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Submission to the House Standing Committee on Industry and Resources

Inquiry into the development of a non-fossil fuel energy industry in Australia: case study into selected renewable energy sectors

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Executive Summary

Introduction

This submission covers the potential for the widespread development of tidal current energy in Australia, both as a source of wholesale electricity for the market, and as a renewable energy source for the electrolysis process to produce hydrogen.

Tidal current energy refers to the extraction of kinetic energy from significant tidal currents, as opposed to tidal power, which refers to the extraction of potential energy from behind barriers taking advantage of significant tidal ranges.

The Tidal Resource in Australia

Australia has excellent tidal current energy potential off the coast of Northern Australia, from Derby in West Australia, through to Darwin in the Northern Territory and Cape York in Queensland. While the energy potential is believed to be enormous, the actual magnitude of the energy has not been investigated.

Other areas of Australia that show promise for commercial development of tidal energy include the Whitsunday Islands area in Queensland, Bass Strait between Tasmania and Victoria, and Kangaroo Island in South Australia.

Development Potential for Tidal Current Energy

Northern Australia has by far the greatest potential for development of tidal current energy in Australia, though there is only a very small residential demand and intermittent agricultural and industrial load. This would lead to the initial conclusion of a viable renewable resource without a market. However, with the huge potential of this renewable energy source, creative and innovative solutions may be realizable. These could include progressively:

- Developing small amounts of power to provide electrification of remote communities
- Desalination facilities on a local or regional basis.
- Larger power developments to supply specific mines and other commercial/industrial developments, either existing or constructed to tap available mineral or agricultural resources.
- Local or regional transmission to bring power to existing communities, such as Darwin or Cairns.
- Development of large projects with power used in the electrolyse process to produce hydrogen. The gas would be compressed, stored and transported to the load centre, or exported.

Economic Development Opportunities

By far the majority of the structural and equipment components of tidal energy generators would be sourced in Australia. There would be significant employment opportunities for Australians in the design, fabrication, installation and operation of the generation devices. In addition, universities and research institutions would be involved in monitoring and R&D into continuous improvements.

Australian Government Support

In general the Australian Government as well as the State Governments need to continue, but also to increase their regulatory and financial support for the renewable energy sector.

In particular, support is required to investigate and define the resource potential for tidal current energy, encourage the uptake of this technology through funding of demonstration projects and provide a stable market structure for renewables taking into account sustainability, zero emissions and true life cycle costs.

Background Information on Tidal Energy, the Resource and the Technology

Introduction

European governments have established targets for renewable energy and have committed to reducing carbon emissions. A strong need is developing for new renewable energy technologies, with a focus on diversification of energy sources to provide an effective security of supply.

Tidal currents throughout the UK and Europe represent a significant sustainable energy resource and much effort and resources have been allocated to tidal current energy technology R&D over the last few years. The technology is still at an early stage of development with companies and research institutions focused on economically and technically feasible solutions. While other energies sources, such as wind, biomass and small hydro, have established a market niche, tidal current energy technologies are still in the early development phase. However, with increased support from governments, private investors and, more recently, electric utilities, tidal current power is showing every promise of becoming an acceptable form of renewable energy which meets the environmental and commercial criteria of the market place.

Tidal Current Energy

The major benefits of tidal power are that it is non-polluting, reliable and predictable. A drawback of tidal power is that its peak availability often misses peak demand times because of the 12.5-hour cycle of the tides.

For an energy source to be viable and useful in a modern market, it does not necessarily need to be constant, but it must be reliable i.e. a supplier must be able to predict when the supply will be available, and in what quantities, so that it can be matched with other sources to meet the load demand. This poses a problem for many renewable technologies, such as solar, wind and wave, as their output depends on weather conditions which are difficult to accurately predict. Solar can be predicted only minutes ahead, wind for hours ahead and wave for days ahead, with decreasing precision as the forecast time is extended. Being dependent on astronomical forces rather than weather, tidal power is much more predictable than solar, wind or wave power. If the tidal current flow regime at a particular location has been properly studied, its variation over the tidal cycle, excluding the effects of weather, can be predicted with considerable accuracy years to decades in advance. (EPRI 2006)

The tides are generated by the rotation of the earth within the gravitational fields of the moon and sun. The relative motion of these bodies causes the surface of the oceans to be raised and lowered periodically, according to the following interacting harmonic cycles:

A half-day cycle: due to the rotation of the earth within the gravitational field of the moon, resulting in a period of 12 hours 25 minutes between successive high tides

A 14-day cycle: resulting from superposition of the gravitational fields of the moon and sun. At new moon and full moon, the sun's gravitational field reinforces that of the moon, resulting in maximum (spring) tides. At quarter phases of the moon, the sun's attraction partially cancels that of the moon, resulting in minimum (neap) tides. The range of a spring tide is typically about twice that of a neap tide

Other cycles, of lesser significance, arise from the eccentric nature of the earth's orbit around the sun and the moon's orbit around the earth, and the tilt of the moon's orbital plan relative to the earth's axis of rotation.

The gravitational forces of the sun and the moon create two "bulges" in the earth's oceans: one closest to the moon, and other on the opposite side of the globe. These "bulges" result in the two tides (high water to low water sequence) a day, the dominant tidal pattern in most of the world's oceans.

The solar tidal bulge is only 46% as high as the lunar tidal bulge. While the lunar bulge migrates around the Earth once every 27 days; the solar bulge migrates around the Earth once every day. As the lunar bulge moves exactly into and then 90° out of phase with the solar bulge, this gives rise to spring and neap tides, respectively, (Figure 1).

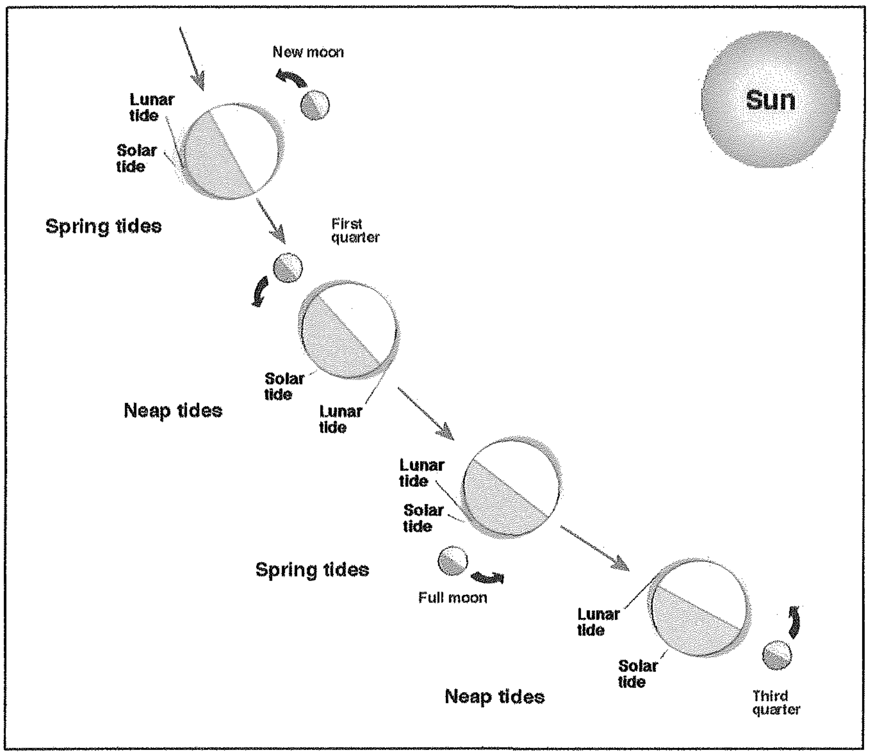

Figure 1. Sun's Influence on Earth-Moon Tidal Forces (EPRI 2006)

Resources in Australia

A review of the literature indicates that very little information is publicly available on tidal energy resources in Australia. While individual government agencies and private companies may have collected such data, this lack of information is a major impediment for a rapid take up of the technology.

One map, obtained from the National Tidal Centre, Australian Bureau of Meteorology (2005) is shown on Figure 2. This indicates that excellent tidal current energy potential can be found off the coast of Northern Australia, from Derby in West Australia, through Darwin in the Northern Territories to Cape York in Queensland. While the energy potential is believed to be enormous, the actual magnitude of the energy has not been investigated.

Other areas of Australia that show promise for commercial development of tidal energy include, the Whitsunday Islands area in Queensland, Bass Strait between Tasmania and Victoria, and Kangaroo Island in South Australia.

Tidal power is all about tidal currents; their magnitude, direction and variability. Crucial for the technologies and not well understood is the fact that currents can vary rapidly over a few hundred meters. Variability depends on a number of factors, including the channel and sea floor geometry, and materials. Therefore when considering an area for potential as a tidal current energy resource, the most important task is to produce a simulation model with a high grid resolution that will provide sufficient data to allow for detailed evaluation of various siting options. Available information can be used to ground truth the model, but it will probably need to be verified in the "sweet spots" by surface current and Doppler vertical profile measurements.

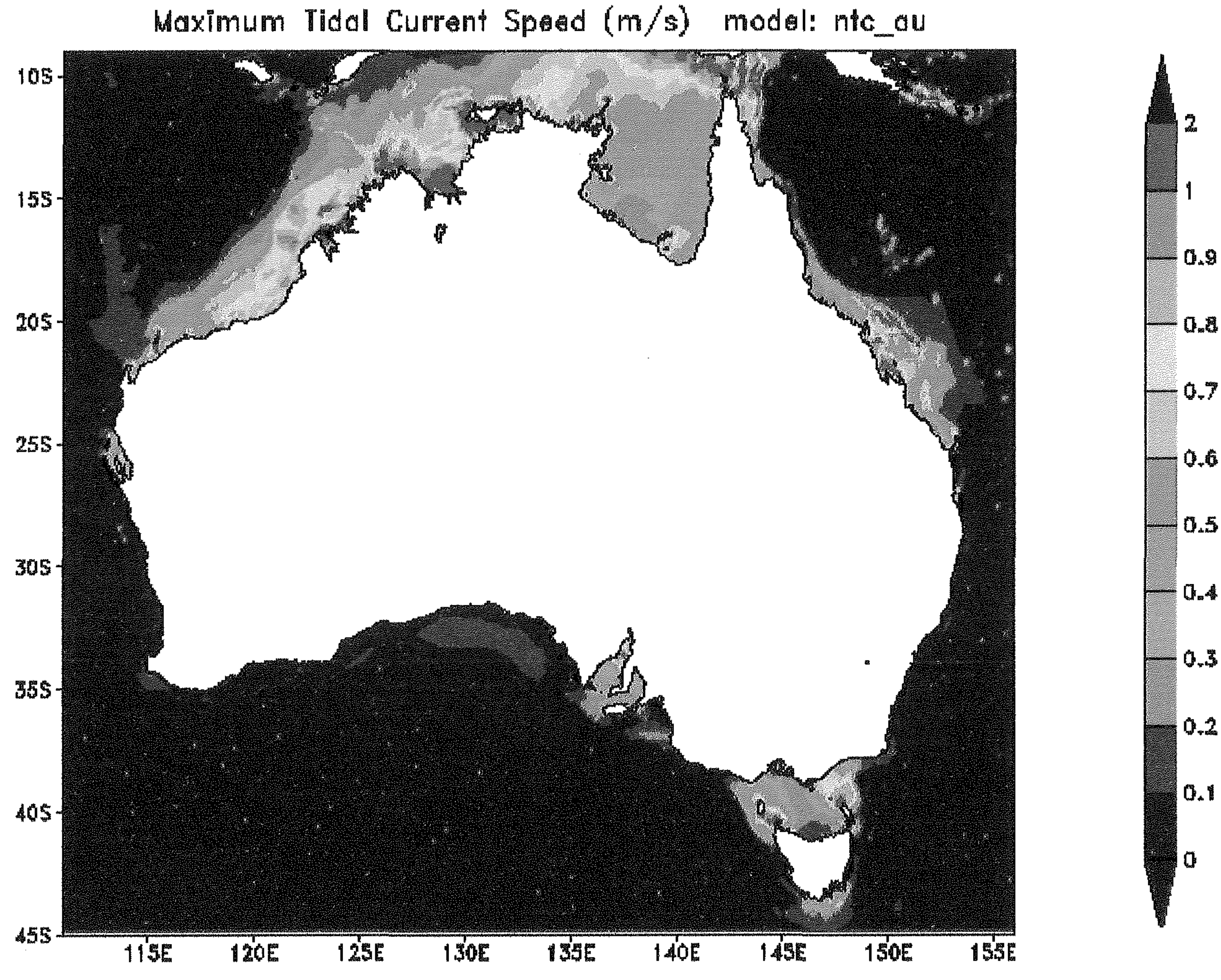

Figure 2. Tidal Energy Resources in Australia (BOM 2005)

Once the model is produced and verified, arrays of tidal generation devices can be "laid out", based on the input received from technology providers. As part of the development of a simulation model, there is the need to estimate the maximum overall tidal current energy that can be extracted from the area without unacceptable environmental impacts. There is a good analogy with wind farm analysis and siting, which uses accepted commercial models such as WASP. While there is no such tidal farm model yet, it will not be long in coming as soon as significant development occurs.

Tidal Energy Technologies

The potential for Government funding and the prospect of a new commercial technology has brought many talented scientists, engineers and financiers together to develop their concepts and ideas. Unfortunately many do not fully appreciate the rigours of a harsh, unforgiving marine environment and, to date, successful prototypes have been developed by companies with solid marine engineering experience, particularly in the offshore oil and gas sector. Presently, technologies are being developed that use monopile and gravity foundations, have either ducted or unducted horizontal axis units, are comprised of tidal fences, based on venturi principles, etc. Like wind energy technology development from 20 years ago, only one or two concepts will survive to commercial viability.

Lunar Energy

Lunar Energy Limited (Lunar Energy), based in the UK, commissioned Rotech Engineering Limited (Rotech) of Aberdeen, Scotland to develop the technology, known as the Rotech Tidal Turbine (RTT). The RTT has considerable benefits over other tidal stream devices as Lunar Energy has focused the development on generating electricity for the commercial market, with a target cost of 45-60US$/kWh. The RTT deliberately incorporates known, proven and relatively simple technology, keeping operation and maintenance costs to a minimum and speeding up the time to commercialise.

All development activity has been commercially focused. Lunar Energy's philosophy has been not to 'reinvent the wheel' but to collaborate with partners who bring commercially proven design, components, or procedures to the project. Several such companies are now collaborating with or contracted to the 1MW demonstration project, to be deployed at the European Marine Energy Centre (EMEC) in the Orkney Islands, Scotland in 2008. These include: Atkins (structural design); ABB (generators); Hägglands and Bosch Rexroth (hydraulic pumps, motors and circuits); SKF (bearings); Garrad Hassan (control algorithms and hardware) and Wichita Clutch (brake system).

The Rotech Tidal Turbine (RTT)

The RTT is a sub sea device, comprised of a ducted rotor, which extracts the tidal-flow energy and drives commercially available hydraulic pumps and motors, which in turn drive a commercially available generator. (Figure 3). Using hydraulics means that there is no need for a conventional mechanical gearbox, and that all the electrical components can be located in an airtight chamber with no rotary seals; this having the advantage that the device needs infrequent servicing. The configuration prevents water leaking into the generation compartment and hydraulic oil leaking out.

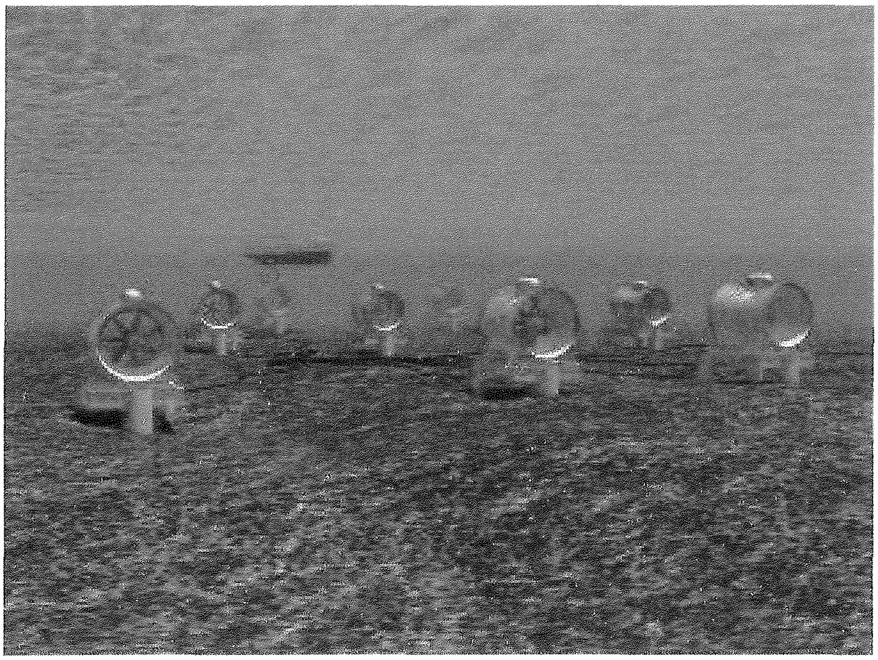

Figure 3. Schematic of Lunar Energy's RTT Tidal Energy Array

The ducted rotor is bi-directional and the turbine blades are symmetrical. The duct makes the device insensitive to off-axis flow of up to 30 degrees. There is therefore no need for a yawing mechanism to rotate the device at the turn of each tide and to keep it pointing directly into the flow, a complicated mechanism that is expensive to design, build and maintain. There is also no need for a blade pitch control. The venturi shape of the duct accelerates water through the turbine, increasing the energy that can be captured by turbine blades of a given diameter. This keeps the size of the complex moving components to a minimum, thus reducing manufacturing and O&M costs. The turbine is designed to rotate at around 20 rpm.

Tidal turbines need to survive in a technically challenging marine environment. Mechanical devices do not fare well when exposed to seawater, and electrical equipment is averse to any moisture. Tidal turbines need to be installed in areas with high current velocities and, because of the high density of water, tidal turbines are exposed to large forces both from the movement of the tides and from the effects of surface waves. Because of the costs associated with accessing off shore devices, the frequency of servicing them must be kept to a minimum throughout the design life of over 25 years.

Atkins Engineering used standard offshore oil & gas industry design codes to design the duct and foundations. A three point-of-contact gravity foundation concept was selected to both ensure that the base has no instability by allowing for local undulations of the seabed, and also to improve the economics by using steel cans instead of a concrete box structure. The overall weight required to prevent the unit from sliding across the seabed comes from inexpensive ballast in the cavity spaces in the base structure or in the cans in the pre-commercial design. The duct is now load-bearing and self supporting. The removable cassette design has remained the same throughout the design iterations. The dimensions of the 1 MW EMEC unit are: a 15 metre duct intake diameter, the base of which stands 8 metres above the seabed: a 10 metre turbine diameter; and a duct length of 25 metres.

Operation & Maintenance

The installation and operation and maintenance processes continue to evolve. The procedure to install the 1MW device at EMEC will be in a single heavy-lift, and will require little or no seabed preparation. For future devices, the design will likely incorporate internal buoyancy, considerably reducing the initial lift. All the moving parts and electrical components are contained in the modular central cassette which can be removed, using proven North Sea remote extraction techniques, without the routine need for divers or ROVs. Once the cassette is removed, it is taken to shore for servicing and replaced by another unit. This keeps the generation downtime to an absolute minimum and means that there is no expensive off-shore servicing needed. All the electrical and moving parts are contained in the cassette and when it is removed, only the steel structure remains. The hermetically sealed container housing all the generation equipment sits on top of the cassette.

The RTT is designed to be left unattended for many years at a time. This is possible because the RTT is inherently simple and reliable; the components operate at the atmospheric pressure for which they were designed, and are housed in a leak-free environment. The operations and maintenance approach for the RTT is predictive rather than reactive, with periodic servicing initially scheduled at only once every 4 years a plan endorsed by all the component manufacturers. Since the devices can be installed with little or no seabed preparation, the process can be completed in less than 24 hours. Removing the cassette for servicing can be done during one slack tide period. Shipping cost for installation and servicing is therefore kept to a minimum.

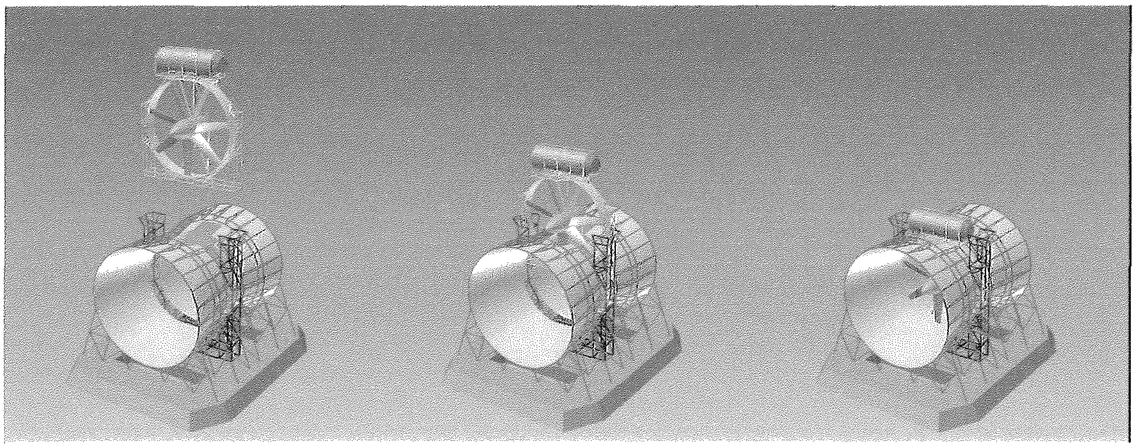

Figure 4 Remote Removal and Replacement of the Centre Cassette for Routine Maintenance

Environmental Considerations

Because the RTT is invisible from the surface and is installed in deep water, with about 20m clearance above the top of the unit in the case of the 1MW unit at EMEC, it will pose little, if any, impact on shipping or marine usage. A UK Department of Trade and Industry feasibility study for the development of tidal turbines in Scotland concluded that the environmental impact on fishing, transport routes, Ministry of Defence property and other environmental factors would be minimal. However, the UK Environment Agency in its Position Statement, "Generating Electricity from Tidal Power" (2005) stated that *tidal power technologies could play an important role in reaching renewable energy targets and limiting climate change.*

Lunar Energy commissioned an environmental impact assessment by The Robert Gordon University. The report predicted that the RTT would have a limited effect on marine life and only in a localised area of the seabed and concluded: *Overall with respect to present knowledge it can be concluded that the system in question has no significant detrimental environmental impact.*

In a policy statement on marine renewables, the Scottish Natural Heritage concluded that *tidal stream devices would have less impact than shoreline wave devices, offshore wind farms or tidal barrages.*

The issues of bio-fouling and anti-fouling coatings have been considered with advice from QinetiQ, formerly the UK Defence Research Establishment. It is expected that most of the RTT will not require anti-fouling coatings, though that may depend on specific site conditions. The plan is to remove the RTT from the seabed at the end of its useful life.

Monitoring

Lunar Energy is working closely with EMEC to produce a robust monitoring package that will clearly demonstrate the effect of the RTT on the local environment. This will include installing video monitoring equipment on the unit to record the flow though the duct and the turbine. Lunar Energy is currently in talks with manufacturers of advanced, highly sophisticated acoustic monitoring devices that would track the movements of marine life around the unit.

Development Scenarios

The UK Government Department of Trade and Industry (DTI) in the UK, has supported tidal energy technology development through a broader ocean energy program with the expected result that the first economic deployments will take place in the UK. The drivers for this government support have been energy security and economic development to partially offset the development maturity of the North Sea Oil and Gas sector. As part of the support, the European Marine Energy Centre (EMEC) has been set up in the Orkney Isles, just north of mainland Scotland, to test, monitor and validate tidal current energy devices. Lunar Energy's RTT 1000 will be deployed there in 2008.

The Electric Power Research Institute (EPRI), a USA-based research organization, funded by over 100 utility and other organizations with interests in the electrical generation sector, has conducted a far reaching assessment of tidal stream technology (Bedard 2006). The study included technology assessment, the identification of pilot development sites in the 7 States and Provinces in the USA and Canada with a significant tidal stream resource, and matching of chosen technologies to those sites. The Lunar Energy RTT was identified as one of only 2 technologies currently viable for transmission-level projects and was identified as ideal technology to be developed in 5 of the 7 EPRI sites (the other 2 sites were pre-selected before the study started and were considered too shallow for the RTT and for significant power extraction).

The Canadian Hydraulics Centre (CHC), working on behalf of National Research Council Canada, have recently prepared an Inventory of Canadian Marine Renewable Energy Resources (Cornett 2006). This shows that Canada is extremely well-endowed with tidal energy potential with over 40,000MW available for exploitation. While over 30,000MW of this potential is in Arctic regions, which will no doubt preclude development for many years, both British Columbia and Nova Scotia/New Brunswick have excellent opportunities for a rapid uptake of the technology. In British Columbia, on Canada's west coast, the resource is concentrated in the straits between Vancouver Island and the mainland. While the tidal range is quite modest in this area, differences in tidal cycle between the north and south ends of the Island result in tidal currents of significant magnitude. In the Bay of Fundy in Eastern Canada, a huge tidal range cycling into the upper reaches, with narrowing channels and shallower depths, also results in tidal currents of significant magnitude. In both areas, the potential is estimated to be in the order of 3000MW.

Based on technology development in the UK and elsewhere, it is estimated that commercial tidal farms will be developed starting in 2009/10. By 2013 to 2015 many hundreds of MW's will be deployed worldwide at energy costs competitive with other attractive forms of renewable energy (hydropower and wind energy).

The development scenarios for Australia show potential for significant opportunity. There appear to be excellent resources in many regions, there is an appetite for cost effective renewable energy, and the required manufacturing capability and infrastructure is in place. The key to a successful development scenario is to investigate the resource thoroughly, as it can be quite variable locally, and to start building pilot or demonstration projects. It is most important that the demonstration projects be based on technologies having a sound background in the marine environment, and that they be of a type and size suitable for utility scale development (MW's not kW's).

Summary & Conclusions

New technology for the conversion of tidal current energy to electricity is one of the newest forms of renewable energy being developed with significant government support in the UK. Demonstration projects will prove the technical and market feasibility in the next year or so and commercial deployments will abound within the next five years. Resource studies have already proven major resource potential in the UK, Europe and North America.

There are significant opportunities for tidal energy to be a major source of renewable energy in Australia, with its good tidal resource, demand for energy and manufacturing and fabrication capability. A considerable effort is required to prove the resource and build market demonstration projects to take advantage of this opportunity.

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