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SELECTING OFFSHORE RENEWABLE ENERGY FUTURES FOR VICTORIA

Abstract

Australia's population is continually growing, making land more valuable and adding to energy demand. As the coast of Victoria, Australia has regular high winds, the development of offshore renewable energy is an excellent alternative to conventional energy sources. This provides an opportunity to meet growing energy needs while caring for the environment; and supporting regional communities. There are currently no offshore energy projects in Victoria. This paper investigates demand, supply, feasibility and planning of the wind and wave power options. Analytical (GIS) and visual aids (Google Earth) are used to illustrate these options and so to assist the community in making an informed decision for the renewable energy approaches suitable in Victoria.

Keywords
Renewable Energy
Offshore
Visualisation

1. INTRODUCTION

1.1 THE OFF-SHORE OPTION

Australia's energy demand increased by 2.1% each year – and Victoria's by 1.6% each year from 1960 to 2007 (Sustainability Victoria, 2008). The Australian Government is "... committed to ensuring 20 per cent of Australia's electricity supply comes from renewable energy by 2020." (Department of Climate Change, 2008). Options for renewable energy development in Australia are predominantly wind, solar and geothermal. Discussion has previously focussed almost entirely on on-shore development potentials. However, on-shore wind farms can be controversial and as land becomes more valuable the advantages of off-shore development become more apparent.

Figure 1 shows that Victoria has an extensive coastline that may provide considerable opportunities for both wind and wave generated energy. (Harries et al, 2006) say the potential of offshore renewable energy resources (RER) development "...is related to the distribution of the winds, and the strongest occur between latitudes 40° and 60°...". The Victorian coast is predominantly between 38° and 39° south and so is well situated to maximise the use of wind related RER.

This paper reviews the offshore RER potential in Victoria including demand, supply, feasibility and planning.

1.2 GLOBAL OFFSHORE ENERGY

1.2.1 Wave Power

Wave power is a much more recent power generation technology than wind power technology, with energy captured by turbines that are either fixed to shore, fixed to the sea floor or float on the water's surface (Sustainability Victoria, 2009; Harries, 2006). They are approximately three times more efficient than coal power stations, and have minimal visual and noise impacts. The first commercial wave farm was installed in Portugal in early 2008 and was closely followed by similar projects in Spain, the USA and the UK.

FIGURE 1. Location of this research (World of Maps, 2009)

According to research analyst Gouri Nambudripad (Cleantech Group, 2008) with an investment of 500 billion British pounds, 2.000 terra Watt hours (tWh) of electricity could be produced each year from wave power.

However, the technology is still developing and is largely experimental. Developed countries have the capacity to trial wave power installations and may lead the way for long-term adoption in the developing world.

1.2.2 Wind Power

The first modern commercial wind farm was installed in Denmark in 1991. Since then, wind turbines have become more powerful and economical, with offshore installation becoming increasingly popular.

The United Kingdom (with 590 mega watts) is the world leader in terms of installed offshore wind power; closely followed by Denmark (409 MW) and the Netherlands (246 MW).

Countries like China and India have also turned to offshore wind power due to their "large coastlines and vast oceanic areas, which provide excellent conditions for offshore wind power development" (Yu'an, 2009). For such developing countries, offshore power is an excellent solution as no land is required for power generating facilities; and can instead be used for housing and public services.

1.3 ECONOMIC FACTORS

Offshore winds are more uniform in strength and consistency compared with the onshore environment, meaning that more electricity is generated and there is less wear on electricity generating components through varying turbine speeds (Musial and Butterfield, 2004).

The costs associated with the installation and operation of offshore renewable energy can be seen in figure 2. The graphs suggest that wave power is more economical than coal; while offshore wind power is cheaper than coal to install but more expensive to operate.

However, there are scaling issues which have to date militated against significant investment in wave power. Large scale development is currently not feasible due to the power generating capacity of wave buoys – the largest being 150 kilo watts (kW).

The main advantage of offshore wind turbines is that visual and noise impacts are minimised. Wind turbines can be more powerful, while land can remain available for housing or other needs. Noise reduction technologies also don't have to be used in the offshore environment, thus reducing the cost of individual turbines. As the depth of water increases, so does the cost of the structures. However, as land based wind technologies became more widely accepted, production and installation costs reduced significantly (Musial and Butterfield, 2004). So as costs reduce deeper water offshore wind technologies should become increasingly viable.

2. METHOD

2.1 ENERGY DEMAND AND GENERATION

In 2008/2009, Victorians consumed nearly 63 million mega watt hours (MWh) of electricity (ABARE, 2009) meaning over 7 giga watts (GW) of energy had to be generated. In 2019/2020 – the year in which the Australian Government wishes to have 20 per cent of Australia's electricity supply to come from RER – Victoria is predicted to consume 78 million MWh of electricity (ABARE, 2009). So to meet Australia's renewable energy target, approximately 1.8 GW of renewable energy would need to be generated. This could be achieved through:

- approximately 720 of 5 MW wind turbines (running at 50 per cent of their maximum capacity all year round) or,
- approximately 14.900 of 0,15 MW wave buoys (running at 80 per cent of their maximum capacity all year round).

Seasonal wind speeds don't vary much around the study area. For example in the 90-mile beach area, the weakest wind speeds occur in July (13 km/h) and the fastest in November (18,5 km/h); with an annual average wind speed of 15,6 km/h (BoM, 2010). But as energy demand varies greatly throughout the day, more power generating devices may be needed than the amount suggested here. This energy generation scenario for 2020 is planned and visualised in this paper to enable an informed debate on the renewable energy approaches suitable for Victoria.

2.2 SPATIAL ANALYSIS

Key considerations in planning for new energy infrastructure include:

- economic issues – cost and efficiency in relation to; water depth, location of existing infrastructure, wind speed and wave power (Harries et al, 2006; Musial and Butterfield, 2004; Sustainability Victoria, 2009),
- environmental issues – positioning restrictions due to the location of endangered animals and marine national parks (ABCSE, 2004; Thorpe, 1999),
- social issues – concerns in regards to aesthetics, noise and loss of recreation areas (Sustainability Victoria, 2009; Thorpe, 1999).

These factors are all weighted equally, in this initial assessment, and can be mapped and combined using a geographic information system (GIS) in order to determine an optimum solution for offshore RER. The maps created can be used to compare suitable locations and the impacts of the different factors. An interactive decision making system (such as a web-mapping tool like Geoscience Australia's MapConnect; www.ga.gov.au/mapconnect) would also improve the decision making process, allowing layers to be turned on and off for comparison, although this is beyond the scope of this study.

ArcGIS (ESRI, 2009) was used for the analysis but some data the data acquired was less than ideal resolution. For example, the bathymetry data acquired had a 250 metre grid spacing, which may have smoothed some ocean features making them unidentifiable.

2.2.1 Economic Issues

To incorporate the economic issues into the planning process bathymetry, shipping lane, petroleum platform, wind speed and wave power data was collected.

The bathymetry data determines the feasibility of offshore RER and water depths were zoned as follows using (Musial and Butterfield's, 2004) research:

- most suitable (0-30 metres deep),
- possibly suitable (30-50 metres deep),
- future suitability (50-200 metres deep),
- not suitable (greater than 200 metres deep).

Based on (Jeng, 2007) a 1 km exclusion buffer was created around major shipping lanes. Petroleum platforms can provide the infrastructure needed to transport the power created from wind and wave farms to the shore (Jeng, 2007). Many of these are due for decommissioning in Bass Strait, and a 2 km inclusion buffer was created around these as possibly suitable (considering also the dependence on corresponding depth information).

For wind turbines to be viable wind speeds must be over 5 m/s at 80 metres height and wave power required a level of sea wave energy over 20 KW/m^2. From the available wind and wave power maps (Dewha, 2007) all the areas in this study were well above the minimum requirements and so were not included in the ArcMap layers.

2.2.2 Environmental Issues

The environmental factors stated above were incorporated into the planning process by collecting marine national park and endangered animal location information. These areas were given a 1 km buffer and labelled as "Not Suitable", as wind and wave farms cannot be placed in areas of environmental importance (Abcse, 2004).

2.2.3 Social Issues

The main social issues involved with renewable energy implementation (Thorpe, 1999) are aesthetics, noise and loss of recreation areas.

Denmark requires that large-scale wind farms be at least 8 km from shore (Ladenburg and Dubgaard, 2007). This ensures that the visual im-

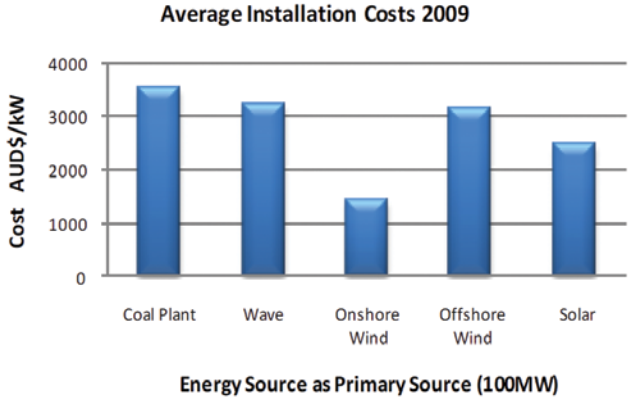

FIGURE 2a. Average installation costs of different energy sources in Australian Dollars (Synder and Kaiser, 2009; Vining and Muetze, 2007)

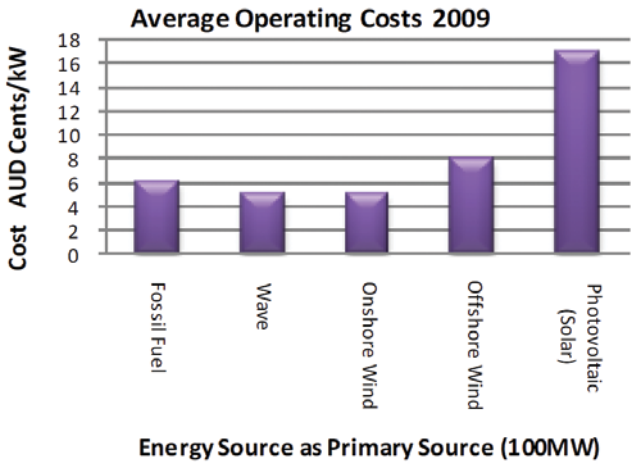

FIGURE 2b. Average operating costs of different energy sources in Australian cents (Synder and Kaiser, 2009; Vining and Muetze, 2007)

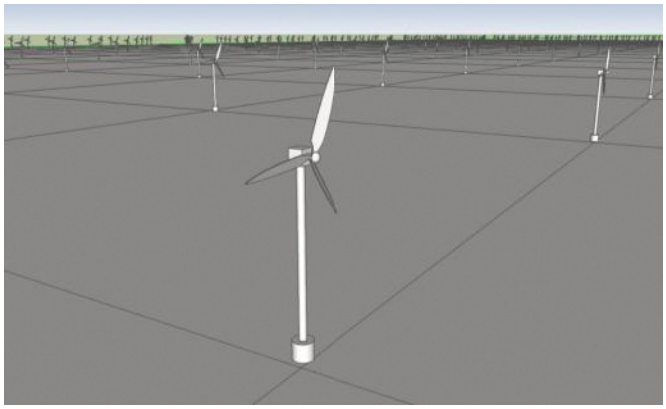

FIGURE 3. Place the wind turbines at the intersection of each grid line

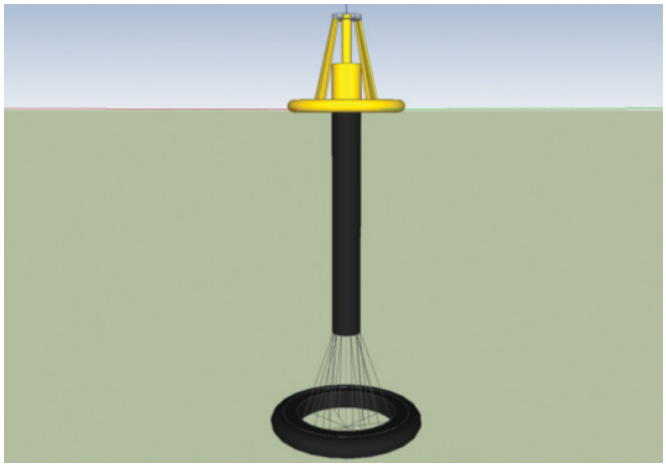

FIGURE 4. Wave power buoy made in Google Sketchup

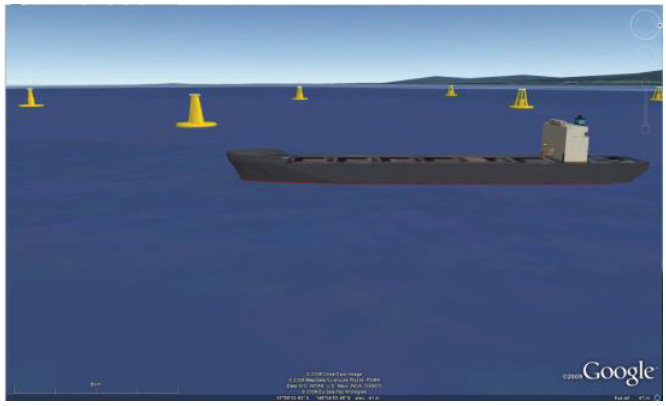

FIGURE 5a. 180x30x18 metre cargo ship – shows scale of wave buoy

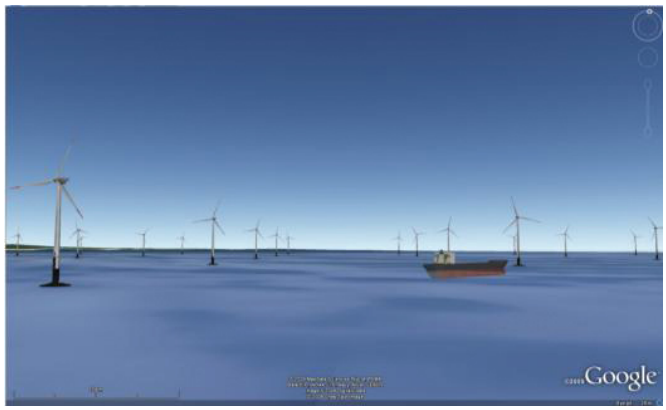

FIGURE 5b. 180x30x18 metre cargo ship – shows scale of wind

pacts of the turbines are minimised. However, this requirement may not be practical in other countries due to the underwater topography and the current technology of offshore wind structures.

Nevertheless, an 8 km exclusion buffer was placed along Victoria's coast. The aesthetics of wave power buoys would not be an issue as they sit only 30 metres above the water level – not visible from 8km.

2.3 VISUALISATION

2.3.1 Building the Wind Farm Model

The wind farm model was constructed from simple shapes using Google Sketchup. A single wind turbine was downloaded from the 3D Google Sketchup Warehouse. Several wind turbines were created by copy and pasting the original turbine. To work out the placement of 100 wind turbines, a 10x10 cell grid, with 600 metre spacing was used. Each wind turbine was placed at the intersection of the grid lines (figure 3), then the grid lines were deleted to prepare the model for insertion into Google Earth.

2.3.2 Building the Wave Farm Model

The wave buoys in the wave farm model were constructed from simple shapes in Google Sketchup using a dimensioned buoy found at (Opt, 2009). The same method used above was used for positioning the wave power buoys.

2.3.3 Importing into Google Earth

Once the wind turbine and wave buoy models were constructed, they were positioned in Google Earth, based on the suitable areas defined using the GIS analysis, to create representations of the new seascapes.

The first step to create the wind and wave farm models in Google Earth was to import an image of the map created in the planning process by "add . image overlay".

Importing the models into Google Earth involved adding the model as a DAE file. This was done by saving the Google Sketchup model as a DAE file, then opening it in Google Earth using "add . model".

Finally, a cargo ship approximately 180 metres long 30 metres wide and 18 metres high was placed in the visualised environment to give the viewer a sense of scale (figure 5).

3. RESULTS AND DISCUSSION

3.1 SPATIAL ANALYSIS

As a result of the application of the data and procedures detailed in section 2.2, figure 6 was produced. It is evident that the 90 Mile Beach area (a coastal region on Victoria's eastern coast) is the most suitable location, with shallow water (water less than 30 metres deep) and petroleum platforms in the area. Further offshore, the water around King Island and Flinders Island is also shown as suitable. However, the threatened fauna and marine national park data obtained does not cover these areas. This would reduce their suitability.

Therefore, the area in eastern Victoria along the 90 mile beach is the focus of the visualisation component of this study.

The main focus of this study was to illustrate how the transition to RER would affect the Victoria's visual environment with an overview visualisation. Thus the spatial analysis in this study was simplified. A more complete analysis would include a view-shed analysis and would use weighted factor combinations.

3.2 VISUALISATION

3.2.1 Different Size Farms

Google Earth was the visualisation tool used in this project, primarily due to its familiarity and connectivity. The models created were easily

positioned in Google Earth and once complete, were effective as a basic visualisation tool. However realism was difficult to achieve as there is a need for elevation and distance to see the extent of the RER impacts. Other software packages could be used to achieve more realistic ground level visualisation as well.

Farms of 100, 200 and 500 wind turbines (at 100 metres height from the ocean surface to the hub) and 100 wave buoys (at 30 metres height from the ocean to the highest point) were visualised from the beach at approximately ground level, with an example shown in figure 7.

It is apparent from this visualisation that the individual wind turbines are very small and would have very limited individual impact on the aesthetics or recreational values of the coast. However, when 100 of them are seen together, particularly in conditions of high visual contrast, the effect is quite noticeable. To what extent this might have significant impact on scenic values is not known in the Australian context. European research has shown that as the number of turbines in a wind farm increases, so does the visual impact (Ladenburg and Dubgaard, 2007). However, further evaluation is necessary, especially with reference to context and comparison with the impact of alternative energy options. At 8 km noise will not be a factor.

As the wave buoys only sit 30 metres above the water and are no closer than 4 kilometres from shore, they do not create any significant visual impacts. At this distance from shore, noise will also not be a factor and recreational activities will not be impacted.

Although wave power is commercially viable, it is not yet suitable for such large-scale projects. With current technology there would not be sufficient space to accommodate the number of wave buoys needed. For every wind turbine installed, 20 wave buoys would be needed to get the equivalent amount of power. However, smaller projects using wave energy to power remote coastal communities appear to be clearly viable.

3.2.2 Wind Power Contribution to 20% RER by 2020

Figure 8 shows three wind farms – with 100, 280 and 400 wind turbines – spread across the extent of the 90 mile beach area. From this viewpoint and at this resolution the turbines are barely noticeable. However this is not a representative view point and conclusions about impact cannot be drawn. What is clear is that there will be few points along this coast which are not within view of a large number of turbines. Coastal activities – swimming, surfing, fishing etc – are not likely to be affected, but the public response to the intrusion (even in the knowledge that this could power over 2 million homes) is problematic.

3.2.3 Local Impacts of Offshore RER

Each of the wind and wave farms was positioned in the areas available derived from the spatial analysis. The most suitable area was confined to the 90 mile beach region. To help answer the question posed above about the impact of such pervasive infrastructure, further visualisations were developed from the beach; 200 metres inland from the beach (the approximate location of the 90 mile beach ocean road) and from urban centres such as Lakes Entrance; Golden Beach; Paradise Beach; and Woodside Beach.

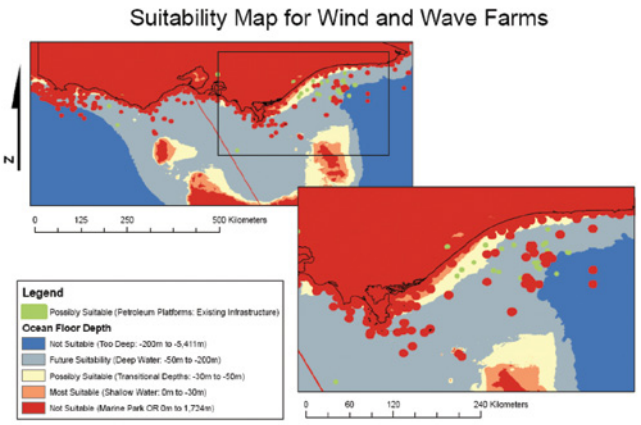

FIGURE 6. Overall suitability map for the location of wind and wave farms off Victoria's coastline with 90 Mile Beach zoom

The wind turbines were most noticeable from the beach. As the wind farms are over 8 kilometres from shore, their visibility varies depending on the weather conditions. (Bishop and Miller, 2007) found significant differences in impact levels according to haze levels and their effect on the contrast between the turbines and their background. As technologies advance, the turbines could be placed in deeper water further offshore and could have increasingly less visual impacts. Even with the cost reducing, putting turbines further from shore remains more expensive. The point at which society will find a balance between these costs and the amenity benefit is unknown. More detailed visualisation and survey research will be needed to address these questions.

A limited evaluation was undertaken in this research. Looking at the visualisations from the 90 mile beach ocean road, there were limited views of the wind farms. The road winds along the coast, going both behind and in front of the sand dunes. There is a lot of trees and scrub on the sand dunes, blocking the view of the ocean the majority of the time.

The visualisations and Google Street View also confirmed there was limited visibility of the wind farms from urban centres. Google Street View was used as a preliminary ground - truthing tool that confirmed the view of the wind turbines would predominantly be blocked by man-made structures, topography or vegetation (figure 9). This being said, Google Street View is a static medium and therefore if this project were to go ahead, thorough ground-truthing would have to be performed by site visits.

3.2.4 Google Earth as a Visualisation Tool

As an evaluation tool for the general public, Google Earth and Google Sketchup are effective, inter-operable and accessible programs.

When looked at from the beach, the wind turbines and water look quite realistic since there is nothing in the scene to take away from the overall effect: such as topography, trees, houses and animals. Various lighting conditions were also looked at in Google Earth and Google Sketchup to enhance the visualisation.

These effects act to enhance the overall visualisation, but in order to evoke a more valid emotional response from those evaluating the visua-

FIGURE 7. 100 wind turbines of the 90 mile beach coast, viewed at 8km from the beach at approximately ground level at sunrise

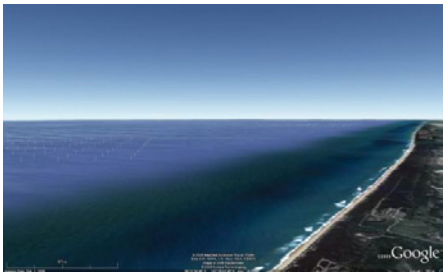

FIGURE 8. 20% RER by 2020 – 720 wind turbines in 3 wind farms

FIGURE 9. A typical view of the beach from the 90 mile beach ocean road (Google Street View)

lisations, specialised modelling programs with more advanced rendering capabilities are necessary. Google Earth provides a capacity for movement of the camera but not movement of the turbine blades. This movement can also have a significant effect on people's affective responses (Bishop and Miller, 2007). Game engines are another software option for providing interactive options in conjunction with dynamic elements in the landscape. Whatever product is being used the ideal is for a user to navigate through the virtual environment at their own pace and leisure.

There were also issues will the relative size of modelled objects in Google Earth. Although the objects were of the correct scale, they appeared to be smaller when imported to Google Earth than in comparable simulations in the literature. This may have been due to the angular field of view. In Google Earth the field of view is 60° and cannot be adjusted; whereas to give perceptual sizes similar to the typical human eye, the field of view size must be around 45°. This difference acts to make the turbines look smaller than in reality. With no field-of-view adjustment available, the only way to correct for perceived size is to somewhat increase the scale of the modelled object before importation into Google Earth. However, this approach can alter the visibility relationship between, for example, turbines and sand dunes, trees or houses. Hence that too can be misleading. Getting scale and visibility both correct is very important to visualisation products for public consumption.

3.3 PROJECT EXTENSION

Further exploration into visual impacts should be done through a community evaluation phase. This could involve RER planning workshops inspecting and evaluating the on-site visualisations and commenting on:

- the amenity of the farms – to help planners understand the implications of renewable energy sites from the ground level,
- the configurations of the wind farms – 100, 200 or 500 turbines in one farm,
- different renewable energy scenarios – 20, 50 or 80 per cent of energy covered by RER by 2020,
- the alternatives to renewable energy – visually, would they prefer a coal fired power station or a wind turbine,
- the broader implications of more renewable energy.

4. CONCLUSION

Planning for RER can begin as a straightforward process. Selecting the correct layers and using a GIS can account for economic, environmental and social issues within one program. The offshore RER can then be visualised using a simple program like Google Earth to get initial insights into the visual effects of the development. More rigorous evaluation of public responses would require the use of software providing for greater user control over the visualisation and dynamic objects.

Although Victoria has a large per capita energy consumption, it was found that it was feasible to provide 20 per cent of total energy production with offshore renewable energy sources. Currently wind power has the capacity to supply a greater load than wave power, although wave power would be generated a higher proportion of the time. Public acceptance may be enhanced by initially supplying smaller communities with RER, then building a base to link to the State (and now national) electricity grid.

However, a large portion of Victoria's coastline would be required to develop such resources and a significant amount of capital investment would be needed for implementation. Existing energy companies still see potential to expand the on-shore renewable capacity and are therefore not currently making any active plans for more expensive offshore installation. Moving such infrastructure offshore would therefore require financial or legislative intervention. At this stage there does not seem to be a willingness to move in this direction. Two factors might change this: (i) improved wave power technology making it a viable large scale alternative, or (ii) rapidly increasing density of on-shore wind farms to the point at which there is public pressure for an off-shore energy mix.

The consistently strong winds over Victoria's oceans, international success, climate change pressure and technological advances seem to indicate that at some future date we will see offshore RER in Victoria.

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