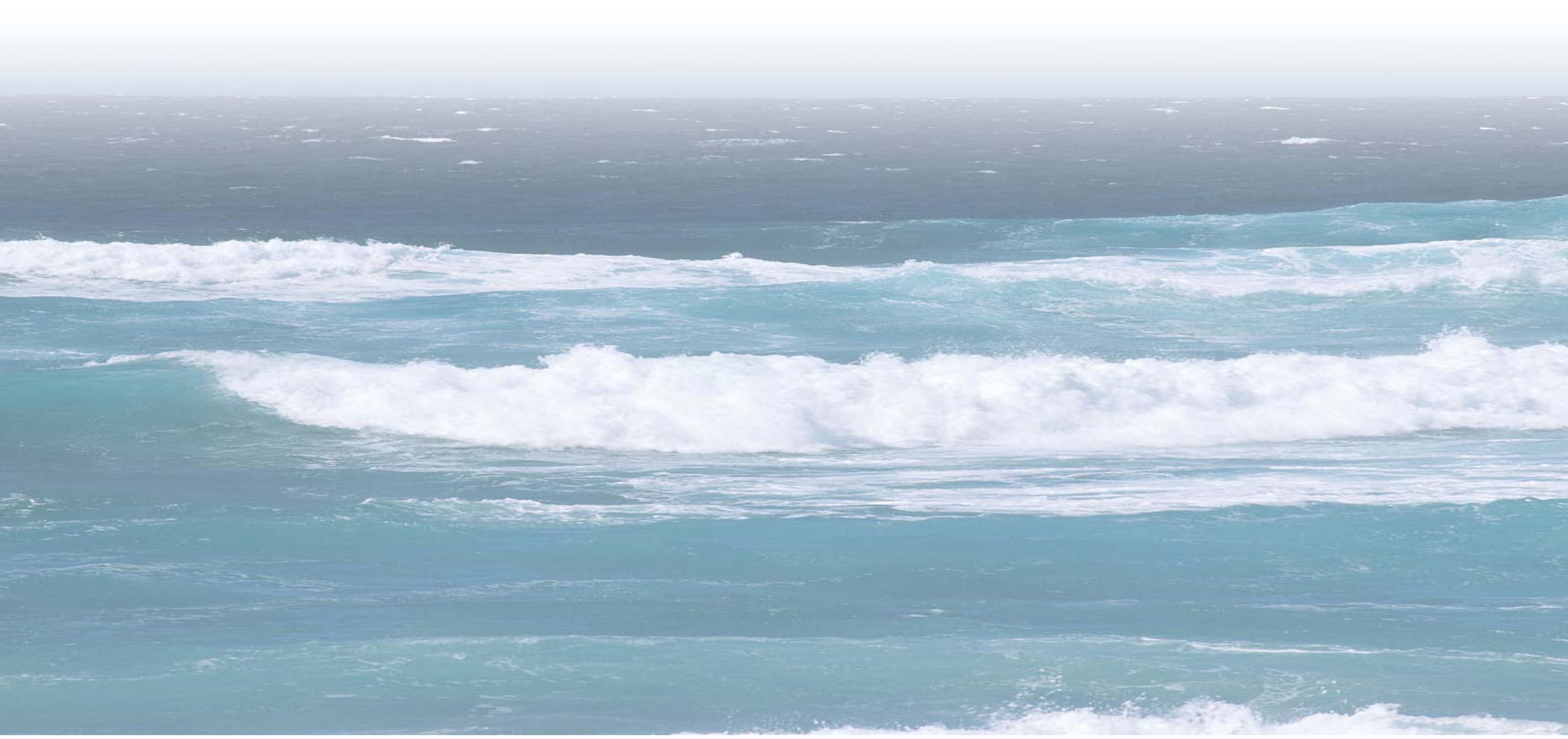

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Table of Contents

1. Introduction and Summary

This document describes the results of the system level conceptual design, performance and cost study of both a single unit deployment and a commercial-scale offshore wave power plant installed off the coast of San Francisco California. For purposes of this point design study, the selected single unit deployment site is within the boundaries of an exclusion zone in the Monterey Bay National Marine Sanctuary at a water depth of 25m-35m, the commercial plant deployment is further offshore, in 50m water depth, because of the higher energy wave climate and the selected wave energy conversion (WEC) device is the Ocean Power Delivery (OPD) Pelamis. 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. A new 115 kV line would be required for the 90 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 Pelamis unit plant is estimated to be 668 MWh. Performance numbers were established using deep water wave measurements further offshore from the proposed single unit site and an adjustment was made for energy losses of waves traveling to the single unit deployment site. The single unit wave power conversion system would cost \$5.6 million (with an uncertainty range of -21 to +31%)to build. This cost only reflects the capital needed to purchase a single Pelamis unit, the construction costs to build the plant and the cost to interconnect to the grid and does not include the of Detailed Design and Permitting, Yearly O&M nor 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 further offshore in deeper water to tap into the more energetic wave power resource. The yearly electrical energy produced is estimated to be 1,407 MWh for each Pelamis WEC device. In order to meet the commercial plant target output of 300,000 MWh/year a total of 213 Pelamis WEC devices are required. The elements of cost and economics (with cost in 2004\$) are:

- Total Plant Investment = \$279 million
- Annual O&M Cost = \$13.1 million; 10-year Refit Cost = \$28.3 million
- Levelized Cost of Electricity (COE)[1] = 13.4 (Nominal) 11.2 (real) cents/kWh

The COE for wind energy is about 3 cents/kWh (\$2004 and with Federal Production Tax Credits). Therefore, the first wave energy plant, with essentially no learning experience, cannot economically compete with wind energy at 40,000 MW of cumulative production experience.

In order to compare offshore wave power economics to shore based wind on an equivalent cumulative production experience basis, industry 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 volume.

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

[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.
- Given a device type and rating, what capacity factor is optimal for a given site?
- 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 Pelamis 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 single-unit wave power plant is about 6 miles offshore of Ocean Beach. This site is within the boundaries of an exclusion zone in the Monterey Bay National Marine Sanctuary at a water depth of 35m. A commercial plant deployment site is selected further offshore, in 50m water depth, because of the higher energy wave climate. The location of these sites and that of two reference wave measurement buoys (NDBC 46026 and CDIP 0062) are shown in Figure 1. A map showing the exclusion zone and environmental monitoring stations is shown in Figure 2. It is important to understand that the Pelamis device was designed for a water depth of 50m and the mooring system will need to be adapted to the shallow deployment site off Ocean Beach.

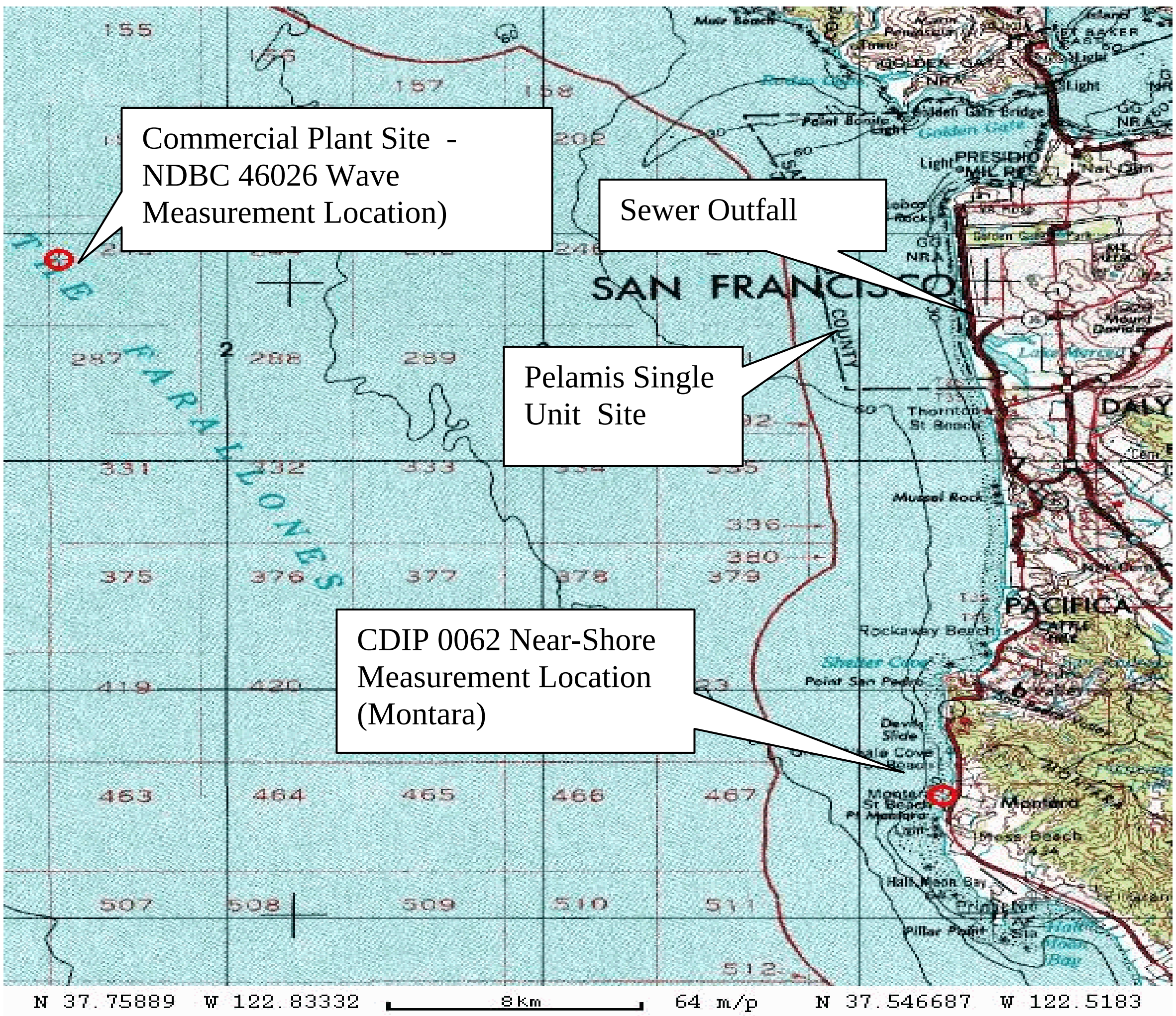

Figure 1: Site Map

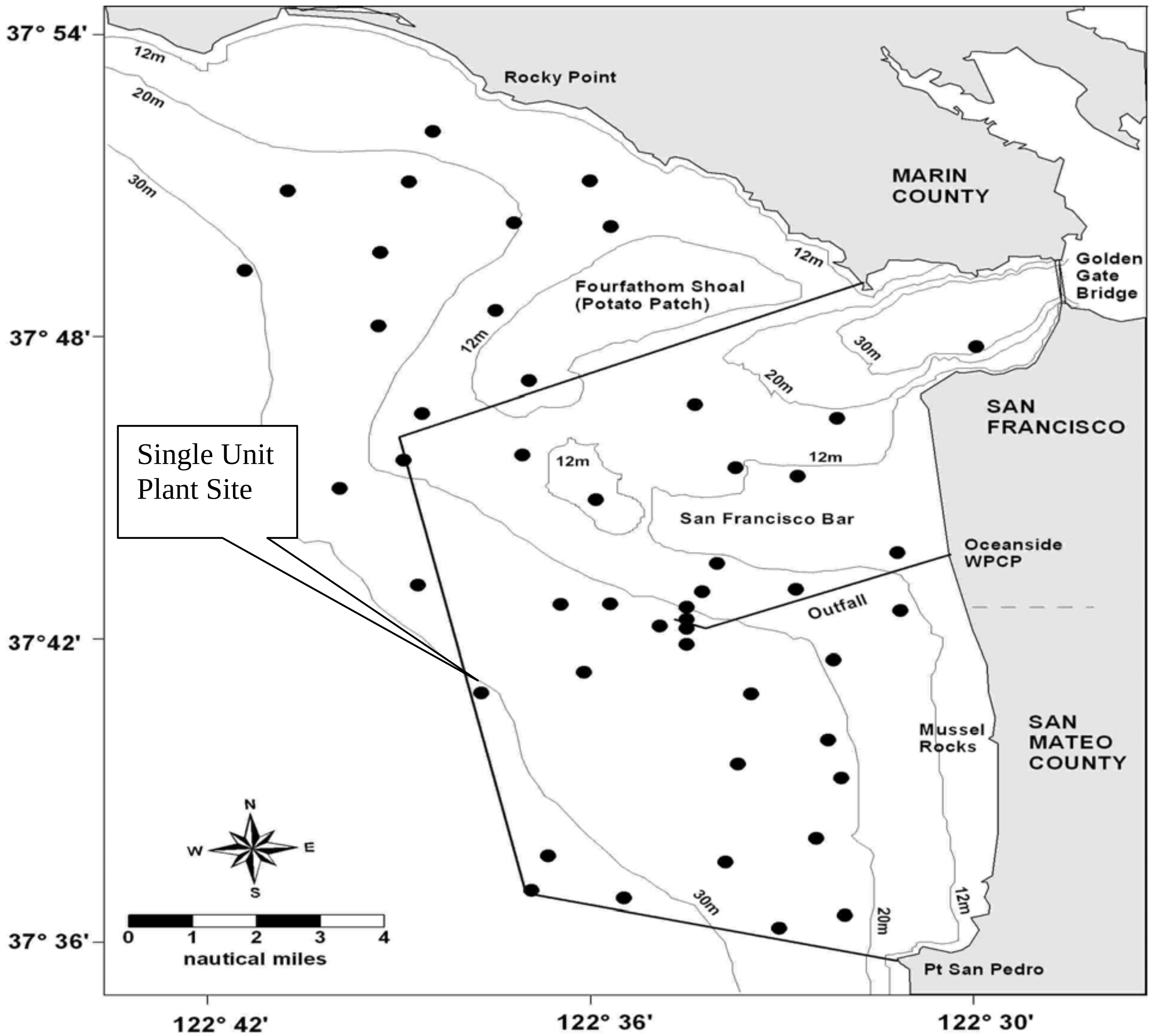

Figure 2: San Francisco exclusion zone, showing environmental monitoring stations and Proposed Pelamis Demonstration site in 35m water depth.

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. Preliminary estimates suggest that the existing connection provides enough capacity to interconnect up to 8 MVA. To interconnect a commercial wave power plant the transmission from the SF Wastewater Treatment Plant to Martin sub-station will need to be upgraded to accommodate the 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.

Alternative grid interconnection points do exist further south along the coast which could accommodate such loads at lower cost. Pacifica and Half Moon Bay have both substations in close proximity to the coastline, which could be used to interconnect to the power grid. Determining optimal siting options remains a task that will need to be addressed in subsequent detailed siting studies.

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

In 2000, San Francisco's peak load demand was 944 MW. After the energy crisis, and with implementation of energy efficiency measures, the load was reduced to 840 MW, but has begun creeping upward again. To meet the renewable portfolio standard of 20% by 2014, San Francisco needs 168 MW of renewable generation. California has the highest electricity costs in the contiguous 48 states, with no relief in sight.

Figure 2 shows the San Francisco exclusion zone from the Monterey Bay Marine Sanctuary. 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 deep water devices such as Pelamis could be deployed. 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 available for the deployment of near-shore devices.

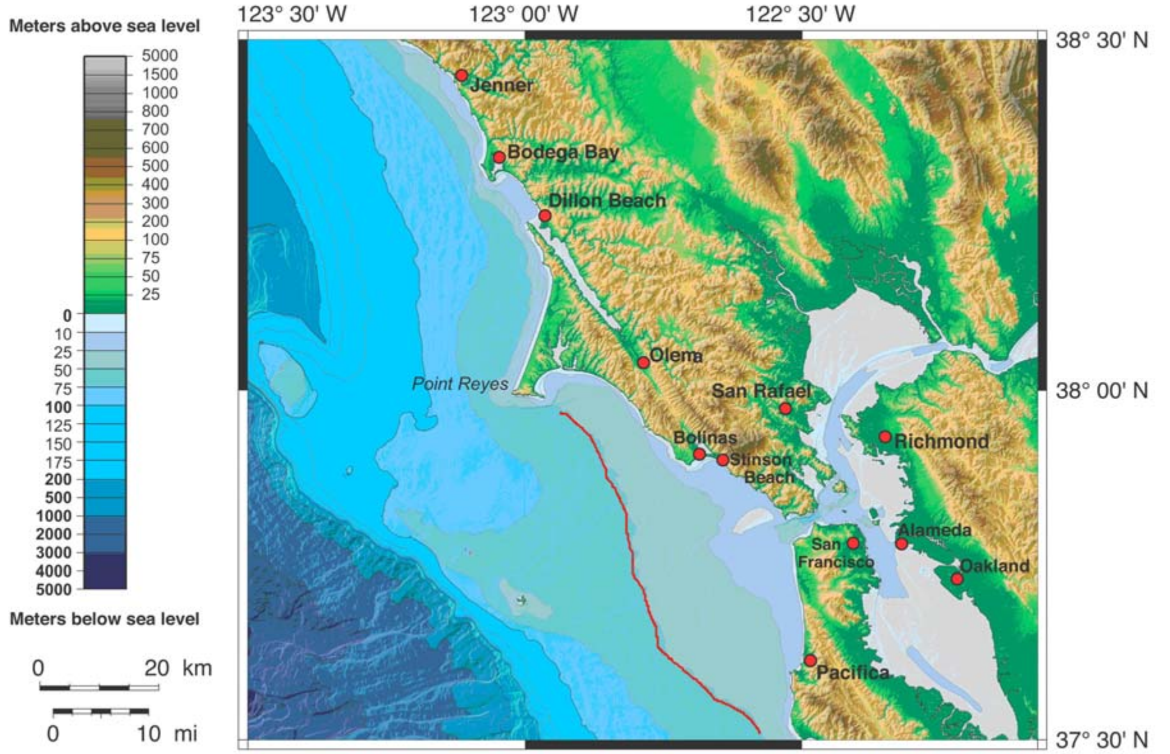

Figure 3: Bathymetry contours around San Francisco. Potential Deep water sites at 50m contour line shown in red.

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 environmental data can be used in the permitting process.

In summary, the San Francisco single unit 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	25 - 35 m
Pipe Outfall to Deployment Site	6 km
Sewage Pipe length	6.5 km
Grid Interconnection Allowance	0.5 km
Total Cable Length Required	13 km
Ocean Floor Sediments	Soft Sediments
Transit Distance to Hunters Point Naval Shipyard	31 km
Estimated Transit Time	1.5 hours
Estimated Pelamis Tow Time	3 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. The following parameters exist for this relevant commercial deployment site.

Water Depth at Deployment Site	51m
Pipe Outfall to Deployment Site	22 km
Sewage Pipe length	6.5 km
Total Cable Distance	28.5 km
Ocean Floor Sediments	Soft Sediments
Transit Distance to Hunters Point Naval Shipyard	40 km
Estimated Transit Time	2 hours
Estimated Pelamis Tow Time	4 hours

Although the 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 wave measurement buoy, with a 21 year data set, was chosen to characterize the wave resource at the proposed sites. The buoy is sited at a water depth at which the commercial plant is planned to be deployed. The wave power levels at the proposed single unit deployment site will likely yield lower power levels as it is located in more shallow water then at the deep water site where the measurement buoy is located. An adjustment of 20% on the device output is believed to be a reasonable assumption of power loss to the shallow water site.

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 6 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 Pelamis 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

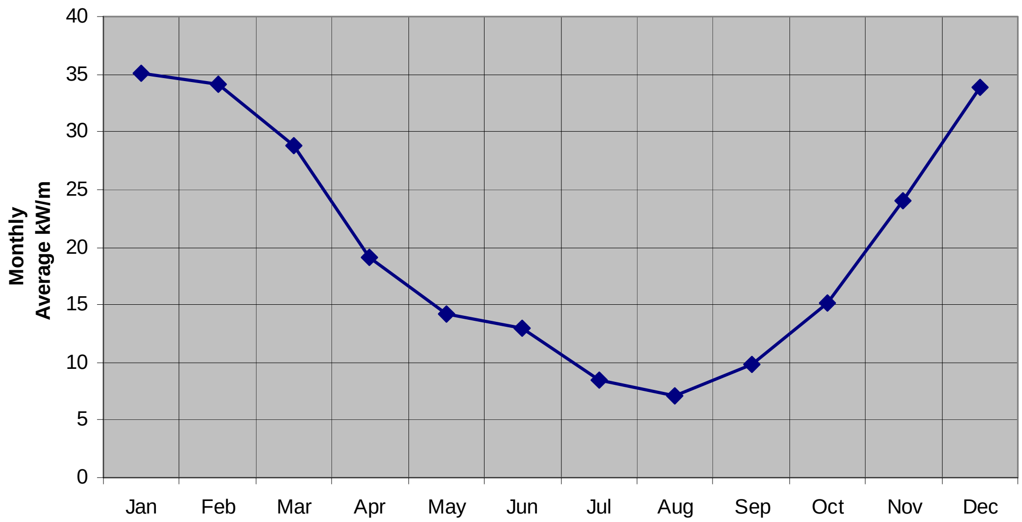

Figure 6: Monthly Average Wave Power Flux at NDBC 46026 (kW/m)

4. The Technologies

The WEC device chosen for the San Francisco point design is the Pelamis from Ocean Power Delivery (OPD). The device consists of a total of 4 cylindrical steel sections, which are connected together by 3 hydraulic power conversion modules (PCM). Total length of the device is 120m and device diameter is 4.6m. Figure 7 shows the device being tested off the Scottish coast. Individual units are arranged in wave farms to meet specific energy demands in a particular site as illustrated in Figure 8.

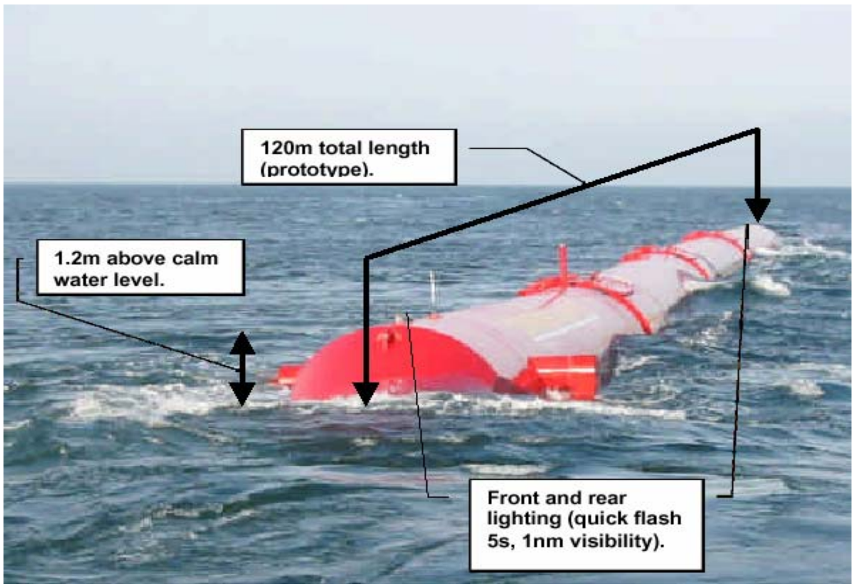

Figure 7: Pelamis pre-production prototype undergoing sea-trials

Figure 8: A typical Pelamis wave farm

The following sections provide a high level overview of the different subsystems that are device specific. Subsystems covered include the power conversion modules (PCM), the structural steel sections and the mooring system. The summary table below shows the key specifications of the Pelamis.

Table 1: Pelamis Device Specifications

Structure	
Overall Length	123 m
Diameter	4.6m
Displacement	700 tons
Nose	5m long conical drooped
Power Take Off	3 independent PCM’s
Total Steel Weight	380 tons
Power Conversion Module (PCM)	
Power Take Off	4 x hydraulic rams (2 heave, 2 sway)
Ram Speed	0 – 0.1 m/s
Power Smoothing Storage	High pressure Accumulators
Working Pressure	100 – 350 bars
Power Conversion	2 x variable displacement motors
Generator	2 x 125kW
Generator speed	1500 rpm
Power	
Rated Power	750kW
Generator Type	Asynchronous
System Voltage	3-phase, 415/690VAC 50/60Hz
Transformer	950kVA step up to required voltage
Site Mooring	
Water depth	> 50m
Current Speed	< 1 knot
Mooring Type	Compliant slack moored

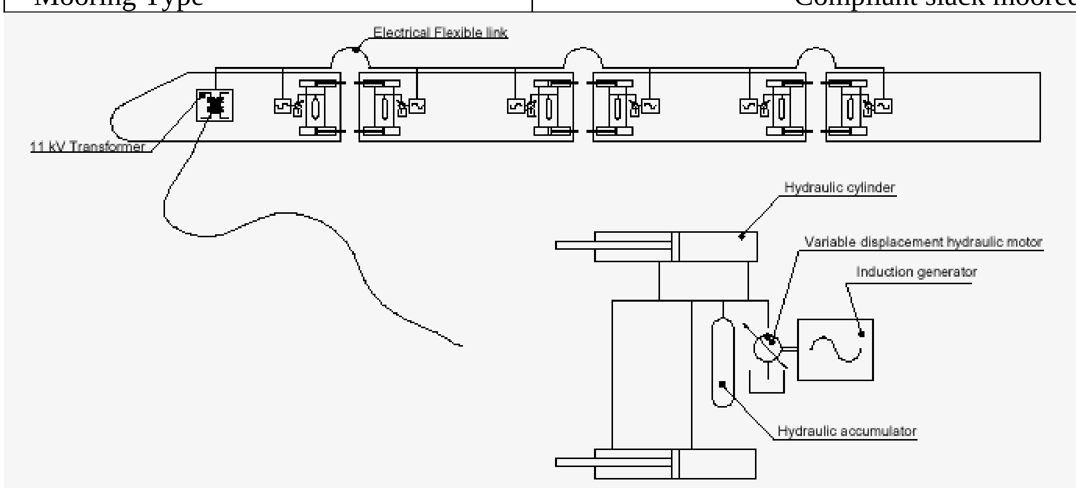

Figure 9: Pelamis Power Conversion Train

The Power Conversion Module (PCM)

As illustrated in Figure 9, a total of 3 power conversion modules (PCM's) connect the 4 individual steel tubes forming a Pelamis device. Each PCM contains a heave and sway joint. The modular power-pack is housed in a second fully sealed compartment behind the ram bay so that in the event of seal failure only the hydraulic rams are immersed. Access to all system components is via a hatch in the top of the power conversion module. Maximum individual component weight is less than 3 tons to allow replacement using light lifting equipment.

The wave-induced motion of each joint is resisted by sets of hydraulic rams configured as pumps. These pump oil into smoothing accumulators which then drain at a constant rate through a hydraulic motor coupled to an electrical generator. The accumulators are sized to allow continuous, smooth output across wave groups. An oil-to-water heat exchanger is included to dump excess power in large seas and provide the necessary thermal load in the event of loss of the grid. Overall power conversion efficiency ranges from around 70% at low power levels to over 80% at full capacity. Each of the three generator sets are linked by a common 690V, 3 phase 'bus' running the length of the device. A single transformer is used to step-up the voltage to an appropriate level for transmission to shore. High Voltage power is fed to the sea bed by a single flexible umbilical cable, then to shore via a conventional sub-sea cable.

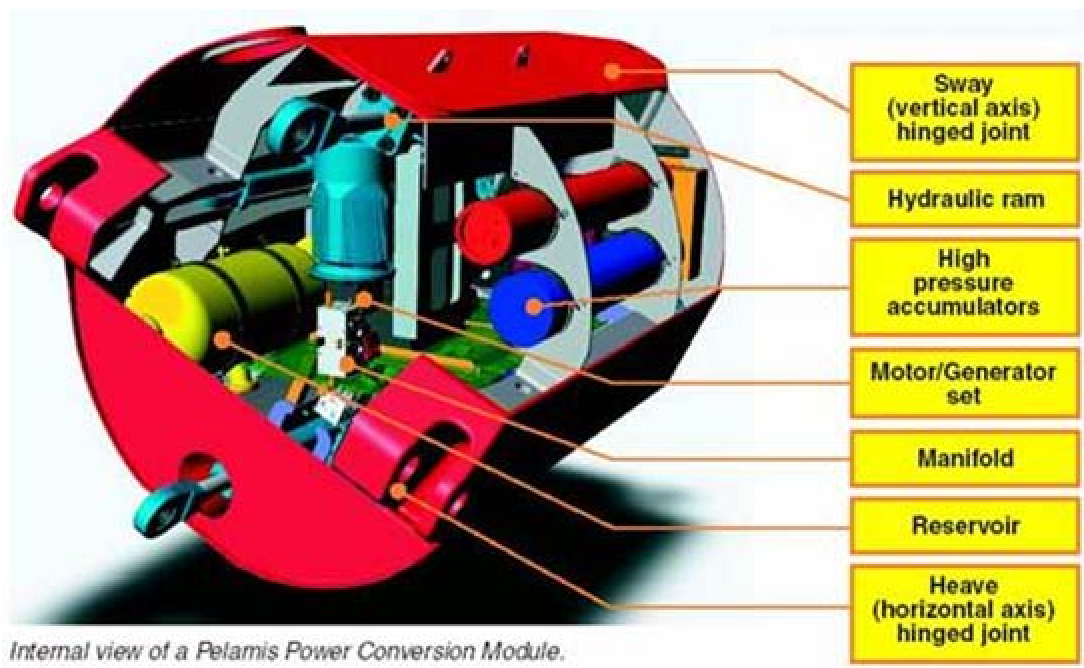

Figure 10: Internal View of the Pelamis PCM

Tubular Steel Sections

There are a total of 4 tubular steel sections, which are the main structural elements of the device. Each steel section is 25m long and weighs roughly 70tons. The main tube sections are manufactured in segments using steel plates that are rolled into shape as shown in Figure 8. Once formed, individual sections are welded together to form a segment. This manufacturing process is extensively used in the wind industry to manufacture wind turbine towers. The process can be automated and lends itself well to cost reduction.

Cast end caps on the steel tubes incorporate hinges, which then interconnect to the Power Conversion Modules. In order to properly ballast the device, sand is added.

Alternative construction materials were evaluated under a contract by the Department of Trade and Industry. Materials analyzed and compared to each other were steel, pre-tensioned concrete and GRP (filament wound composite). Out of the 3 options, concrete emerged as the preferred option (Reference 5).

Figure 11: Manufacturing Steel Tubular Sections

Mooring System

The mooring arrangement of Pelamis needs to be designed specifically for the site conditions. Similar to a wind turbine foundation, which needs to be type approved, the Pelamis mooring system needs to be designed by OPD 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.

For the purpose of this project, the reference mooring system used for Ocean Power Delivery prototype testing was used to establish a costing base case as shown in Figure 12.

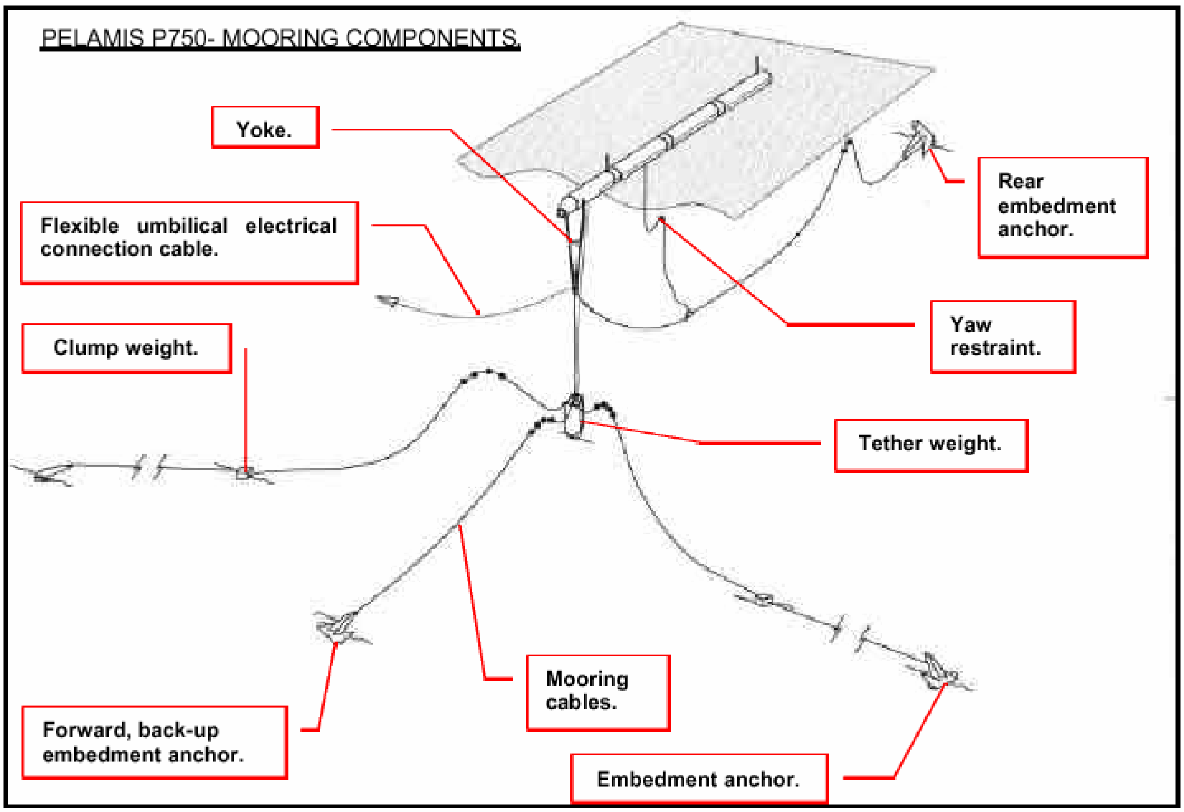

Figure 12: Mooring Arrangement of Pelamis

As shown in Figure 12, the Pelamis mooring system is a catenary type mooring using a combination of steel wire, chain, dead weights and embedment anchors. The following four pictures of Figure 13 show some of the individual mooring elements to provide the reader with an understanding of the size of these individual components.

Embedment anchor.

Clump weight.

Mooring cable.

Figure 13: Mooring Illustrations

Electrical Interconnection & Communication

Each Pelamis device 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. A flexible riser cable is connecting the Pelamis to a junction box, sitting on the ocean floor. If multiple devices are connected together, they are 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. Riser and jumper cables undergo a large number of cyclic loadings and it is likely that they will need to be replaced after 10 years of operation.

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 Pelamis unit, reducing the physical intervention requirements on the device and optimizing operational activities. Operational activities offshore are expensive and minimizing such intervention 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 14 shows the cross-sections of armored XLPE insulated submersible cables.

Figure 14: 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 Pelamis 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 Pelamis plant, it was assumed that the 3 Power Conversion Modules are procured from Ocean Power Delivery (OPD) and is shipped from the UK to California and that the structural steel sections are built locally in an appropriate shipyard. Manufacturing facilities, which are capable of constructing the larger steel sections do exist in California. Figure 15 shows the Pelamis prototype under construction in Scotland. The picture on the left shows a hydraulic ram being mounted in one of the Power Conversion Modules. The picture on the right shows the large tubular steel sections of the Pelamis being completed.

Figure 15: Manufacturing the Pelamis

Mooring components such as wire, chain and the various anchor components 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 Power Conversion Modules (PCM's). 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 such as anchor handler vessels, barges and heavy uplift cranes. 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 Ocean Power Delivery who deployed a prototype device this year, local offshore operators in Oregon and Sea Engineering Hawaii who managed the installation of Ocean Power Technologies Power Buoy in Hawaii. 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
4. Commissioning and Deployment of Pelamis

Offshore handling requirements were established based on technical specifications supplied by Ocean Power Delivery. Figure 16 below shows the anchor handler vessel used for the installation of the prototype in the UK. It is a standard vessel used in the UK offshore Oil & Gas industry. After querying offshore operators on the US west coast and Hawaii, it became apparent, that such equipment will not be available to a demonstration project. As a result, installation activities had to be adapted to be carried out on a barge, pulled by an offshore tug.

For the commercial plant, it proved to be cost effective to include a AHATS class vessel in the project cost and hire dedicated staff to carry out operational activities. Figure 17 shows the prototype Pelamis being towed to its first deployment site off the coast of Scotland.

Figure 16: AHATS class vessel used for prototype installation in UK

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.

Figure 17: Towing the Pelamis P-750

Operational Activities

Pelamis was designed with a minimum amount of physical intervention in mind. 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. In addition, the device features many levels of redundancies which will reduce the need to immediately respond to a failure.

The devices maintenance strategy is to completely detach the device from its moorings, tow the unit into a nearby harbor and carry out any repair activities along a dock-side. Initially it is envisioned, that the device is removed every year for maintenance activities. As the technology becomes more mature, these regular maintenance activities will become more infrequent. For the commercial reference plant, we assumed that removal for scheduled maintenance occurs every 2 years.

Every 10 years, the device will be recovered for a complete overhaul and refit. For that purpose, it will need to be de-ballasted and 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 hydraulic rams will take place at that point. 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 – Single Unit

The outline below (Figure 18) shows the electrical setup of the single unit plant. A single Pelamis WEC device is floating on the surface and moored in a water depth of 35m. An umbilical riser cable is connecting the Pelamis 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 3.75 miles out from the shore. The cable landing site for the demonstration site is at the San Francisco Oceanside wastewater treatment facility. The wastewater treatment facility is connected by a 12kV distribution line to the nearest substation, which can be used to feed power into the grid.

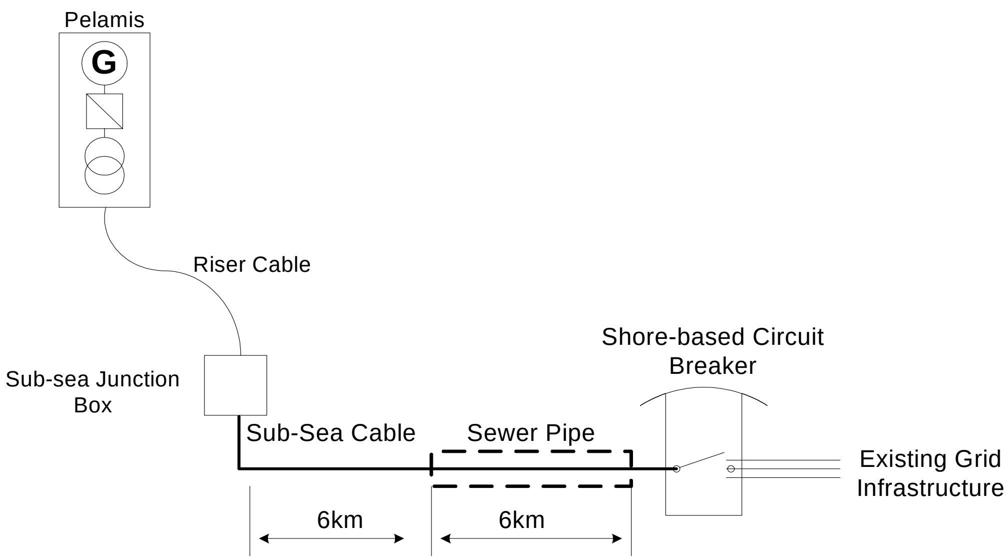

Figure 18: Electrical Interconnection of a Single Pelamis Plant

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 the 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 of the Monterey Bay National Marine Sanctuary provides an excellent demonstration opportunity, 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 19 illustrates the commercial system with a total of 4 clusters, each one containing 53 or 54 Pelamis units (213 Pelamis WEC devices), connected to sub-sea cables. Each cluster consists of 3 rows with 17 or 18 devices per row. Four sub-sea cables connect the four clusters to shore. 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.

The 4 clusters are each 2.67 km long and 1.8 km wide, covering an ocean stretch of roughly 11 km. The 4 arrays and their safety area occupy roughly 20 square kilometers. Further device stacking of up to 4 rows might be possible reducing the array length, but is not considered in this design, as subsequent rows of devices will likely see a diminished wave energy resource and therefore yield a lower output. Such effects and their impacts on performance are not well understood at present.

Based on the above setup the following key site parameters emerged:

Array Length	11 km
Array Width	1.8 km
Device Spacing	150m
Number of Rows	3
System Voltage	26kV
Sub-sea cable specs	26kV / 40MVA / 3-phase with fiber optic core

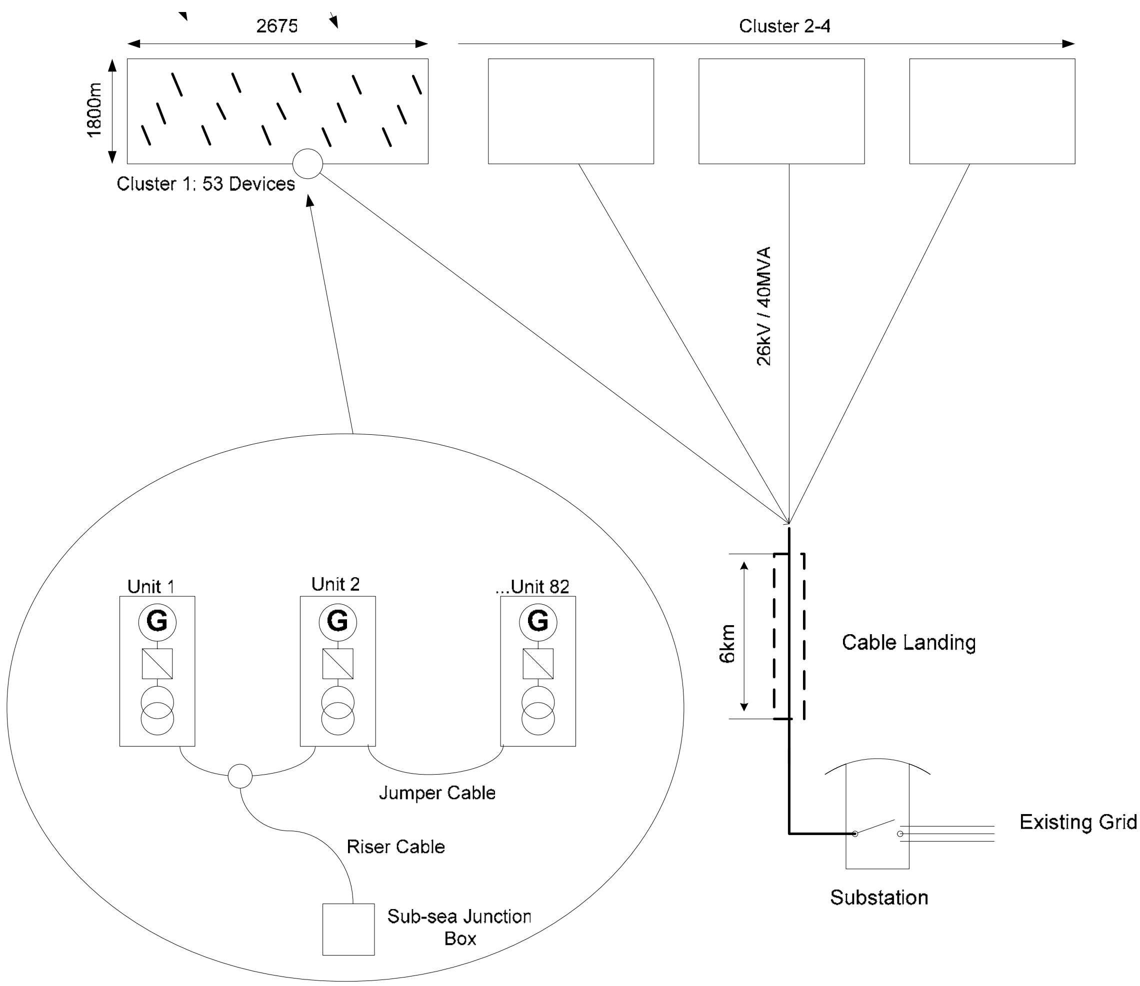

Figure 19: Overall System Layout and Electrical Connections

Operational and Maintenance Requirements

General operational activities are outlined in a previous section. It made economic sense for this wave farm to include an AHATS class vessel in the capital cost of the project. Based on the workload, the vessel 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.

This type of vessel has sufficient deck space to accommodate the heavy mooring pieces and a large enough crane to handle the moorings. In addition the vessel has dynamic positioning capabilities and is equipped for a 24-hour operation. Based on the work loads involved with O&M and 10-year refit operation a total full-time crew of 21 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 Pelamis performance data supplied by Ocean Power Delivery

Scatter or joint probability diagrams for the wave energy resource were created for each month and used for power production calculations. Figure 20 shows the monthly average power (kW) delivered to the grid by a single Pelamis WEC Device sited as described in Section 4. As pointed out earlier, a 'rule of thumb' estimate, and not shallow water wave transformation modeling, was used to bring the modify the deep water resource (52m) for the more shallow demonstration site (35m) within the exclusion zone of the Monterey Bay National Marine Sanctuary. We estimate that the devices performance will drop by about 20%. This is a preliminary estimate and validation will be required in a detailed design phase. In addition, transmission line losses for the sub-sea cable from the offshore farm to the grid interconnection point were ignored as they are likely not significant at the design voltage levels used and can only be estimated in a detailed design phase.

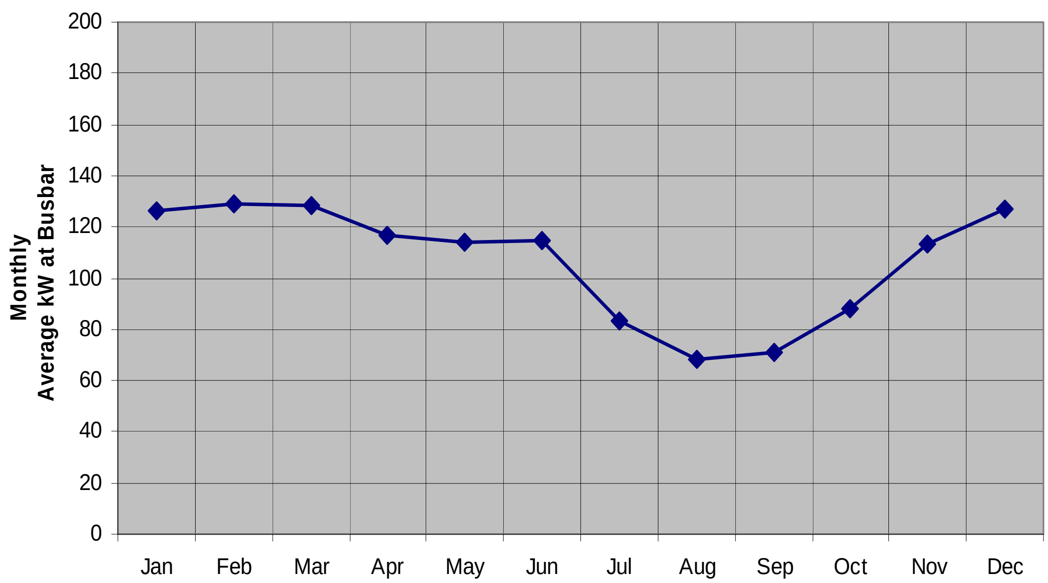

Figure 20: Monthly average power delivered to bus bar – Single Unit Pelamis Plant

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 Pelamis wave energy absorption performance for each cell in the scatter diagram is shown in Table 3

Table 2: San Francisco Site Annual occurrence of hours per sea-state

CDIP 0034 Makapuu Point		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	Total hours
		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	
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: Pelamis Wave Energy Conversion Absorption Performance (kW) in each sea-state (Excluding Power Take Off losses)

Hs (m) \ Tp (s)	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20
10	750	750	750	750	750	750	750	750	750	750	750	750	711	750	750	738	734
9.5	750	750	750	750	750	750	750	750	750	750	750	750	691	750	710	694	662
9	750	750	750	750	750	750	750	750	750	750	750	750	670	746	668	650	592
8.5	750	750	750	750	750	750	750	750	750	750	750	750	650	699	626	606	551
8	750	750	750	750	750	750	750	750	750	750	750	750	630	653	584	562	509
7.5	750	750	750	750	750	750	750	750	750	750	750	748	610	607	542	518	467
7	750	750	750	750	750	750	750	750	750	750	750	692	566	560	500	474	425
6.5	750	750	750	750	750	750	750	750	750	750	723	592	617	513	458	430	384
6	597	630	663	684	750	750	750	750	750	750	616	633	525	476	396	386	329
5.5	428	497	566	612	750	750	750	750	750	635	642	532	482	400	399	341	322
5	259	364	469	539	750	750	750	750	644	641	531	482	399	394	330	308	274
4.5	94	233	371	467	735	744	738	634	626	520	473	390	382	319	299	250	208
4	105	216	326	394	632	616	583	585	494	454	374	361	339	283	236	197	153
3.5	0	86	211	326	484	577	568	502	421	394	330	312	260	216	196	164	140
3	0	91	180	246	402	424	417	369	343	331	275	229	208	173	144	120	93
2.5	0	7	93	171	279	342	351	320	274	230	210	174	145	120	100	84	65
2	0	0	66	109	199	219	225	205	195	162	135	112	93	77	64	54	41
1.5	0	0	26	62	112	141	143	129	110	91	76	63	52	43	36	30	23
1	0	0	11	27	50	62	64	57	49	41	34	28	23	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

By multiplying each cell in the hours of reoccurrence scatter diagram (Table 2) by each corresponding cell of the Pelamis 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 Pelamis WEC device was derived. Single Unit plant performance numbers are summarized below. The effects on power output of using the shallower site at 35m water depth was taken into account by a reduction in power output of 20%. This is an estimate at this point and further investigation into the effects of using such a shallow water site on both cost and performance need to be investigated with a detailed wave modeling study.

Table 4: Pilot Plant Pelamis Performance

Device Rated Capacity	750kW
Annual Energy Absorbed	1,229 MWh/year
Device Availability	85%
Power Conversion Efficiency	80%
Performance Reduction to demo-site (35m)	80%
Annual Generation at bus bar	668 MWh/year
Average Power Output at bus bar	76 kW

The commercial plant performance was assessed using the demonstration plants performance data as its basis. In addition certain performance improvements were considered. Based on well established wave theory, the Pelamis device is only absorbing a small fraction of its theoretical limit. An increase in performance by a factor of 2-3 is possible without significant changes to the device geometry. For the purpose of this study, only performance improvements were considered which could be achieved in the near future, without any additional research. The following shows the changes incorporated in the commercial Pelamis performance numbers:

- Changing the mooring configuration will yield a performance improvement of 37%. This mooring configuration has been evaluated in wave tank tests and theoretical studies by Ocean Power Delivery and is well quantified.
- The current Power Conversion Modules use standard off the shelf components. Customizing some of these components could increase the power conversion efficiency by more then 10%. The technologies to improve the conversion efficiency exist and are therefore included in the performance for the commercial plant.
- The rated capacity was changed to 500kW, because the 750kW design is overrated for the Hawaii wave climate. The 500kW power conversion module is also reflected in the cost assessment of the power plant and has little impact (<5%) on the annual output of the Pelamis in San Francisco.

Table 5 summarizes the performance values for a commercial-scale Pelamis module incorporating improvements as outlined above.

Table 5: Commercial Plant Pelamis Performance

Device Rated Capacity	500kW
Annual Energy Absorbed	1,683 MWh/year
Device Availability	95%
Power Conversion Efficiency	88%
Annual Generation at bus bar	1,407 MWh/year
Average Electrical Power at bus bar	161 kW
# Pelamis required to meet target 300,000 MWh/yr	213

8. Cost Assessment – Demonstration Plant

The cost assessment for the demonstration plant was carried out using a rigorous 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. O&M 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 Ocean Power Delivery, based on their production experience of their first full scale prototype machine, which was deployed in 2004.

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	$162,000	(1)
Subsea Cables	$1,438,000	(2)
Pelamis Power Conversion Modules	$1,565,000	(3)
Pelamis Manufactured Steel Sections	$850,000	(4)
Pelamis Mooring	$243,000	(5)
Installation	$841,000	(6)
Construction Mgmt and Commissioning (10% of cost)	$509,000	(7)
Total for single Unit	**$5,609,000**	
1 - Unit cost	**5,609,000**	
2 – Unit cost	**7,859,000**	
4 – Unit cost	**11,684,000**	
8 – Unit Cost	**18,187,000**	

1) Cost includes a breaker circuit and allowance for electrical demonstration

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 6km 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.

3) Based on estimate by Ocean Power Delivery. Shipping cost is included from Edinburgh (UK) to San Francisco, California, based on quote by Menlo International.

4) Cost for 4 manufactured steel sections was estimated by using $2,850/per ton of manufactured steel. Each steel section of this unit weighs roughly 70 tons (excluding ballast). This is consistent with OPD experience with manufacturing their pre-production machine and input from local manufacturers. It includes cast elements and protective coatings. Range of cost from different sources was $2,500/ton - $3,500/ton.

5) Based on OPD's 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 E2I EPRI Project Team experience managing like custom construction projects and commissioning to owner acceptance.

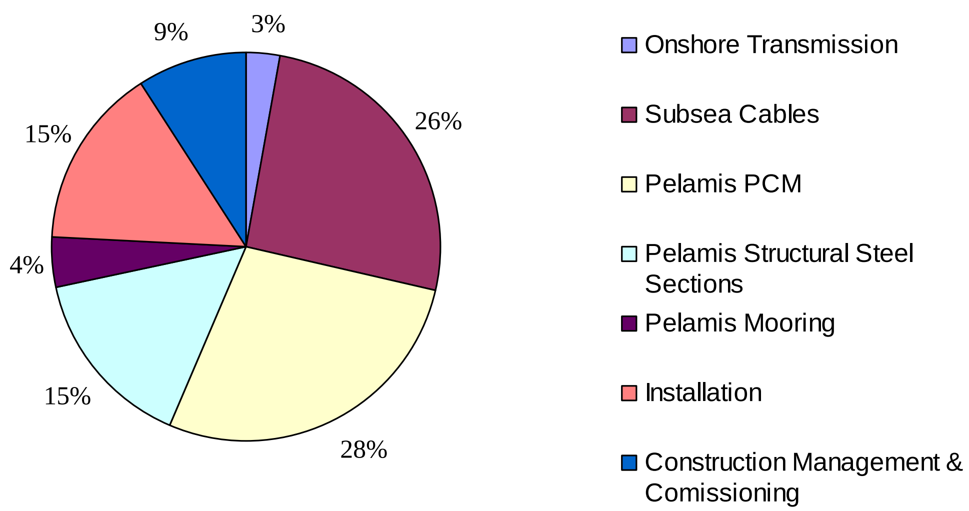

Figure 21: Pie Chart of cost centers for single unit installation

The cost of additional units was estimated based on the cost elements of table 6. A learning curve effect of 82% was assumed on the cost of individual units, while the infrastructure in place would be sufficient to add up to about 8 MVA in generation. This is the equivalent of

16 Pelamis units. With other words, the basic demonstration setup offers sufficient capacity to add additional devices or allow for a gradual build-out. It is envisioned, that further cost reductions are possible, if a gradual build-out is chosen. This would allow the implementation of cost reduction measures while gaining experience in the Operation of the offshore wave farm and measuring impacts on the environment.

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 22 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 -21% to +31%. 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).

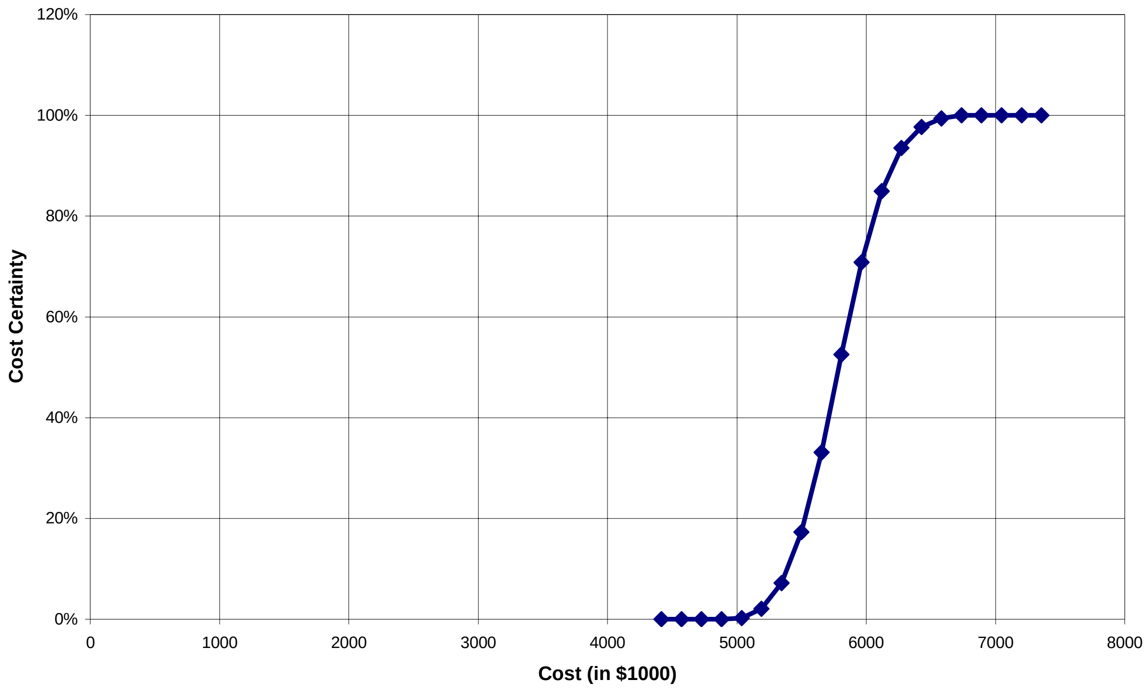

Figure 22: Cost Uncertainty based on Monte Carlo Simulation

9. Cost Assessment – Commercial Scale Plant

The cost assessment for the commercial wave power plant followed a rigorous assessment of each cost center. Instead of simply applying learning curves, a point design for the commercial plant using 213 devices was outlined and its cost estimated. For cost centers, which lend themselves well to cost reduction, outlines were created of how such cost reduction will be achieved. Installation activities were outline in detail and hourly breakdowns of offshore operational activity created to properly understand their impacts on cost and resources. Cost centers were validated by Ocean Power Delivery, based on their production experience of their first full scale prototype machine, which was deployed in 2004. Operational tasks and outlines were validated by local operators.

Table 7: Installed Cost Breakdown for Commercial Scale Plant

Cost Element	**213-Pelamis Device System**		**Basis**
Constant Dollar Year	2004	in %	
Installed Cost			
Onshore Transmission & Grid Interconnection	$3,360,000	1.4.%	(1)
Subsea Cables	$13,441,000	1.8%	(2)
213 x Mooring Spread	$24,895,000	9.7%	(3)
213 x Power Conversion Modules	$132,903,000	51.5%	(4)
213 x Concrete Structural Sections	$52,142,000	20.2%	(5)
Facilities	$12,000,000	5.5%	(6)
Installation	$11,421,000	5.4%	(7)
Construction Mgmt and Commissioning (5% of cost)	$11,937,000	4.5%	(8)
Total Plant Cost	**$262,101,000**	**100%**	
Construction Financing Cost	$16,899,000		
Total Plant Investment	**$279,000,000**		
Yearly O&M			
Labor	$2,584,000	21.0%	(9)
Parts (2%)	$5,242,000	39.5%	(10)
Insurance (2%)	$5,242,000	39.5%	(11)
Total	**$13,068,000**	**100%**	
10-year Refit			
Operation	$10,858,000	41.0%	(9)
Parts	$17,460,000	59.0%	(9)
Total	**$28,318,000**	**100%**	

(1) The current 12kV line limits transmission capabilities to about 8-10MVA. 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:

a. 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 costed out 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.

b. Interconnect in Pacifica or Half Moon Bay. Grid Interconnection in Pacifica would cost only about $4 million. 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, 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 was added to the project cost. Part of that cost is found in the installation 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 spread is an assembly of standard elements and equipment. 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) Three (3) Power Conversion Modules (PCM) are required for a single Pelamis unit. Cost of a hydro-electric power take off will be significantly lower then initial production units. The performance assessment for our reference site also shows that the PCMs are overrated and reducing the rated power to 500kW per device would yield a relatively small decrease in annual output. This is mainly attributed to the fact that the Oregon site has lower energy levels then UK sites for which the device was originally developed. Reference 6 shows that the cost for the three (3) PCM 500kW prototype unit in production volume is $289,00 for the power conversion train alone and another $234,000 for the manufactured steel enclosure, hinges and assembly for a total Pelamis unit cost (3 PCMs) of $523,000.

(5) The summary table in Reference 5 shows a production cost of $51,000 per tube or $204,000 per device excluding the end caps on the tubes. Including the end caps, the cost for the 4 concrete sections is $245,000 per Pelamis device. Concrete is widely used in the offshore industry and is considered the most reliable option among construction materials. However, it is important to understand that a design using concrete tubes will require design efforts up-front, to properly test the long-term fatigue characteristics of a particular design.

(6) Includes an AHATS class vessel, which is equipped to operate 24 hours per day and some provisions for dock modifications and heavy lift equipment.

(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) The most cost effective approach to operate the wave power plant included an AHATS class vessel capable to operate effectively 24-hours per day. Based on a rigorous assessment of the tasks involved in operating the wave farm, it was concluded, that the vessel would be at less then 50% capacity. Shore-based and offshore operations and maintenance tasks were estimated and the results showed that a crew of 21 persons is required to operate a 213 Pelamis wave farm. In other words, it will require 0.1 full-time crew per device is required. Reduction in personnel is possible with appropriate redesign of the units to make them easier to handle and improve their reliability. A major refit is required every 10-years for a commercial plant. In other words, assuming a 20-year life, one refit is required. Elements such as hydraulic rams are replaced during that period. In addition, some of the hull is repainted. Unlike the bi-annual maintenance activities, which can be carried out on a pier side, the 10-year refit requires de-ballasting the device and recovering it onto land. It will also need to be inspected at that point by ABS or a related agency.

(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 for a commercial project.

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

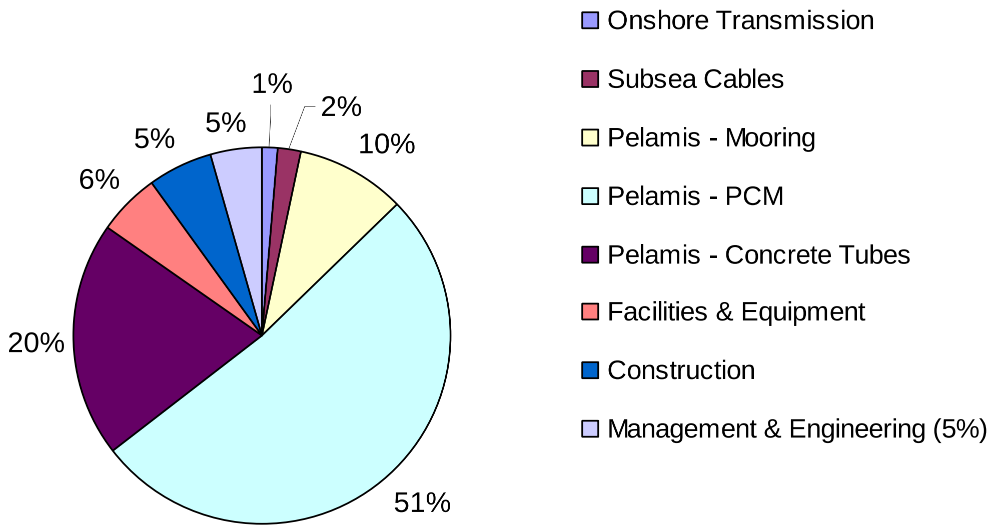

Figure 23: Installed Cost Breakdown for commercial scale plant

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 21 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 -24% to + 34%. This bottoms-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 than for a single unit demonstration plant is because certain cost centers include cost reduction measures, which have a higher uncertainty.

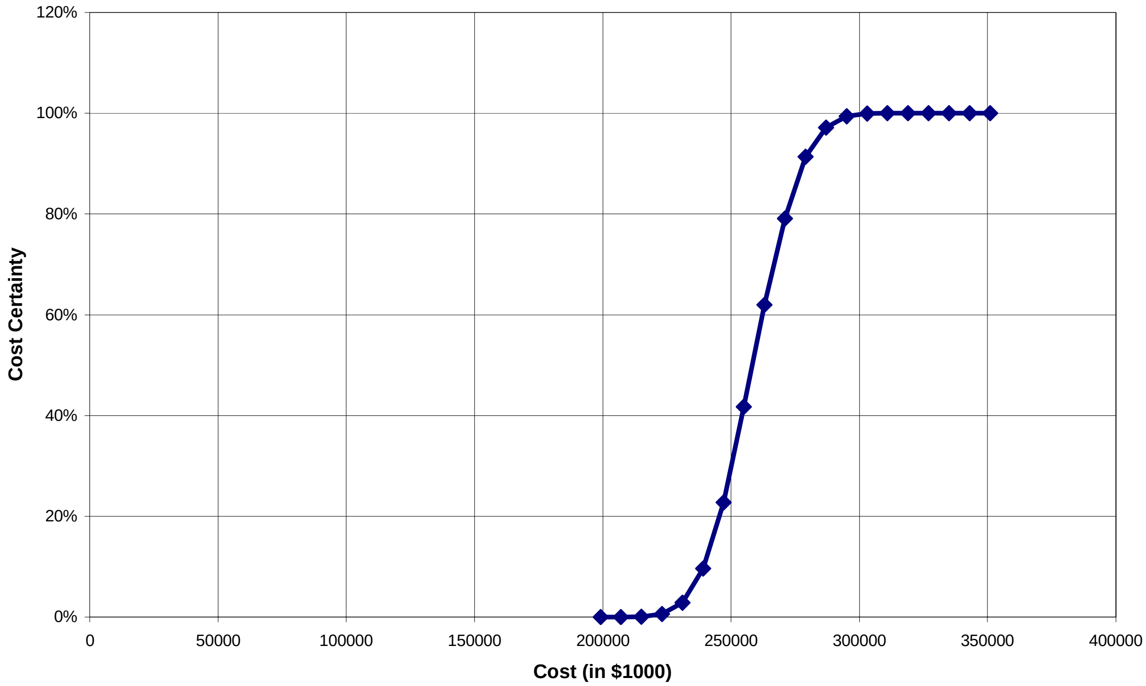

Figure 24: Installed Cost uncertainty S-curve

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$) Based on DOE EIA Data for CA	N/A	10.8 cents/kWh
Avoided Cost of Electricity (2004$)	N/A	5.4 cents/kWh[2]
Industrial Electricity Price Forecast (2002$)	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	$211,900,000	$279,000,000	$374,000,000
Annual O&M Cost	$10,500,000	$13,100,000	$19,600,000
10-year Refit Cost (1 time cost)	$18,900,000	$23,300,000	$37,800,000
Fixed Charge rate (Nominal)	8.8	9.2	9.6
Cost of Electricity (c/kWh) (Nominal)	**10.0**	**13.4**	**19.1**
Fixed Charge rate (Real)	6.6	6.9	7.2
Cost of Electricity (c/kWh) (Real)	**8.4**	**11.2**	**16.1**

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

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

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 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 price of 10.8 cents/kWh))

Cost Element	Lowest Estimate	Best Estimate	High Estimate
Total Plant Investment (2004)	$212,800,000	$280,100,000	$375,100,000
Annual O&M Cost (2004$)	$10,500,000	$13,100,000	$19,600,000
10-year Refit Cost (2004$)	$18,900,000	$23,300,000	$37,800,000
Internal Rate of Return	34.3%	16.6%	None

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 22 shows the cumulative cash in current year dollars for the 20 year life of the project and Figure 23 shows the net cash flow.

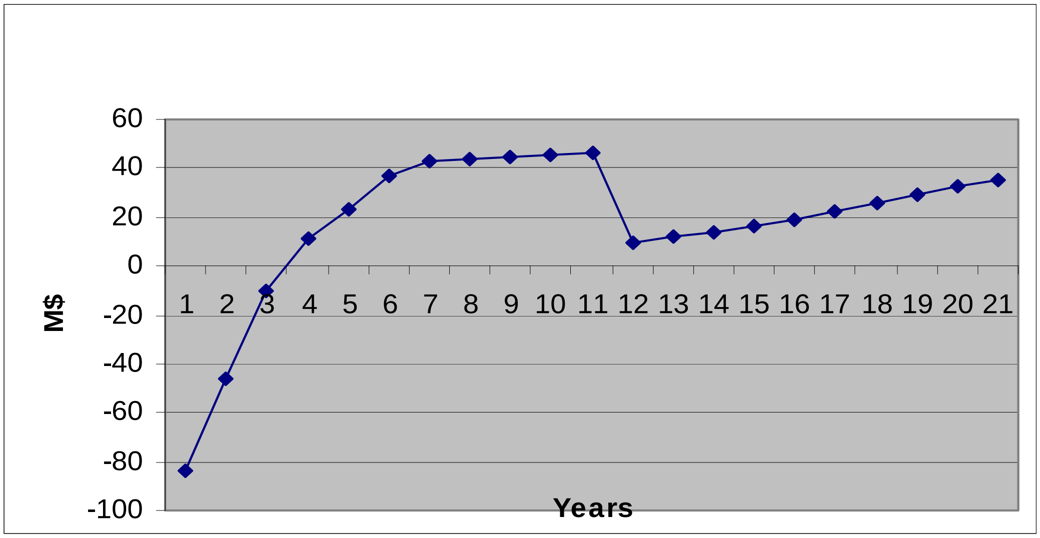

Figure 22: Cumulative Cash Flow Over 20 Year Project Life

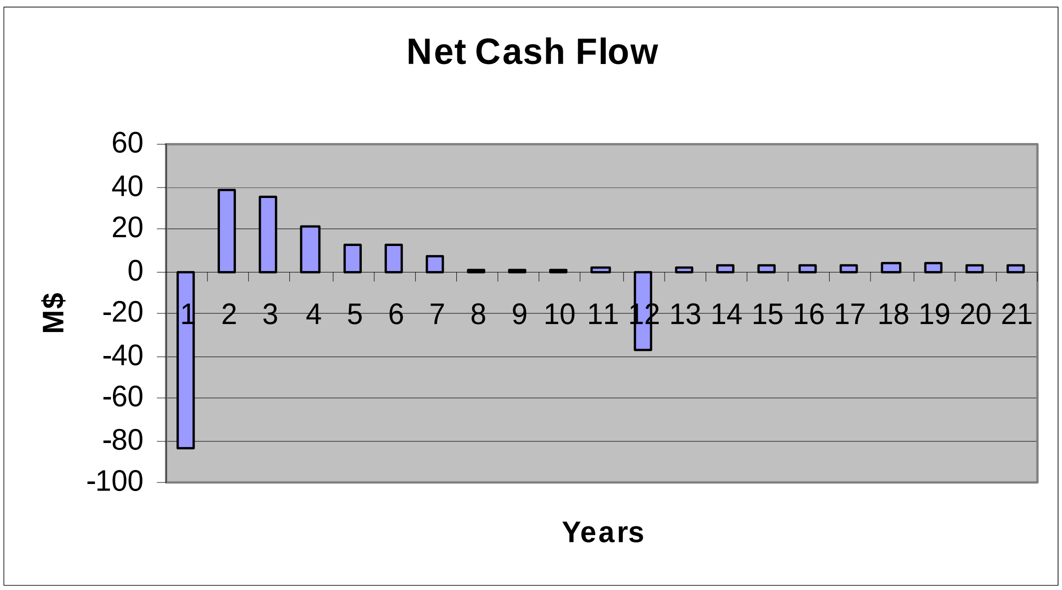

Figure 23: Net Cash Flow Over 20 Year Project Life

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)	$212,800,000	$280,100,000	$375,100,000
Annual O&M Cost (2004$)	$10,500,000	$13,100,000	$19,600,000
10-year Refit Cost (2004$)	$18,900,000	$23,300,000	$37,800,000
Internal Rate of Return	None	None	None

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.

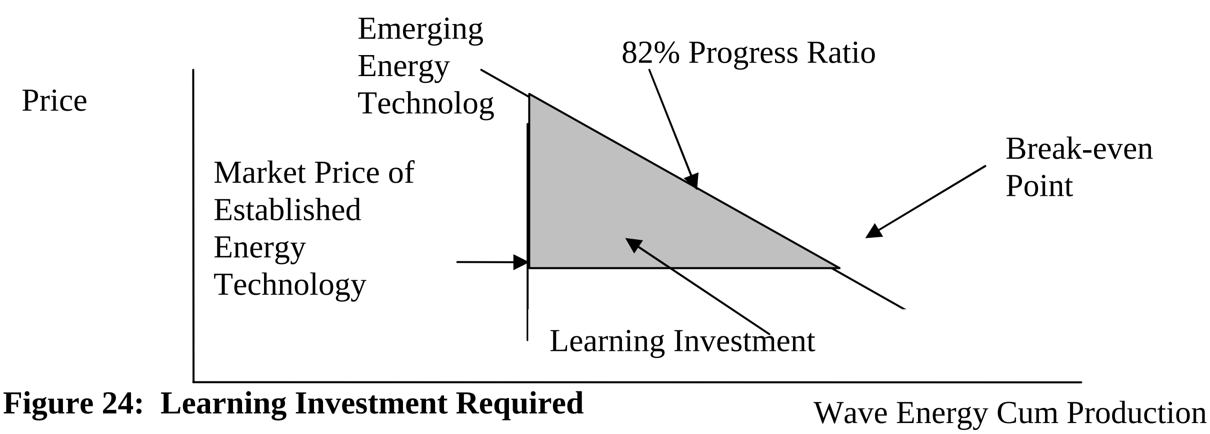

Figure 24: Learning Investment Required

12. Comparison with Commercial Scale Wind Power Plant

The costs (in 2004$) of a pilot offshore WEC device are described in Section 7 using the production experience gained by OPD from the build of the first prototype machine. The costs (in 2004$) 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 90 MW 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 derated energy conversion devices. The 213 device Pelamis 1st commercial plant system has a rating of 106.5 MW, however, it could be overrated or derated 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 Pelamis 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

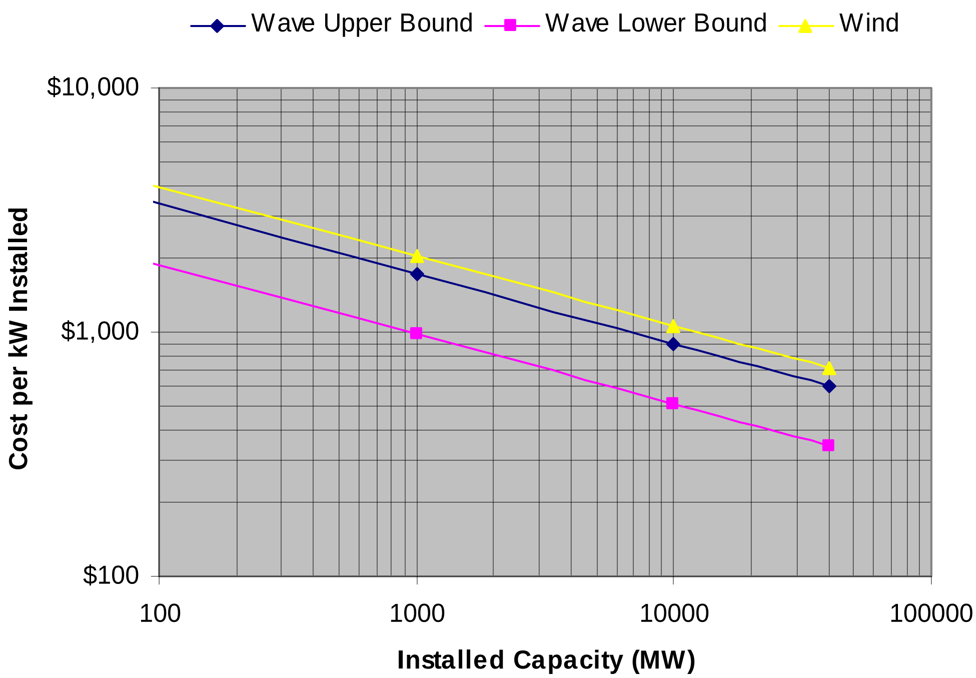

Figure 25: Installed Cost per kW installed as a Function of Installed Capacity

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**

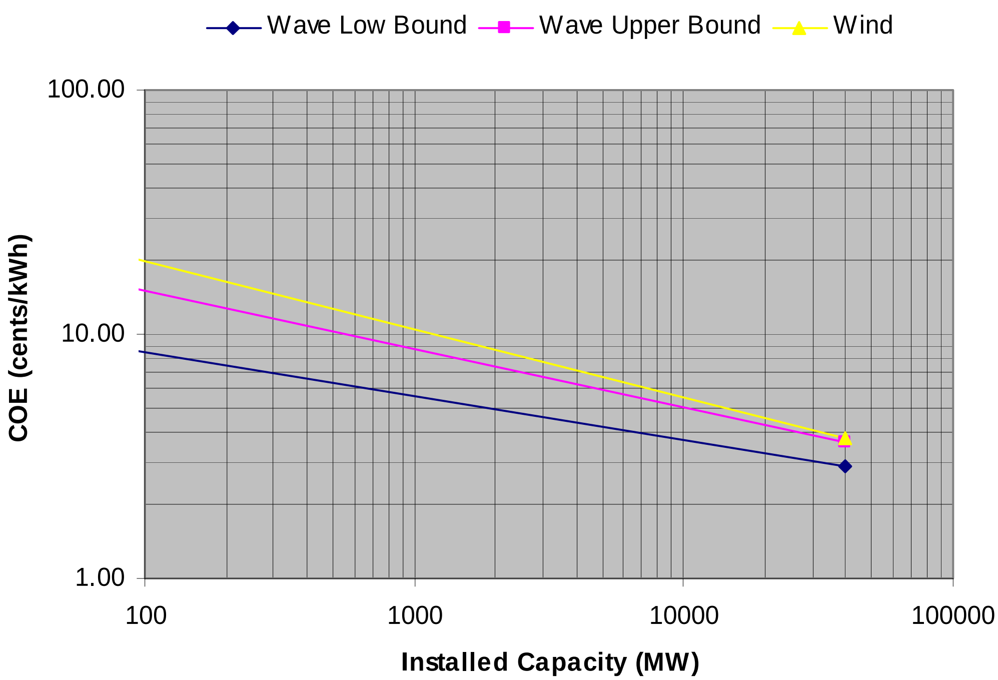

Figure 26: Levelized COE comparison to wind

Figure 26 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 26 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 in San Francisco, 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 wastewater 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

4. 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

5. 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

1. 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:

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

2. 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. "Pelamis WEC – Main Body Structural Design and Material Selection", Department of Trade and Industry (DTI)

6. "Pelamis WEC – Conclusion of Primary R&D", Department of Trade and Industry (DTI)

7. 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	$13,441,000	$13,441,000	
Mooring	213	$116,878	$24,895,014	
Power Conversion Modules (set of 3)	213	$623,961	$132,903,693	
Concrete Structure Sections	213	$244,800	$52,142,400	
Facilities	1	$12,000,000	$12,000,000	
Installation	1	$11,421,000	$11,421,000	
Construction Management	1	$11,937,000	$11,937,000	
TOTAL			$262,100,107	

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	$131,050,054	$9,828,754	$8,874,721	$139,924,775
2007	$131,050,054	$9,828,754	$8,013,293	$139,063,346
Total	$262,100,107	$19,657,508	$16,888,014	$278,988,121

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

Costs	Yrly Cost	Amount	
LABOR	$2,584,000	$2,584,000	
PARTS AND SUPPLIES (2%)	$5,242,000	$5,242,000	
INSURANCE (2%)	$5,242,000	$5,242,000	
Total		$13,068,000	

OVERHAUL AND REPLACEMENT COST (OAR) - 2004$

O&R Costs	Year of Cost	Cost in 2004$	
10 Year Retrofit			
Operation	10	$10,858,000	
Parts	10	$17,460,000	
Total		$28,318,000	

FINANCIAL ASSUMPTIONS

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

1	Rated Plant Capacity ©	90	MW
2	Annual Electric Energy Production (AEP)	300,000	MWeh/yr
	Therefore, Capacity Factor	38.03	%
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 = $278,988,121

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	**278,988,121**					**278,988,121**
2008	278,988,121	13,949,406	13,949,406	0.2000	17,051,475	247,987,240
2009	278,988,121	13,949,406	27,898,812	0.3200	30,692,655	203,345,179
2010	278,988,121	13,949,406	41,848,218	0.1920	16,142,063	173,253,710
2011	278,988,121	13,949,406	55,797,624	0.1152	7,411,708	151,892,596
2012	278,988,121	13,949,406	69,747,030	0.1152	7,411,708	130,531,482
2013	278,988,121	13,949,406	83,696,436	0.0576	863,941	115,718,135
2014	278,988,121	13,949,406	97,645,842	0.0000	-5,683,825	107,452,554
2015	278,988,121	13,949,406	111,595,248	0.0000	-5,683,825	99,186,973
2016	278,988,121	13,949,406	125,544,654	0.0000	-5,683,825	90,921,392
2017	278,988,121	13,949,406	139,494,060	0.0000	-5,683,825	82,655,811
2018	278,988,121	13,949,406	153,443,467	0.0000	-5,683,825	74,390,230
2019	278,988,121	13,949,406	167,392,873	0.0000	-5,683,825	66,124,648
2020	278,988,121	13,949,406	181,342,279	0.0000	-5,683,825	57,859,067
2021	278,988,121	13,949,406	195,291,685	0.0000	-5,683,825	49,593,486
2022	278,988,121	13,949,406	209,241,091	0.0000	-5,683,825	41,327,905
2023	278,988,121	13,949,406	223,190,497	0.0000	-5,683,825	33,062,324
2024	278,988,121	13,949,406	237,139,903	0.0000	-5,683,825	24,796,743
2025	278,988,121	13,949,406	251,089,309	0.0000	-5,683,825	16,531,162
2026	278,988,121	13,949,406	265,038,715	0.0000	-5,683,825	8,265,581
2027	278,988,121	13,949,406	278,988,121	0.0000	-5,683,825	0

CAPITAL REVENUE REQUIREMENTS

TPI = $278,988,121

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	247,987,240	16,763,937	3,385,026	6,509,665	13,949,406	21,104,503	50,038,099	11,674,438
2009	203,345,179	13,746,134	2,775,662	5,337,811	13,949,406	28,796,462	5,400,000	59,205,475
2010	173,253,710	11,711,951	2,364,913	4,547,910	13,949,406	17,652,669	5,400,000	44,826,849
2011	151,892,596	10,267,939	2,073,334	3,987,181	13,949,406	10,841,349	5,400,000	35,719,209
2012	130,531,482	8,823,928	1,781,755	3,426,451	13,949,406	10,033,456	5,400,000	32,614,997
2013	115,718,135	7,822,546	1,579,553	3,037,601	13,949,406	4,970,634	5,400,000	25,959,740
2014	107,452,554	7,263,793	1,466,727	2,820,630	13,949,406	155,454	5,400,000	20,256,009
2015	99,186,973	6,705,039	1,353,902	2,603,658	13,949,406	-157,157	5,400,000	19,054,849
2016	90,921,392	6,146,286	1,241,077	2,386,687	13,949,406	-469,767	5,400,000	17,853,689
2017	82,655,811	5,587,533	1,128,252	2,169,715	13,949,406	-782,377	5,400,000	16,652,528
2018	74,390,230	5,028,780	1,015,427	1,952,744	13,949,406	-1,094,988	5,400,000	15,451,368
2019	66,124,648	4,470,026	902,601	1,735,772	13,949,406	-1,407,598		19,650,208
2020	57,859,067	3,911,273	789,776	1,518,801	13,949,406	-1,720,208		18,449,047
2021	49,593,486	3,352,520	676,951	1,301,829	13,949,406	-2,032,819		17,247,887
2022	41,327,905	2,793,766	564,126	1,084,858	13,949,406	-2,345,429		16,046,727
2023	33,062,324	2,235,013	451,301	867,886	13,949,406	-2,658,039		14,845,566
2024	24,796,743	1,676,260	338,476	650,915	13,949,406	-2,970,650		13,644,406
2025	16,531,162	1,117,507	225,650	433,943	13,949,406	-3,283,260		12,443,246
2026	8,265,581	558,753	112,825	216,972	13,949,406	-3,595,871		11,242,085
2027	0	0	0	0	0	-3,908,481		-3,908,481
Sum of Annual Capital Revenue Requirements								418,929,844

FIXED CHARGE RATE (FCR) - NOMINAL AND REAL LEVELIZED

TPI = $278,988,121

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	11,674,438	0.9117	10,644,050	10,683,765	0.9391	10,033,038
2009	59,205,475	0.8313	49,215,701	52,603,298	0.8819	46,390,519
2010	44,826,849	0.7579	33,974,332	38,668,034	0.8282	32,024,066
2011	35,719,209	0.6910	24,682,290	29,914,276	0.7777	23,265,426
2012	32,614,997	0.6300	20,548,109	26,518,977	0.7304	19,368,564
2013	25,959,740	0.5744	14,911,652	20,492,858	0.6859	14,055,662
2014	20,256,009	0.5237	10,608,408	15,524,545	0.6441	9,999,442
2015	19,054,849	0.4775	9,098,562	14,178,597	0.6049	8,576,267
2016	17,853,689	0.4353	7,772,596	12,897,885	0.5680	7,326,417
2017	16,652,528	0.3969	6,609,814	11,679,748	0.5334	6,230,384
2018	15,451,368	0.3619	5,591,739	10,521,630	0.5009	5,270,750
2019	19,650,208	0.3300	6,483,627	12,991,102	0.4704	6,111,440
2020	18,449,047	0.3008	5,550,035	11,841,742	0.4418	5,231,440
2021	17,247,887	0.2743	4,730,734	10,748,313	0.4149	4,459,171
2022	16,046,727	0.2501	4,012,823	9,708,534	0.3896	3,782,471
2023	14,845,566	0.2280	3,384,786	8,720,206	0.3659	3,190,486
2024	13,644,406	0.2079	2,836,351	7,781,214	0.3436	2,673,533
2025	12,443,246	0.1895	2,358,359	6,889,523	0.3227	2,222,980
2026	11,242,085	0.1728	1,942,648	6,043,175	0.3030	1,831,132
2027	-3,908,481	0.1575	-615,781	-2,039,807	0.2846	-580,432
	418,929,844		224,340,838	316,367,613		211,462,756

	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	224,340,838		211,462,756
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)	25,778,535		19,170,020
6. Booked Cost	278,988,121		278,988,121
7. The levelized annual fixed charge rate (levelized annual charges divided by the booked cost)	**0.0924**		**0.0687**

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	$278,988,121	$	From TPI
FCR	9.24%	%	From FCR
AO&M	$13,068,000	$	From AO&M
LO&R = O&R/Life	$1,415,900	$	From LO&R
AEP =	300,000	MWeh/yr	From Assumptions
COE - TPI X FCR	8.59	cents/kWh	
COE - AO&M	4.36	cents/kWh	
COE - LO&R	0.47	cents/kWh	
COE	$0.1342	$/kWh	Calculated
COE	**13.42**	cents/kWh	Calculated

REAL RATES

	Value	Units	From
TPI	$278,988,121	$	From TPI
FCR	6.87%	%	From FCR
AO&M	$13,068,000	$	From AO&M
LO&R = O&R/Life	$1,415,900	$	From LO&R
AEP =	300,000	MWeh/yr	From Assumptions
COE - TPI X FCR	6.39	cents/kWh	
COE - AO&M	4.36	cents/kWh	
COE - LO&R	0.47	cents/kWh	
COE	$0.1122	$/kWh	Calculated
COE	**11.22**	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

Indicates Input Cell (either input or use default values)

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 Producient 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	$13,441,000	$13,441,000	
Mooring	213	$116,878	$24,895,014	
Power Conversion Modules (set of 3)	213	$623,961	$132,903,693	
Concrete Structure Sections	213	$244,800	$52,142,400	
Facilities	1	$12,000,000	$12,000,000	
Installation	1	$11,421,000	$11,421,000	
Construction Management	1	$11,937,000	$11,937,000	
TOTAL			$262,100,107	

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	$131,050,054	$10,484,004	$9,470,645	$140,520,699
2007	$131,050,054	$10,484,004	$8,555,235	$139,605,289
Total	$262,100,107	$20,968,009	$18,025,880	$280,125,987

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

Costs	Yrly Cost	Amount
LABOR	$2,584,000	$2,584,000
PARTS AND SUPPLIES	$5,242,000	$5,242,000
INSURANCE	$5,242,000	$5,242,000
Total		$13,068,000

OVERHAUL AND REPLACEMENT COST (LOAR) -

O&R Costs	Year of Cost	Cost in 2004$	Cost Inflated to 2018$
10 Year Retrofit			
Operation	10	$10,858,000	$16,423,699
Parts	10	$17,460,000	$26,409,817
Total		$28,318,000	$42,833,516

FINANCIAL ASSUMPTIONS

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

1	Rated Plant Capacity ©	90	MW
2	Annual Electric Energy Production (AEP)	300,000	MWeh/yr
	Therefore, Capacity Factor	38.03	%
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	$/kWh for 1st 10 yrs
18	State Investment Tax Credit	6	% 1st year only
19	State Production Tax Credit	0	
20	Wholesale electricity price - 2002$	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	28,012,599	0	0	0	0	0	0	0
TOTAL REVENUES	63,604,916	36,660,080	37,759,883	38,892,679	40,179,638	41,509,182	42,882,721	44,301,710
AVG $/KWH	0.212	0.122	0.126	0.130	0.134	0.138	0.143	0.148
OPERATING COSTS								
Scheduled and Unscheduled O&M	14,708,149	15,149,394	15,603,875	16,071,992	16,554,151	17,050,776	17,562,299	18,089,168
Scheduled O&R	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0
TOTAL	14,708,149	15,149,394	15,603,875	16,071,992	16,554,151	17,050,776	17,562,299	18,089,168
EBITDA	48,896,766	21,510,687	22,156,007	22,820,687	23,625,486	24,458,406	25,320,422	26,212,542
Tax Depreciation	56,025,197	89,640,316	53,784,190	32,270,514	32,270,514	16,135,257	0	0
Interest PaId	15,687,055	15,344,258	14,974,038	14,574,200	14,142,374	13,676,003	13,172,322	12,628,347
TAXABLE EARNINGS	-22,815,486	-83,473,888	-46,602,220	-24,024,026	-22,787,402	-5,352,854	12,148,099	13,584,195
State Tax	-2,016,889	-7,379,092	-4,119,636	-2,123,724	-2,014,406	-473,192	1,073,892	1,200,843
Federal Tax	-7,279,509	-26,633,179	-14,868,904	-7,665,106	-7,270,548	-1,707,882	3,875,973	4,334,173
TOTAL TAX OBLIGATIONS	-9,296,398	-34,012,270	-18,988,541	-9,788,830	-9,284,955	-2,181,074	4,949,865	5,535,016

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
18,631,843	19,190,799	19,766,523	20,359,518	20,970,304	21,599,413	22,247,395	22,914,817	23,602,262	24,310,329	25,039,639	25,790,829
0	0	64,789,536	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
18,631,843	19,190,799	84,556,058	20,359,518	20,970,304	21,599,413	22,247,395	22,914,817	23,602,262	24,310,329	25,039,639	25,790,829
27,135,810	28,091,307	-35,709,388	30,103,488	31,162,524	32,258,490	33,392,665	34,566,373	35,780,981	37,037,905	36,308,595	37,587,419
0	0	0	0	0	0	0	0	0	0	0	0
12,040,853	11,406,360	10,721,108	9,981,035	9,181,757	8,318,536	7,386,258	6,379,397	5,291,988	4,117,586	2,849,231	1,479,409
15,094,957	16,684,946	-46,430,496	20,122,453	21,980,767	23,939,954	26,006,408	28,186,976	30,488,993	32,920,319	33,459,364	36,108,010
1,334,394	1,474,949	-4,104,456	1,778,825	1,943,100	2,116,292	2,298,966	2,491,729	2,695,227	2,910,156	2,957,808	3,191,948
4,816,197	5,323,499	-14,814,114	6,420,270	7,013,183	7,638,282	8,297,604	8,993,337	9,727,818	10,503,557	10,675,545	11,520,622
6,150,591	6,798,448	-18,918,570	8,199,095	8,956,283	9,754,573	10,596,571	11,485,065	12,423,045	13,413,713	13,633,352	14,712,570

CASH FLOW STATEMENT

Description/Year	2006	2007	2008	2009	2010	2011
EBITDA			31,100,611	3,180,646	3,276,066	3,374,348
Taxes Paid			-16,547,620	-41,481,028	-26,681,362	-17,712,435
CASH FLOW FROM OPS			47,648,231	44,661,675	29,957,427	21,086,783
Debt Service			-19,972,015	-19,972,015	-19,972,015	-19,972,015
NET CASH FLOW AFTER TAX		-84,037,796	27,676,215	24,689,660	9,985,412	1,114,768
CUM NET CASH FLOW		-84,037,796	-56,361,581	-31,671,921	-21,686,509	-20,571,742

IRR ON NET CASH FLOW AFTER TAX

2012	2013	2014	2015	2016	2017	2018	2019
3,535,667	3,703,815	3,879,061	4,061,687	4,251,984	4,450,254	-60,132,723	4,871,985
-17,470,752	-10,637,740	-3,786,632	-3,490,571	-3,173,653	-2,834,335	-28,870,102	-2,081,734
21,006,420	14,341,555	7,665,693	7,552,258	7,425,636	7,284,589	-31,262,621	6,953,719
-19,972,015	-19,972,015	-19,972,015	-19,972,015	-19,972,015	-19,972,015	-19,972,015	-19,972,015
1,034,404	-5,630,461	-12,306,322	-12,419,757	-12,546,379	-12,687,426	-51,234,637	-13,018,297
-19,537,337	-25,167,798	-37,474,120	-49,893,877	-62,440,256	-75,127,683	-126,362,319	-139,380,616

2020	2021	2022	2023	2024	2025	2026	2027
5,096,110	5,329,538	5,572,635	5,825,778	6,089,360	6,363,788	5,634,478	5,898,295
-1,664,738	-1,217,897	-738,979	-225,578	324,897	915,237	1,134,877	1,800,520
6,760,848	6,547,436	6,311,614	6,051,356	5,764,463	5,448,550	4,499,601	4,097,776
-19,972,015	-19,972,015	-19,972,015	-19,972,015	-19,972,015	-19,972,015	-19,972,015	-19,972,015
-13,211,168	-13,424,580	-13,660,402	-13,920,660	-14,207,553	-14,523,465	-15,472,414	-15,874,240
-152,591,784	-166,016,364	-179,676,765	-193,597,425	-207,804,978	-222,328,443	-237,800,857	-253,675,097
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