

Public Utilities Commission

Docket No. 05-0145

O`ahu Power Plant

Testimony of

Tom Denniss

re: Energetech Wave Energy System

LOL T-12

1 My name is Tom Denniss. I am Executive Director of Energetech Australia Pty Ltd.

2

3 **Education**

4 B.Math, B.Sc (1st Class Honours), Dip. Ed., Ph.D (in Mathematics and Oceanography).

5

6 **International Affiliations**

7 I am a member of the Global Roundtable on Climate Change (which meets twice per year

8 – recently in Iceland, prior to that in NY); a member of the Communications Committee

9 for the Global Roundtable on Climate Change, and an Expert Reviewer of the United

10 Nation’s Intergovernmental Panel on Climate Change Fourth Assessment Report.

11

12 **Professional Experience**

13 15 years working in the wave energy field; 4 years as a university professor; 5 years in

14 banking.

15

16 **Articles Written**

17 The Propagation of Tides Near the Critical Latitude (Geophysical and Astrophysical

18 Fluid Dynamics, 1993);

19 Effects of Viscosity and Bottom Friction on Recirculating Flows (Journal of Geophysical

20 Research, 1994);

21 Recirculation in the Lee of Complicated Headlands (Journal Geophysical Research,

22 1994).

23

1 **Previous Testimony**

2 I am an expert reviewer of the United Nation's Intergovernmental Panel on Climate
3 Change (IPCC) Fourth Assessment Report, due out early in 2007.

4

5 **Testimony**

6 In principle it is very similar to a Blowhole. It is the air pressure which drives the
7 Energetech turbine. This pressure is increased by utilising the wave height in a chamber
8 to displace and compress the air, driving it past a narrow aperture, at which point the
9 turbine is housed.

10

11 The turbine work in both directions. Tthis is a vital requirement for wave energy turbines.

12

13 The device is 35 meters by 30 meters in plan. The visible part of the structure (above the
14 waterline) rises about 10 meters.

15

16 Distance from shore As far as is necessary. There is no requirement in this regard except
17 that, in general, the further from shore, the greater the cost of connecting to the electrical
18 grid.

19

20 **Interconnection**

21 It can interface with 46 kV or 138kV line, and even with lower voltages such as 11kV.

22

1 My estimate for wave energy production in Hawaii (at this stage of the technology) is
2 about 8-10 cents per kWh. Improvements in the technology over the next few years, with
3 accompanying economies of scale of larger plants, would likely see costs at below 5
4 cents per kWh.

5

6 First installation in Port Kembla, about 100 km south of Sydney, Australia. Soon (within
7 the next year or so) to be installed in several other places around the world.

8

9 **Hawaii**

10 Because the wave climate is very good, allowing for low energy production costs. In
11 addition to this, the reliance of the state on diesel powered electricity makes it an obvious
12 place to implement wave energy.

13

14 Once funding is available, a project could be commissioned within 18 months.

15

16 The only moving part is the turbine, and this is totally isolated from wildlife about 8
17 meters above the waterline. No marine or avian life can be harmed at all.

18

19 The noise levels of the turbine have been independently verified by Lloyds Register at 73
20 dB (one meter from the turbine). This is commensurate with a household vacuum cleaner.

21

22 In essence, it is intermittent power, as are all renewable energy technologies. However,
23 using simple battery technology with some associated losses, the supply can be base load.

1 The losses associated with doing this would add about 10% to the cost of the power
2 (about 1 cent per kWh).

3

4 The wave to wire efficiency (percentage of power converted relative to that in the
5 incoming wave) is currently about 40%. We hope to get this to 50% within the next
6 couple of years.

7

8 The Port Kembla system is operated remotely from anywhere in the world via an internet
9 link. This is essentially how other plants will be operated. Routine maintenance is
10 performed by local firms employed specifically to do so.

11

12 The availability factor is greater than 95%. The life expectancy is 25 years, although this
13 can be extended via planned maintenance. The Capacity Factor is between 40% and 50%
14 (it is somewhat arbitrary, depending on what peak capacity is chosen for the system).

15 This contrasts with the capacity factor of wind turbines, which is usually about 30%.

16

17 Our preferred option is Local Manufacturing. It results in a lower unit cost of energy.

18

19 By displacing fossil fuel based sources of power, the system will result in a reduction of
20 the emission of CO₂, SO₂, and other greenhouse gases into the atmosphere. A single
21 device in Hawaii would prevent the emission of approximately 4000 tonnes of CO₂ per
22 annum.

23

1 **From the Energetech Website:**

2

3 **Energetech** is a renewable energy technology development and industry advisory
4 company. The company has developed a new and commercially efficient system for
5 extracting energy from ocean waves and converting it to electricity or desalinated water.
6 The Energetech technology now makes it possible for wave energy to provide a cheap,
7 sustainable source of power or water to grid-connected and remote users.

8 www.energetech.com.au/

9

10 **Introduction**

11

12 Ocean waves contain enormous amounts of energy, but the energy in each crest is
13 generally spread out along it. If all the energy could be transported to one point it could
14 be harnessed far more readily.

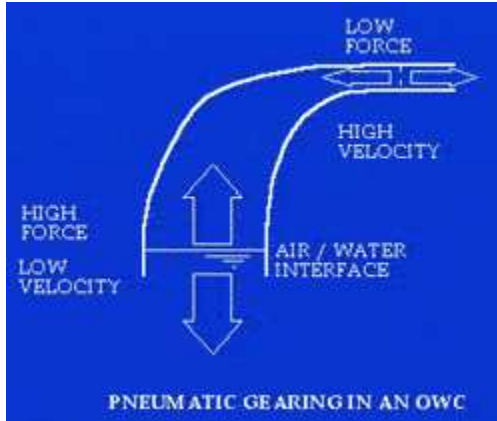
15

16 It is possible to focus all the energy of a plane surface gravity wave crest, the type you
17 see breaking on the beach, on to a single point using a parabolic wave focusser. The
18 section of the wave is reflected by a parabolic wall and converges on the focus of the
19 parabola. As the wave converges, the crest height grows to a maximum in the focus area.
20 Atop the focal region is a chamber that extends deeper than any likely wave trough. The
21 oscillatory wave motion causes a similar oscillatory airflow through the chamber .

22

23

1



2

3

4 At the narrowest point of the chamber, the airflow accelerates and a revolutionary
5 turbine, outlined later, converts the energy in the airflow into mechanical energy which
6 drives an electrical generator. The parabolic wall, chamber and turbine are the essence of
7 the Energetech Australia Wave Energy System.

8

9 **The Parabolic Wall - Focussing The Waves**

10

11 The conditions that must be met to maximize the wave focussing are:

12

13 Ideally, the crests will propagate parallel to the axis of symmetry of the parabola. While
14 slight variations will result in little energy loss, the greater the angle between the axis of
15 symmetry and the propagation direction, the more the energy will be spread out.

16

17 The sea bottom should be reasonably flat, so it does not disturb the wave direction, and
18 deep enough so that when wave section enters the parabola, the crests do not steepen and

1 break as they grow.

2

3 A very choppy scattered incoming wave will scatter some energy away from the focus.

4 The energy loss arising from the above-mentioned conditions can be minimized by

5 choosing the appropriate focal length of the parabola, so that the waves do not have the

6 time or space to vary greatly.

7

8 The wave which converges on the focus will not be a full circle as there will be a missing

9 section on the open ocean side. At the edges of this missing section, there will be some

10 diffraction of energy.

11

12 **The Energy Extracting Device**

13

14 At the focus, the water will rise and fall periodically with amplitude of approximately 3

15 times that of the incoming waves. All the energy of the section of the incoming plane

16 wave converges on this point.

17 The Denniss-Auld Turbine in conjunction with a chamber in which the air flow is

18 oscillatory is the best way to convert the potential energy of the water into mechanical

19 energy. The centre of the chamber should be located above the focus of the parabolic

20 wall.

21

22 **Power Estimation**

23

1 Approximating what the device will produce in the way of power depends on the amount
2 of energy extracted based on sea conditions on a particular day.

3

4 An illustration, however, may be useful. Consider a parabolic focuser with dimensions of
5 40 metres width, 20 metres length, and a focal length of 5 metres. Assume a coastal wave
6 crest amplitude of 1 metre. This would render in the vicinity of ten million joules of
7 energy for extraction from each wave. This equates to between 1 and 2 megawatts of
8 power.

9

10 **The Denniss-Auld Turbine**

11

12 The turbine used in an OWC is a key element in device's economic performance, and has
13 been cited by wave energy experts as the single most important barrier to commercialise
14 OWCs.

15

16 Most turbines are designed to function for gas or liquid flowing in one direction and at
17 constant velocity with the blades designed to take advantage of the optimal 'angle of
18 attack'. However, when the flow is not always from the same direction or a constant
19 velocity, traditional turbines become ineffective.

20

21 Previous attempts to address this difficulty have mostly resulted in turbines with varying
22 degrees of efficiency. The Energetech turbine, however, uses a different method, which
23 with its slower rotational speed with higher torque improves efficiency and reliability and

1 reduces the need for maintenance.

2

3 The turbine uses a sensor system with a pressure transducer which measures the pressure
4 exerted on the ocean floor by each wave as it approaches the capture chamber, or as it
5 enters the chamber. The transducer sends a voltage signal proportional to the pressure
6 which identifies the height, duration and shape of each wave. The system will be
7 calibrated to small-scale "noise" from activating it.

8

9 The signal from the transducer is sent to a Programmable Logic Controller (PLC) which
10 adjusts various parameters which will be selected based on particular conditions and
11 energy content of each site.

12

13 **The Generator**

14

15 The generator, which is coupled to the Energetech turbine, is designed so that the
16 electrical control will vary the speed and torque characteristic of the generator load real-
17 time to maximise the power transfer.

18

19 An induction machine will be used for the generator, with coupling to the electricity grid
20 provided by a fully regenerative electronic control system. The grid connection and the
21 control system will be located in a weatherproof building external to the air duct. The
22 voltage of the 3 phase connection at this point is 415 V L-L at 50 Hz.

23

1 The electrical interface between the generator and the mains supply comprises two bi-
2 directional DC/AC 3-phase inverters, which each operate under independent
3 microprocessor control. The inverters are coupled to each other on the DC sides with
4 sufficient stabilising capacitance to prevent undesirable interaction. The generator side
5 inverter senses the generator speed and provides the appropriate voltage and frequency
6 control so that the generator operates according to the optimised algorithm.

7

8 The generator can be soft started electrically by ramping up applied power at a
9 predetermined rate. We will develop the control so that it incorporates more advanced
10 algorithms, such as ramping up the generator speed electrically in anticipation of an
11 approaching wave, so that the turbine operates at optimum speed as soon as the air
12 movement begins. A flexible microprocessor will enable trying several algorithms in
13 sequence to monitor the results while still permitting easy return to the original algorithm.

14

15 The DC link/mains inverter will sense the mains voltage and waveform zero crossings,
16 with appropriate filtering. With the appropriate phase and pulse width modulation, power
17 will be transferred in either direction with harmonics and power factor variation
18 contained within the electricity authority's requirements. The system will normally be
19 configured to operate at unity power factor at all times.

20

21 It is, however, possible to operate at a leading power factor with suitable control, to give
22 the electricity authority a measure of dynamic power factor compensation. Dynamic
23 simulated inertia using ultracapacitors, recently developed by the Australian CSIRO, will

1 be used to smooth out mains current fluctuations while allowing the turbine to be loaded
2 to its best operating point.

3

4 **GreenWave Rhode Island**

5

6 **September 2004: Deep River, CT:**

7

8 Energetech America LLC today announced plans for a "first of its kind" wave energy
9 project in the United States. Planned for an area more than a mile off the southern coast
10 of Rhode Island, "**GreenWave Rhode Island**" is an estimated \$3.5 million project to
11 convert ocean waves into clean electricity.

12

13 "Harnessing ocean energy has the potential to produce a virtually limitless supply of
14 pollution-free electricity to help meet U.S. and the world's growing energy needs," said
15 Dr. Tom Denniss, chief executive of Energetech Australia Pty. Ltd., the parent company
16 of its Connecticut-based U.S. subsidiary. " **GreenWave Rhode Island** is a major
17 milestone in the development of clean technologies to tap the world's most plentiful
18 natural resource."

19 The pilot project, planned to operate for three years, has received \$1 million in planning
20 and development funds from the renewable energy funds of three New England states
21 (Rhode Island, Massachusetts and Connecticut). Company officials said the facility is
22 planned as a not-for-profit operation intended to demonstrate the commercial viability of
23 its wave energy technology. Research for the project is being conducted by the University

1 of Rhode Island (URI), world-renowned for oceanographic science and education.
2 "Moving America forward on a path toward greater energy independence that will create
3 new jobs and lead to a healthier environment cannot be achieved by the work of a single
4 state," said Rob Pratt, Director of the Massachusetts Renewable Energy Trust. "We are
5 proud to participate in this multi-state coalition working to advance wave energy
6 technology, which has enormous potential to help us build a cleaner energy future."...

7 70

8

9 **Project Introduction & Overview**

10

11 Energetech America is planning a new "wave energy" facility to convert ocean waves
12 into clean electricity. **GreenWave Rhode Island** is a not-for-profit, pilot project
13 proposed for an area outside the Harbor of Refuge near Point Judith. The project has
14 received funding support from three state renewable energy programs (Rhode Island,
15 Connecticut and Massachusetts).

16

17 If approved by state and federal authorities after their detailed review, the facility will
18 demonstrate the potential for using an endless supply of ocean energy to help meet U.S.
19 and worldwide energy needs.

20

21 While similar projects are operating or are under development in other countries,
22 **GreenWave** is the first of its kind in the U.S. In addition to its environmental value as a
23 provider of clean energy, the \$3.5 million project is expected to contribute to economic

1 development in the area. Strengthening Rhode Island 's position as a national leader in
2 ocean energy technology will help attract additional research and development interests
3 to the state.

4 Experts at the University of Rhode Island (URI) – world-renowned for ocean-ographic
5 science and education – are conducting studies for the project. URI's work on
6 **GreenWave** is a collaboration of the Graduate School of Oceanography and the
7 Department of Ocean Engineering graduate program. Their work will assist Energetech
8 in determining final project design and location.

9

10 Energetech is committed to an open dialogue with Rhode Island residents and other
11 interested stakeholders. We look forward to sharing information about our plans,
12 welcoming your comments and responding to your questions. Please note that the
13 proposed project is still in the planning phase and the information in this Overview is
14 preliminary. We'll share additional information about the planned facility when it
15 becomes available.

16

17 We welcome your input in helping us develop the best project possible for Rhode Island.

18

19 *August/September 2004*

20

1 cables moored to the seabed. Two curved walls concentrate waves into a central hollow
2 chamber where the up and down wave motion forces compressed air through a turbine.
3 The turbine powers a generator that transmits electricity to shore via a cable under the
4 seabed. The structure is manufactured from corrosion-resistant steel and measures
5 approximately 100 feet by 120 feet. Its design and location will be finalized after URI
6 completes its studies later this year.

7

8 After a rigorous government permitting process, plans call for the facility to be
9 manufactured in RI and floated to the off-shore site, where it will be erected in less than a
10 week. If needed, the structure can be re-floated and towed to port in less than three days.
11 Operations are projected to begin in 2006 and continue for three years. During this time,
12 **GreenWave** will provide data crucial to wave energy development here and around the
13 globe.

14

15 **Public Benefits**

16

17 **GreenWave Rhode Island** is a not-for-profit pilot project. It will provide important data
18 to help reduce Rhode Island's and the nation's dependence on electricity from coal and
19 imported oil and natural gas.

20 The project will bolster economic development in Rhode Island by enhancing its
21 reputation as a national leader in ocean technology and coastal resource management.

22 The state has the potential to become a center for renewable energy research
23 organizations, resulting in new jobs and state/local tax revenues.

1 Depending on the wave climate at any given time, the pilot project will generate up to
2 500 kilowatts of electricity – enough to power as many as 300 average households. As
3 many as 100 manufacturing jobs for area workers will result from structure fabrication
4 work over the course of a year.

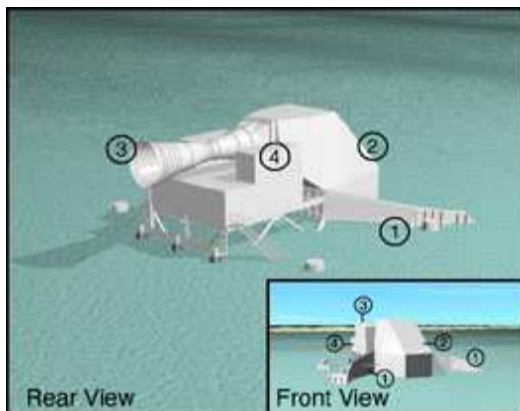
5 **GreenWave** will be an educational aid for RI teachers and students interested in
6 engineering and environmental sciences. Energetech will explore local interest in an on-
7 shore, outdoor educational exhibit near the site for school children and the public.

8 As the first “green energy” technology of its kind in the U.S., the project is a potential
9 eco-tourism attraction likely to draw interested visitors to the area.

10

11 **How it works**

12



13

14

15 Energetech has invested \$1 million and a full year on pre-liminary design by a team of 12
16 engineers at one of the world’s leading offshore engineering firms. The structure,
17 engineered to withstand Pt. Judith’s rough waters and often vicious storms, measures
18 approximately 100 ft. long X 120 ft. wide X 40 ft. above water level. This design is

1 preliminary and could be modified after additional URI research is completed.
2 These images (right) show the above-water portion of the structure. Waves enter the
3 opening between two curved wave walls (1), which concentrate the energy into the air
4 chamber (2). The up and down motion of the water causes air to rush through the
5 chamber. The air is pushed through the narrow end of the chamber and turns the turbine
6 (3) that powers the generator. Electronic controls (4) will send the electricity to a cable
7 under the seabed and connect to an existing transmission line on shore for distribution to
8 area homes and businesses.

9

10 **Key Features**

11

12 **GreenWave will preserve the local environment.** Rhode Island 's coastal waters are
13 critical to the state's economy and recreational interests. The planned facility is similar to
14 an anchored catamaran. There are no moving parts below the water line and the structure
15 does not impede the natural circulation of sediments on the sea bottom. No chemical
16 agents are used on the structure.

17

18 **The project will protect fishing grounds and marine life.** The importance of
19 commercial and recreational fishing near Point Judith is reflected in the project's design.
20 The four-legged structure rests on pads on the ocean floor and is moored by cables to
21 pilings in the seabed. As currently designed, the power cable used to transmit electricity
22 to shore is buried under the seabed using "directional drilling" technology. These design
23 features ensure that the facility will not interfere with fish or bottom-dwelling sea life

1 (such as lobsters), and the structure is expected to attract and enhance marine life much
2 like an artificial reef.

3

4 **Point Judith is the ideal location.** The key to a successful project is locating it where the
5 wave climate is most favorable. Energetech analyzed the waters off four New England
6 states and found Point Judith ideally suited for the project. Based on URI research, the
7 best location is an area seaward of the main detached breakwater outside the Harbor of
8 Refuge (see map). URI oceanographic experts are studying this area to help identify the
9 best spot for the structure. Block Island also has favorable conditions but no access to the
10 New England electric transmission system. The prohibitive cost of laying a power cable
11 from the mainland to the island (up to \$60 million or more) eliminates it as an option.

12

13 **The project will not inhibit the public's use of coastal waters.** Rhode Island 's waters
14 belong to the people for their use and enjoyment. Plans call for manufacturing the
15 structure in Rhode Island , towing it to the site and installing it in less than a week
16 without disrupting normal coastal activities. After beginning operations, the project will
17 not interfere with recreational or commercial uses of public waters – including fishing,
18 boating, shipping, ferry service, surfing or other uses.

19

20 **#More Key Features**

21

22 **The GreenWave structure is safe.** Like a buoy or boat, the structure will include
23 navigational aids to comply with U.S. Coast Guard safety standards. The facility will be

1 engineered and built to meet “100-year storm event” criteria – meaning it will withstand
2 the area’s rough waters and severe storms. It is also designed to be easily towed to port, if
3 needed, after operations begin.

4

5 **Facility operations are quiet.** The project has been designed to minimize sound. The
6 only moving part is the turbine, located above water level and not accessible from the
7 water. The turbine will not be audible on shore, and independent tests verify the sound
8 level at a distance of three feet is equivalent to a modern vacuum cleaner. The turbine is
9 virtually silent to sea life, emitting hundreds of times less sound than a standard outboard
10 motor.

11

12 **GreenWave will have minimal visual impact.** As currently planned, the structure will
13 be located a mile or more from shore and a minimum of 100 yards from the main
14 detached breakwater. While the exact site has not been finalized, this distance from shore
15 will help minimize the structure’s visual impact, making it barely visible from most
16 locations.

17

18 **What’s Ahead**

19

20 **Additional research is needed.** Experts from URI completed an initial dive survey and
21 sediment analysis in 2003. URI is expected to complete additional studies, including a
22 detailed wave analysis and underwater surveying, late this year. This data will be
23 important for final project design and location.

1 **GreenWave must undergo a rigorous government review.** Before structure fabrication
2 begins, the project must undergo a comprehensive assessment by state and federal
3 government experts to ensure it complies with environmental, navigational and other
4 regulations. The permitting process will involve the RI Coastal Resource Management
5 Council, RI Department of Environmental Management, U.S. Army Corps of Engineers
6 and the Federal Energy Regulatory Commission. This rigorous review and public
7 hearings will provide extensive opportunity for public input. Energetech will also work
8 closely with Narragansett officials during this process.

9

10 **Operations are expected to begin in 2006.** Current plans call for filing a permit
11 application with the state and federal agencies later this fall, followed by a public
12 comment period and public hearings. Project manufacturing is slated to begin in 2005,
13 with operations expected in 2006. After operating for three years, the structure's
14 performance will be analyzed and a decision made whether to dismantle it. Another
15 option would be to extend its operating life and move it to another location. The prospect
16 of continuing operations at *any* site after the three-year pilot period is likely to require a
17 new review and approval by state and federal authorities.

18

19 **#Project Sponsor**

20

21 Australia-based **Energetech** is one of the world's leading wave energy technology
22 companies. It was founded by Dr. Tom Denniss (president), an expert in oceanography
23 and wave energy systems. **GreenWave Rhode Island** is sponsored by **Energetech**

1 **America**, the company's Connecticut-based affiliate. The company has begun
2 construction of a similar project in Australia that is expected to begin operations this
3 year. Preliminary work is also underway on projects in Canada and Spain.

4

5 **Results of the Testing of the Energetech Wave Energy**

6 **Plant at Port Kembla on October 26, 2005**

7

8 **Ray Alcorn, Scott Hunter, Chris Signorelli, Ranjith Obeyesekera, Tim Finnigan,**

9 **Tom Denniss**

10 **Energetech Australia Pty Limited**

11

12 **Abstract**

13

14 A full-scale ocean trial of the Energetech wave energy device has taken place at Port
15 Kembla, and real power was generated into the on-board grid. Fresh desalinated water
16 was also produced. The measured power indicates the device performs better than
17 previously predicted from wave tank, wind tunnel, and CFD testing. For example, in two
18 metre waves with periods of seven seconds, the results from the trial indicate the device
19 will produce 321 kW, compared with previous predictions of 268 kW. A lower bound
20 confidence interval estimate suggests the device has a 92.6% probability of producing
21 greater than 218 kW in these conditions. Past analysis had indicated the Energetech
22 technology was capable of producing an annual energy output of at least 500MWh at Port
23 Kembla, where the wave climate averages 7.6 kW per metre of wave front. The results of

1 this floating mode trial predict with even greater probability that the output will likely be
2 in excess of this level. In locations with higher energy densities, the annual output from
3 an Energetech device will be commensurately greater again. The results of this trial are
4 very encouraging, as it indicates the technology is capable of performing better than
5 previously claimed.

6

7 **Introduction**

8

9 On October 26, 2005, at approximately 0600 hours, the Energetech wave energy device
10 was towed to a position in the open ocean, several hundred metres off the southern
11 breakwater of Port Kembla Harbour. The device was then held, facing into the waves, in
12 a quasi-static position between two tug boats (via ropes) for the next
13 few hours, at which point it was towed back into the harbour at the completion of the
14 trial.

15

16 The purpose of this trial was to demonstrate the ability of the Energetech turbine and
17 control systems to produce real power from the energy in the waves. The power was
18 directed into an on-board grid and dissipated into on-board load banks.

19

20 Given the trial was designed such that the device would be operating in a floating mode
21 configuration, the levels of power inside the oscillating water column (OWC) chamber
22 were necessarily going to be low. This was clearly understood to be the case prior to the
23 trial. A floating mode configuration was chosen, as it was more

1 quickly and easily achievable than another fixed mode deployment.

2

3 A previous deployment of the device in a fixed mode configuration a few months prior
4 (June 2005) unequivocally demonstrated the ability of the device to focus and transfer
5 wave energy into an amplified water height inside the OWC chamber and an intense
6 airflow past the turbine. These earlier results were fully consistent with prior predictions
7 regarding the wave amplification based on wave tank and computational fluid dynamics
8 (CFD) testing.

9

10 However, during this earlier fixed mode configuration trial, the generator was not
11 connected to the grid and, therefore, power production figures could only be inferred
12 rather than directly measured. This more recent trial in floating mode allowed for a
13 quantification of the real power production as a function of the incident wave heights,
14 and also facilitated a measure of the turbine efficiency in terms of output shaft power.

15

16 While the actual incident wave heights on the day were moderate, it was recognised the
17 device would heave in response to these waves, resulting in only a fraction of the wave
18 energy being available to the device. By measuring the wave heights which resulted
19 inside the chamber, however, an implicit incident wave height (had the structure been
20 fixed) was calculated from past measurements.

21

22 The fact that the implicit incident wave heights were low during this latter trial
23 demonstrated the ability of the technology to produce power during periods of low wave

1 energy. The results of the earlier trial, along with a vast amount of wave tank and wind
2 tunnel testing (as well as CFD analysis), allows for a simple and quite
3 accurate extrapolation of the results of this trial to cases involving larger wave conditions.

4

5 The results of the floating mode trial are summarised herewith, and compared to the
6 results and analysis of previous extensive research and testing in wave tanks and wind
7 tunnels at smaller scales by Energetech over a number of years. The aim of this trial can
8 be viewed simply as an attempt to demonstrate that the technology at full- scale is able to
9 meet the expectations of power production implied by previous Energetech and
10 independent research.

11

12 It should be noted that, during this floating mode trial, wave periods were approximately
13 seven seconds. All comparisons with previous results should be viewed in this context, as
14 the power available to be extracted is a function of wave period.

15

16 During the trial, the on-board monitoring system indicated the regular production of
17 power. On-board sensors recorded a large variety of data, including wave heights, air
18 velocities, pressures, and power output. Several discrete periods of power generation
19 were examined as separate “events” for the purpose of the data analysis. The power
20 generation events were separated by occasions of non-generation “down-time”. During
21 this time, activities related to the re-positioning of tugs and mooring lines etc. took place.

22

23

1 **Results**

2

3 The average aerodynamic efficiency of the turbine during the operational phase of the
4 trial, (based upon the standard measure of turbine efficiency – that is, power produced as
5 a proportion relative to the product of volume flow rate and pressure drop across the
6 turbine), varied between 52% and 81%, with an average value of
7 69.3%. These results are illustrated in Figure 1.

8

9 Air velocities past the turbine during these events generally averaged between 20 and 25
10 metres per second. This contrasts with the corresponding velocities measured during the
11 fixed mode deployment, where maximums of up to 140 metres per second were
12 encountered.

13

14 Previous Energetech research, conducted in collaboration with the University of
15 Sydney’s Department of Aeronautical Engineering in their large wind tunnel facility (1/3
16 scale model), had indicated an average aerodynamic efficiency of 68% across all wave
17 heights and periods likely to be encountered at Port Kembla. For the case of seven second
18 period waves with small heights, as was encountered during this trial, previous research
19 had indicated an average aerodynamic efficiency of slightly less than 60%.

20

21 Clearly, the actual device performed better in this regard than indicated by previous
22 research. The reason for this is almost certainly due to the ability of the full-scale device
23 to dynamically “track the flow” and optimise both blade angle and rotational speed – an

1 ability not afforded to the smaller scale wind tunnel model. The ability to
2 optimise these parameters is one of the most obvious successes of the technology and of
3 the trial. ...

4

5 **Conclusion**

6

7 A full-scale ocean trial of the Energetech wave energy device has taken place at Port
8 Kembla, and real power was generated into the on-board grid. This measured power
9 indicates the device performs better than previously predicted from wave tank, wind
10 tunnel, and CFD testing.

11

12 For example, in two metre waves with periods of seven seconds, the results from the trial
13 indicate the device will produce 321 kW, compared with previous predictions of 268 kW.
14 A lower bound confidence interval estimate suggests the device has a 92.6% probability
15 of producing greater than 218 kW in these conditions.

16

17 Past analysis had indicated the Energetech technology was capable of producing an
18 annual energy output of at least 500MWh at Port Kembla, where the wave climate
19 averages 7.6 kW per metre of wave front. The results of this floating mode trial predict,
20 with even greater probability, the output will likely be in excess of this level. In
21 locations with higher energy densities, the output from an Energetech device will be
22 commensurately greater again.

23

1 The results of this trial are very encouraging, particularly as it indicates the technology is
2 capable of performing better than previously claimed.

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