Non-technical barriers to wave energy in Europe

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1 Executive summary

This document describes the non-technical barriers which the wave energy industry will encounter after the prototype research and development phase is complete. It is quite possible, that although the prototype successfully produces power required, it may fail to be fabricated or deployed due to the extraneous factors which will be detailed here.

Non-technical barriers exist for all technologies, each facing its own unique combinations. In the case of wave energy converters (WEC), there will be many shared barriers with other renewable energy sources, as well as those unique to it.

Logistics

WECs are marine devices, which require special fabrication process. Production will need specialised construction environments, namely shipyards and a skilled labour force familiar with marine construction. Both these sources have been in decline in Europe for the last 50 years. It is possible that a local developer may not be able to construct the devices in the country of design, and may have to outsource to overseas plants. The lack of local shipyards and skilled labour will also impact on installation and maintenance of the devices.

Choice of location 'hotspots' for the wave farm will be crucial for maximum gain and competition for leases are expected to be intense. However, developers will be limited in choice due to extraneous factors such as suitable ports for launch and maintenance, and closeness to major population centres. Furthermore, the weather window period for possible installation and maintenance times can severely delay time schedules and ultimately impact on costs.

The final logistical barrier facing developers will be the grid connection. This will comprise both practical problems of finding suitable connections to closest gird nodes, and the financial obligations of the developer to upgrade the local infrastructure downstream (if required).

Regulatory

The third major area which can pose problems for a developer is the regulatory requirements. The most important of these will be the application for permits and leases both for testing as well as permanent deployment. Some jurisdictions are trying to streamline the process with ‘one-stop’ application bureaus. However the majority of countries still require multiple departments to be applied to, which can take years to compete.

Each government has their own favoured method of promoting and supporting wave energy development, ranging from fixed tariffs, credits and obligations. Each have their advantages and disadvantages, however a major risk involved is that a project’s viability can be dependant on them, and their withdrawal due to economic downturn or change in government can jeopardise a project.

Environmental

The final major barrier is the environmental issues. These comprise concerns for local flora and fauna due to the wave farm installation and deployment, as well as disruption of local fisheries and recreation. These issues are emotive and will need to be sensitively handled. More research will need to be done to prove that no harm is done to the environment, and there is a hope that wave farms may actually benefit local fisheries. Finally, public concern for visual and noise disruption need to be addressed.

Financing

Capital costs can be the most decisive factor in determining a project's viability, and is a common barrier to all fledgling high initial cost projects. The rising cost of materials, mainly steel, will be the most important factor, making both the fabrication and the sale of the product more expensive. Coincidental are the rising cost of labour and equipment occurring in these inflationary times. In order to mitigate these factors, comprehensive early financial analysis needs to be conducted to forecast these eventualities and factor them into the business plan.

The number of wave energy device companies which are designing and testing WEC at the moment is currently around the 50 mark. Only one or at most a few designs will be ultimately adopted. With such high risk inherent in the design of these devices and thus in the companies that design them, investors and venture capitalists will be reluctant to place large sums of venture capital into projects, especially in today's low liquidity environment.

In conclusion, there are many non-technical barriers that the wave energy industry will need to address in order to successfully complete a development project. None of the barriers are insurmountable, but the number of them can be daunting. State support for wave energy can assist in all these areas with the proposition of the ‘one stop’ application process.

2 Introduction

The European Commission's renewable energy roadmap identifies wave energy as an important element in the EU's future overall energy mix. However there are a number of obstacles that needs to be overcome if wave energy is to fulfil its potential and compete with other more mature technologies. This report will analyse the barriers to wave energy from a generic perspective, with an annex at the end examining sample countries on how they have addressed these barriers.

From an investment perspective, the wave energy converter (WEC) industry can be split into two main phases:

1. Research and development phase.
2. Production and commercial development phase.

Each phase will encounter barriers to its progress. This report will identify the barriers which are exclusively pertinent to each phase of development, and also barriers which are common to both.

The barriers for each development phase will be discussed under the 4 following categories:

- Logistical
- Regulatory
- Environmental/ local
- Financial

This report will discuss each of these problems from the point of view of a start-up company setting up in Ireland, which would be designing the IP, producing the product and installing the device for sale of electricity to the grid.

3 Logistical barriers

3.1 Construction and installation

There are many practical problems that will have to overcome in the construction and deployment of WEC. The following are a list of concerns needing attention.

3.1.1 Shipyards and skilled workforce

WEC devices will more than likely need to be built in shipyards (Previsic 2004), where existing maritime construction expertise and facilities exist. So far, most of the WEC prototypes have been constructed in local shipyards e.g. OE buoy in Cork Dockyards[1], Wavebob in Harland and Wolf, Belfast[2] and the 'Might Whale' in the Ishikawajima Harima shipyards in Japan[3]. The steel sections and power conversion modules of Pelamis are constructed to Scotland, but are assembled at the site of deployment e.g. Peniche shipyards in Portugal[4] and Hunters Bay shipyards in San Francisco (Previsic 2004). Over the last two decades most of Europe's existing shipyards have closed down or drastically curtailed operations (Stopford 1997). Large-scale production of WEC devices in European shipyards may not be available. Even if the choice were available, overseas competing shipyards in Poland, Korea and China, could feasibly outbid local contractors even factoring in shipping costs, due to lower overseas wages and cost of materials (Salonen, Gabrielsson, et al. 2006). There is good news for European wave energy construction: Martifer Enterprises has bought a small Portuguese shipbuilding yard for the exclusive purpose of building wave energy machines[5], and could be the beginning of a dedicated ocean energy construction sector in Europe.

3.1.2 Workforce for Installation, maintenance, cables and mooring

Installation and maintenance of the WEC, cables and moorings requires a skilled workforce and facilities. Specialised tugs companies are required to toe the WECs to site, experienced underwater divers are required for deployment and maintenance of

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[1] http://casey.eurhost.net/uploads/Pressrelease.pdf
[2] http://www.cdnn.info/news/science/sc070302.html
[3] http://www.nsf.gov/pubs/1998/int9815/ssr9809.doc
[4] http://www.cdnn.info/news/science/sc070302.html
[5] http://www.martifer.pt/InvestorRelations/EN/20080102InfoPrivEN.pdf

WEC and moorings, and specialised cable laying services for the electricity connector cable. A local skilled workforce may not available in the location for construction and deployment, or may be in limited supply due to competing technologies such as offshore wind. An example of this situation was when Seagen's tidal turbine was supposed to have been installed by a local specialised tug early 2008. A higher offer made by the Thames off-shore wind project for the tug services left Seagen without a boat for installation (ReNews 2008). It took another 3 months for another contractor to be sourced, at a far higher cost, for the single installation.

3.1.3 Supply chain bottleneck

A supply chain bottleneck is a phenomenon by which the capacity of an entire system is severely limited by the availability of a single component. The uncertainty of supply chain dynamics is a risk for any technology to overcome. With regard WEC production, at the bottom of the scale are the producers of raw materials e.g. steel, followed by the manufactures of ball bearings, hinges and corrosion resistant paint. Finally, are the larger component manufactures such as generators, hydraulics, cable and moorings. Delays or interruptions from any of the stages can put the entire project at risk. The availability of a national and international database of suppliers and relevant associations will be of value to remedy this concern. Finally, small countries that have a high dependency on imported products, such as Ireland, are more susceptible to supply bottlenecks than larger economies with a wider industrial base, such as Portugal.

3.1.4 Demand bottleneck

Ambitious plans to install GWs of WEC by 2020 could be at risk of being derailed by a critical demand bottleneck. Supply can be met from either local production or imports.

A country intending to become a manufacturer or WECs with no traditional industrial marine base, is challenging. For example, if Ireland is to reach its quota of 10% of its energy supplied by wave energy by 2020[6], it is estimated that approximately one Pelamis will need to be produced every week for the next 10 years. Local construction facilities in Ireland at present do not have this production capacity.

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[6] http://historical-debates.oireachtas.ie/D/0641/D.0641.200711150017.html

The alternative to local production is importation. In the wind energy industry, the German engineering giant Siemens reported in 2008 that it has a four-year backlog of orders for its largest machines[7]. Small European economies and supply companies will fall to the back of the queue in preference to larger customers such as the US and China.

3.1.5 Weather window for installation and maintenance

Perhaps one of the most important hidden barriers to both WEC R&D and production will the restricted time periods or 'weather windows' within which WEC will need be installed and maintained. The winter months are in general unavailable due to the prevalence of extreme weather conditions. This leaves approximately 6 months of the year that are reliably available (Thorpe 1999). However, this time period can still prove limiting. Pelamis Wave energy is a typical example of a company that experienced time window difficulties. In 2007, launch of the device in Portuguese was delayed due to problems with the flotation systems as well as some of the underwater connections (Westwood and Hopwood 2008). The summer period of 2007 was unseasonably stormy, and thus it took another 12 months before suitable weather conditions were available for redeployment of the WEC, which was in Autumn 2008. The availability of detailed wind and wave data, such as the North European storm study will be essential for companies to accurately predict weather windows for their WEC deployments (Bierbooms 2001).

3.1.6 Management/ financial personnel

WEC fabrication and development is a new and specialised industry. It is predicted that skilled management and financial experts in the area will be few and difficult to find as the industry expands.

[7] http://www.independent.co.uk/news/business/news/backlogs-threaten-government-targets-for-renewable-energy-782648.html

3.2 Site location

Although the coastal area around the Irish coast is vast, practical sites for wave energy farms will be limited by many extraneous factors. This section will review these factors.

3.2.1 'Hotspot' sites

The transformation of waves from deep offshore, across the continental slope and localised bathymetry, has been found by studies of coastal dynamics to have significant effects upon ocean wave characteristics (swell height, energy flux, period, direction) at specific coastal locations (Frazerhurst 2006). The analysis of the interaction of ocean waves and local bathymetry is necessary order to identify 'hotspot' locations, i.e. premium wave energy locations for ocean wave energy conversion.

From a develops point of view, 'hotspot' assessment should also factor in closeness to coast, closeness to nearest port as well as closeness to nearest grid connection. For example, cable costs are calculated on a per kilometre basis, with quotes ranging from €0.3 to €1.3M/km (ESBI 2005, Marine Institute and ESBI 2008). On this basis, only hotspots that are within a 5km distance from the shore can be currently considered, unless the price of cabling reduces in the future.

Reports can either be presented in layered GIS studies, which are expensive, or locations rated on a weighting system, such as used to chose the Belmullet test site (Ryan 2007).

3.2.2 Transport to launch site

As discussed in a previous section, WECS will either be produced locally in one of a country's main port ship yards, or will be delivered by an overseas manufacture to that main port. From there, the WEC will need various forms of transport to be delivered to their deployment site. Ideally, the deployment site will be within tug boat radius of the port. The advantage of this method is that the WEC can be transported as a finished unit. Logistical problems to be tackled include:

- Tug boat availability.
- Distance travelled by tug boat.

If the distance to site is too far, the WEC will need to be transported overland. The disadvantage of this method is that the WEC would more than likely need to be transported in parts, as the transport of the finished unit would be too large for most national roads. Problems with this method are that most wave energy locations are in remote locations, with a predominance of secondary or minor roads, which are not suitable for transportation of large goods (Hau 2006). Moreover, the process would necessitate final assembly of WEC unit at the final launch port, requiring an assembly plant and skilled personnel.

3.2.3 Suitable port for launch and servicing

The choice of local port for final launch of the WEC will be a very important decision. Factors that will need to be considered and weighted up include:

- Closeness to the 'hotspot site'.
- Shelter from prevailing winds and storms.
- Consideration of tidal ranges and currents.
- Sufficient size and facilities to cater for WEC device handling and tug boats.
- Local and available skilled workforce.
- Road infrastructure cable for delivery of devices to port.

3.2.4 Population centre

Ideally, power production is located as close as possible to population centres to reduce energy loss via cable transmission. In the majority of northern European cases, the premium 'hotspot' sites are in remote locations, far from population centre. Analysis will be necessary to ascertain the economic optimum location taking both these factors into account.

3.2.5 Other factors

Other planning considerations which may temper ideal locations are:

- Existing shipping lanes.
- Ports – an exit clearance of 135 degrees is required from a port mouth.
- Existing underwater cables which have precedence over new developments.
- Proposed oil and gas exploration fields.

3.3 Grid connection

3.3.1 Connection fees

Connection charges vary from country to country and network to network. Charging methods are termed either ‘deep connection’ or ‘shallow connection’. For ‘deep connection’, developers pay for the majority of connection costs upfront and any ‘downstream’ upgrades required to the network. ‘Shallow connection’ charges are defined as where a government or network takes on a certain percentage of the costs and the developer pays for on going costs of connection to the network (New Zealand 2008). From a developer’s perspective, countries with a ‘shallow’ connection charge policy are the most attractive.

3.3.2 Node connection

A developer has to pay for any onshore cabling connecting the WEC farm to the national grid. A moderate size wave farm will require a grid infrastructure of at least 110kV, via the ‘distributed’ network. 110kV grid infrastructure is closest to the coast where there are major population centres. In remote locations, where the majority of northern European WEC farms will be, the 110kV network will be 20-50km from the coast.

Larger wave farms will have to connect to the ‘centralised’, high voltage network, which is usually located further away from the coastal wave energy site. This will involve a dedicated high voltage cable from network to the shore, incurring higher costs.

3.3.3 Planning permission

Cabling from shore to connector node will require normal planning criteria as per wind farms. Thus planning applications to local councils involving environment, visual and safety impact statements have to be prepared and submitted.

3.4 Health and safety

Health/safety has become a costly issue for today's energy companies. The rules have become both extensive and are rigorously patrolled. Lack of observation is costly due to the litigious nature of modern society, as well as judicial severity from the state.
A list of health and safety issues is presented in the 19 page Irish Marine Institutes (2008) safety report for the Galway bay test site. These include:

- Ocean monitoring to be carried out from vessels only. Monitoring buoys can no longer be moored in isolation, but must be manually supervised and withdrawn when finished on the day. This stipulation has made routine monitoring both labour intensive and costly exercise.
- Boats to have flashing lights and radar reflectors.
- Towing eyes for ropes.
- Alarm systems

3.5 Insurance

Recent ocean energy accidents have created major concern in the insurance industry. An example was the sinking of the Aquabuoy (Finnevera), in 2008[8] (reference to be obtained). The lost devices were deemed technically to be a hazard to ocean vessels as well as damaging to local fisheries. The EPRI project in California priced annual insurance as 2% of initial capital costs (Previsic 2004).

4 Regulatory/ government barriers

4.1 Regulations and permits

The difficulty in obtaining the necessary permits for wave energy deployment can be the largest barrier to developers in some jurisdictions. Procedures can vary dramatically from one country to another, and between regions or states within a country. Difficulties mainly arise from the multitude of administrative departments that may need to be applied to, and the resultant time required for their approval.

[8] http://mendocoastcurrent.wordpress.com/2008/08/26/rescued-sunken-wave-energy-buoy-calls-for-better-infrastructure/

A wave energy project in west coast of US required 26 federal, state and local permits[9], in addition to public consultation. An AWS project in Portugal filed permit applications in 10 public departments (Sarmento, Neumann, et al. 2005).

The more permits required and authorities to apply to, the greater the time involved. An example of how the time taken for permit application can vary was reported by Renewable Energy World (2008) where permission for a small hydro project in Austria was obtained in 12 months, and in Portugal took 12 years.

Attempts by various government to overcome barriers in permits applications are the 'one-stop' programs in the US (Washington State House of Representatives 2008) and Ireland[10], where all the ocean energy permits are processed through the one organisation/department. This method can potentially speed the application process significantly, although has yet to be applied in any jurisdiction.

4.2 Wave energy strategies and targets

Strategies and targets set by local governing bodies for wave energy development are essential motors for R&D, development and production. Strategies are based on the following corner stones:

- To provide financial incentive and support schemes for research in industry and academia.
- To provide financial incentive and support schemes for product development in industry.
- To provide the infrastructure for testing the devices (tank, benign and pre-commercial scale test sites).
- Power purchase support schemes for electricity produced by ocean energy.

Targets are also an important avenue to focus national goals into a definite time frame. Although many targets these days appear somewhat ambitious, many are still achieved, and it could be argued that overly ambitious targets are ultimately more successful than what appears to be more realistic but conservative targets.

[9] http://mendocoastcurrent.wordpress.com/2008/04/23/green-wave-to-harvest-wave-power-in-slo-mendocino/

[10] Ocean Energy development unit: http://www.sei.ie/index.asp?locID=1692&docID=-1

4.2.1 Testing infrastructure

The high cost of testing prototype devices may prove an insurmountable barrier for wave energy development. Governments can assist the technology development by provide testing zones with the essential infrastructure provided. This consists mainly of undersea cabling and grid connection facilities, as well as a variety of mooring mechanisms for the various types of devices. Besides enabling shared costs, the test facility would bypass other barriers such as permits applications, interconnection, resource data collection and monitoring.

4.3 Price support schemes and incentives

There is much debate at present concerning appropriate electricity supplier support schemes to stimulate growth in the wave energy sector. There is an array of schemes which developers can avail of, with varying degrees of effectiveness. The bewildering variety and complexity of schemes can prove daunting to a developer as to which is the most appropriate. There is much current debate as to which scheme is the most effective in promoting WEC technology.

4.3.1 Fixed tariff rates (FIT)

Fixed tariff rates are gaining universal consent as the most successful method to stimulate RE development. The main proponents of the scheme are Germany and Spain (Porter 2006), and has resulted in a RE boom in those respective states, almost exclusively in on-shore large wind and PV.

Ocean energy has inherently large initial costs, with the addition of higher risk as an emerging technology. A successful FIT will have to very high to provide the returns necessary to attract financiers and venture capitalists to invest in the industry. Future cost of electricity for wave energy is quoted to be around €0.12-20/kWh. FITs will need to be in the order of €0.20-30/kWh or higher (if the costs of steel increase).

4.3.2 Renewable Portfolio Standard (RPS)

The Renewable Portfolio Standard (RPS), is a quota system where a government place an obligation on either an electricity supply company or on consumers (albeit usually manifested through their supply company) to source a specified fraction of their electricity from renewable energy sources (Espey 2001). Companies which fail to meet the obligation are required to pay a penalty price for every unit of electricity by which they fall short of their obligation. The mechanism acts to create a market for RE electricity, allowing competition amongst renewable generators to meet the needs of that market. Concerns about RPS/ROC are that the cost is effectively paid by electricity consumers, since most electricity suppliers pass this cost on as a small increase in the tariff for the electricity they sell. Moreover, the scheme tends to favour established RE producers and may prohibit marginal technologies, such as wave energy, from getting established (Connor 2007). In order to provide balance with established REs, special grants will need to be established to provide the support mechanisms necessary to nurture fledgling ocean energy sector.

4.3.3 Credits and Tax schemes

Many countries are supplying some form of credit schemes to wave energy suppliers/investors. The most successful to date is the US production tax credit (PTC) and investment tax credit (ITC) schemes. Started in 2005, both schemes have caused a boom in RE projects, mainly wind. The schemes were due to cease in 2008, but have been extended to 2009. The main downside of the scheme is the temporary nature for the scheme. This is not so much an issue for the ITC which is a one off tax credit, but is a severe limitation to the PTC, which is related to annual output of the WEC.

4.3.4 Market liberation

There is a trend in many countries to move from state owned suppliers of electricity, to private suppliers and companies. This encourages market forces and has the intention of reducing prices of electricity for the consumer. The downside of the trend is that it encourages production by the cheapest electricity possible at that time (Ringel 2003). Up till now this is thermal fossil fuel derived electricity. Without regulatory support, wave energy as well as other RE’s will be disadvantaged.

4.4 Policy change

A serious worry for any company seeking grants and permits from regulatory bodies are the possibility of change or removal of those regulatory agencies and the policies introduced. Election of opposition parties in governments invariably bring about policy changes in many core directives. A recent example is where the 2001-2006 EU support mechanisms for ocean energy, represented in Framework Program for Research and Technological Development FP6, were altered in the revised FP7 proposal in 2008. Grants, available originally for ocean energy projects, were now only available only to joint wind/wave projects. The change in subsidy eligibility reflected a change in the EU confidence in the economic viability of wave energy projects.

The following a range of factors that are vulnerable to policy change:

- Permits and licences, due to tighter environmental laws.
- Grants, rebates, GHG credit incentives.
- Renewable energy targets and quotas.
- Corporate tax rates.
- Discount rate of cash due increase in borrowing rates.

4.5 State support for conventional thermal supply

World fossil fuel subsidies totalled about $300 billion a year or 0.7 percent of world gross domestic product (GDP) (UNEP 2008). Subsidies were biggest in Russia, with about $40 billion a year spent mainly on making natural gas cheaper, ahead of Iran with $37 billion. China, Saudi Arabia, India, Indonesia, Ukraine and Egypt also had big subsidies on fuels. In Western Europe and Japan, subsidies to local coal producers exceed those for agriculture (Anderson and McKibben 2000). Similarly, in the USA, the Energy Bill of (2007) directly supports the fossil fuel and nuclear industry. RE companies receiving similar support as received by the coal, oil and nuclear industries would be very competitive.

4.6 Banks and financial support

Because of the lack of knowledge with regards wave technology, financiers and banks are defensive in developing financial instruments for wave technology (UNEP 2004). The reluctance by banks to provide finance and funds for wave energy projects is recently compounded by the ‘credit crunch’ of 2008. Solution to the financial bottleneck with local banks could be solved by seeking international finance. It has been suggested that the World Bank could provide credit to commercial banks, who in turn will make loans to wave farm developers (Wijayatunga, Siriwardena, et al. 2006).

The European Investment Bank has announced its first renewable energy financing operation in France[11]. The loan finances small/medium ventures in the renewable energy sector, particularly wind farms. A Brazilian manufacturer of wind rotor blades for wind power turbines is to obtain US$120 million in loans from the Inter-American Development Bank to restructure its debt and invest in new production lines[12].

5 Environmental/ local barriers

5.1 Fisheries

The near-shore area has been the traditional domain of fishing communities, and interference may lead to conflict for wave energy development. Wave energy farms will typically be deployed in water depths of approximately 50m, which is on average between 5-10 km from the coast. Traditional small-scale fisheries in shallow waters usually have a radius of fishing of up to 5 km from the coast, while deep-sea fishing is restricted to seas greater that 10 km from the coast. Thus, wave energy farms installed in waters of 50m should generally not interfere with main types of fisheries (Sarmento, Neumann, et al. 2005). Despite this fact, objections from fishermen have begun in the USA to proposed wave farms[13]. It may be necessary to consider navigation corridors to go around areas delimited by wave farms, and ensure that farms are not located in prime fishery areas, or in navigation corridors between. EPRI (Bedard 2005) did a feasibility study to identify sites in Oregon that would be good for a commercial wave energy facility. Results showed that the 'hotspot' best site was the prime Dungeness crab fishery area. Wave farm deployment may have to cooperate with local fisheries, and could be mutually beneficial, as described in the next section.

5.2 Environmental concerns and nature reserves

There is controversy as to whether the farms would effect ecology and decrease fish populations due to their physical presence as well as destruction to installation and

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[11] http://goliath.ecnext.com/coms2/summary_0199-7443924_ITM
[12] http://www.iadb.org/news/articledetail.cfm?Language=EN&artid=4709
[13] http://www.newportnewstimes.com/articles/2007/07/03/news/news03.txt

maintenance (Sutherland, Bailey, et al. 2008). However, others claim that fouling on moorings and buoys due to algae, mussels and barnacles leads to an increased local biodiversity, which in later stages might lead to an influx of fish (Ó'Cléirigh 2000). It has been suggested by a Swedish company that concrete foundations for both generators and buoys could be cast in special designs that could be beneficial to certain organisms like crabs and lobsters (Leijon and Sundberg 2008). They also suggest that marine parks could be created around wave energy farms.

The creation of new marine parks is increasing as global environmental awareness is increasing. The location of wave farms within these boundaries could be problematical. For example, 25% of the California coastline is within the State Park System (Barry, Lasko, et al. 2005). A wave farm within the boundary of a marine park can be seen as human interference in an environmentally protected area, posing a hazard to navigation and conflicting with recreational use within the park (Sivas and Caldwell 2008). Wave farms seeking to be sited within marine reserves will need to go through extra and probably lengthy planning permission approval, unless the marine park has prior provision for wave farm applications.

5.3 Visual, noise and energy extraction impacts

Visual appearance and noise impacts are device-specific, and their impacts could cause difficulties in planning permission applications. The visible freeboard height and noise generation above and below the water surface vary with device type. Devices with OWC's and overtopping devices typically have the highest freeboard and are most visible, especially if they are the near-shore or coastal variety (U.S. Department of the Interior 2006). Offshore devices would require navigation hazard warning devices such as lights, sound signals, radar reflectors, and contrasting day marker painting. However, in comparison to the height of off-shore wind farms, these visual interferences should be minimal.

The air being drawn in and expelled in OWC devices is likely to be the largest source of above-water noise, especially for the near-shore and coastal designs. It is anticipated that since the vast majority of wave farms will be located 4-5 miles off shore, there will be little noise objection (Sarmento, Neumann, et al. 2005). Preliminary modelling in the Scottish Siadar (2008) wave energy project indicated that the noise of their turbines would be similar to the naturally present background noise levels in the area .

Some underwater noise would occur from devices with turbines, hydraulic pumps, and other moving parts with the frequency of the noise a consideration in evaluating its impacts. A study conducted by the US on a wave energy device reported that a WEC system would produced a continuous acoustical output similar to low-grade noise associated with light to normal ship traffic (Hagerman and Bedard 2004).

Finally, concerns about energy extraction from the ambient ocean state are a concern to ecologists as well as human recreation. A Scottish study reported that up to 10% of the wave energy and 5% of the wave height arriving at the shoreline might be absorbed by a wave energy array 3 km long (Maunsell and METOC. 2007, McMurray 2007). The report concluded there would be only minor effects, but with low confidence. A 10% reduction in intensity of incident beach surf may be of concern for coastal tourism, and there have already been expressions of concern from anxious surfers[14].

5.4 Public opinion and awareness

Public opinion on large energy projects may be crucial for final approval. Misinformation, lack of understanding and not-in-my-backyard (NIMBY) syndrome toward wave technology by industry, government and public, may slow down wave energy development (Clément, McCullen, et al. 2002).

Moreover, an under-informed public may be generally unaware of the benefits of nascent renewable energy services, and as a result fail to demand or purchase energy produced from that source (Dalton, Lockington, et al. 2008).

Remedies to overcome these obstacles would be state and governmental initiatives to provide promotional material and web sites for increasing public awareness, technical material for planners and would-be investors, and articles in the public press to raise the technology's profile (Clément, McCullen, et al. 2002). Firms will need to market and promote their products and services to the general public and choose suitable channels for the effective dissemination of company-relevant information (Christiansen 2002).

[14] http://www.iht.com/articles/2007/04/05/news/surf.php

6 Financial barriers

6.1 Cost

Cost evaluation of a project is often left to the last stage of a project evaluation. This could be detrimental as it is ultimately costs that will be the final decision factor as to whether a project is essential viable or not. There are many cost variables that need to be assessed to provide the entire picture. The following sections describe the most important that should be examined.

6.1.1 Capital cost– material, wages and construction cost escalation

The cost of materials is the single most influential factor for a company planning to produce WEC devices, and to the energy developer who intends to purchase a finished WEC product for deployment. Steel, which is currently the main material constituent of a WEC, has had major price fluctuations over the past few years (Figure 1). Recent factors influencing steel prices fluctuation were increasing demand from China for raw materials which led to a price escalation, followed by the credit crunch and global recession, causing steel prices to fall to 2007 prices[15]. However, the final cost of manufactured steel, typically grade 50 (S355), painted with corrosive protection, can cost anywhere from €5000-7000/ton[16], and this price has not substantially fallen yet, although is forecast to do so in 2009.

[15] http://scrapmetalpricesandauctions.com/iron-steel/historical-steel-price-index-american-metal-market-amm/

[16] Personal communication Paul Collins, Malacky Walsh Engineers, Cork.

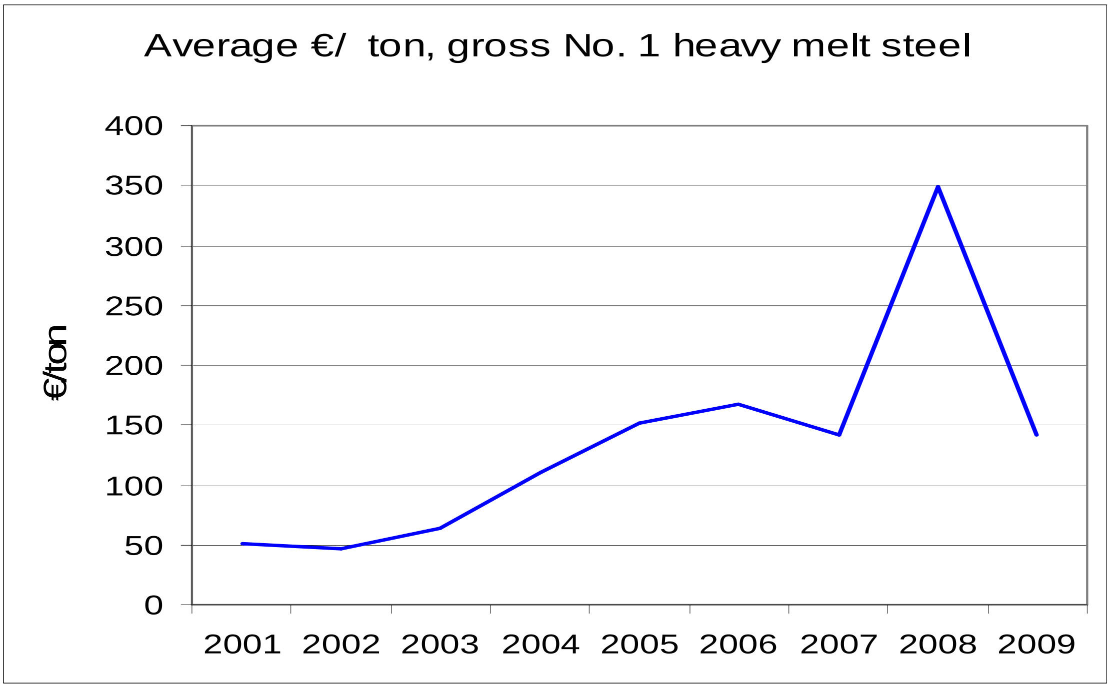

Figure 1: Historical heavy melt steel price, American metal market. 2001-2007 (www.scrapmetalpricesandauctions.com/iron-steel)

6.1.2 Project development costs

An electrical supply company intending to purchase and install WECs will need to evaluate all the costs involved in deployment. The two main infrastructural costs are mooring and power cables. The cost of cabling for WEC projects is often grossly underestimated. Cable cost can equal the cost of a single WEC, with costs ranging form €0.5-4M/km, depending on the kV size (ESBI 2005). The capacity of wave farms will be sized to match the specification of the closest cable size. An increase in wave farm size that requires a cable size increase to the next bracket could make a project economically unviable.

Further cost estimations for wave energy project development include transport, installation, grid connection, insurance, maintenance, refurbishment and decommissioning costs. The sum cost of all these outlays, which are more expensive for wave energy generation in comparison to other RE, may make wave farms un-competitive.

6.1.3 Further economic factors

Important factors that can jeopardise a project's viability if not accounted for include:

- WEC lifespan and replacement. WEC lifespan can vary from 15 -25 years, depending on the manufacturer. A typical project may be financed over 25 years. Thus if a WEC needs to be replaced within a project life, it will add a large financial burden to the project.
- Discount rate and inflation rate. Discount rates can vary substantially depending on whether there is inflation or deflation.
- Borrowing rate, increasing lately due to the credit crunch.
- Tax rate. Many countries offer low business tax rate, however this rate may not continue due to tougher EU legislation intending to harmonise corporate tax rates.

Finally, the most prevalent economic indicator of project viability at present is cost of electricity (COE, €/kWh). This is a simple guideline, and does not account for tariff rates paid by the utility companies or any financial incentives offered by the government. Net present cost and internal rate of return are more informative and reliable indicators forecasting projected profit and return on investment, however many companies neglect look at these other parameters when assessing financial viability.

6.2 Investor/ venture capital

Attracting venture capital for WEC projects will be a major challenge for a company. The following are list of barriers that an investor will face when considering wave energy investment:

6.2.1 Risk of obsolete technology

Wave energy technologies face the risk of being obsolete from two directions:

- There are currently more than fifty WEC designs for an investor to choose from. Convergence on a single design type or group of designs has not happened yet[17], unlike wind, where technologies quickly converged on one device type, the 3-bladed horizontal axis turbine. Venture capital investment in any of the new WEC start-up companies will be very risky.

[17] http://westcoastoceans.gov/Docs/Walt%20Musial%20Offshore%20Renewable%20Technology.pdf

- The status of WEC technology today can be compared to wind energy development in the 80's (Joule & Thermie 2002). Presuming that one or more WEC technologies will eventually make it to commercial status, it is certain that the technology of that design will be subsequently improved, leading to increased efficiency, capacity and ultimately financial returns. Thus present-day commercial WEC designs could be obsolete in 10 years time. From an investment perspective it would make sense to wait till the technology is more mature, before large-scale purchasing of WEC devices.

6.2.2 Immature and small companies

Venture capitalists prefer to deal with large companies, which have large funds to support R&D projects and importantly reserve funds to shore up failed projects. In WEC R&D, the majority of research is carried out by small start-up companies. Investment in small start-ups carries the highest risk[18], with the majority of ventures written off as a loss. Small companies have high initial outgoings, low cash flows for the first few years, and high transaction fees due to the relatively small scale investment.

6.2.3 IP security for small companies

Security of intellectual property is of paramount concern for an investor. This issue is not of major concern for large companies where all R&D can be completed in the one environment. This is not the case for small companies, where much of the testing and construction is outsourced to other companies, research institutes and universities (Foxon, Gross, et al. 2005). This dramatically increases the risk of IP leakage, and damage to an investment.

7 Summary and conclusion

This report has examined the non-technical barriers that wave energy is likely to encounter in its path to development and deployment. The report details a list of obstacles in descending order of importance, although any one could be the factor which could stall a project.

[18] http://www.sba.gov/smallbusinessplanner/start/financestartup/SBA_INVPROG.html

Once a prototype has been successfully developed and tested, a suitable site for production needs to be selected. Any country trying to break into the production side of device fabrication will try and emulate the Danish experience, where a small country with high labour force costs and no previous major experience in large-scale manufacturing, managed to become the largest producer of wind energy devices in the world – supplying 50% of global demand at present. Private enterprise considering setting up manufacturing will need to source skilled maritime work force, establish a reputable certifying process and find construction locations suitable for production. Faced with these problems, it is quite probable that wave energy devices will be fabricated outside the EU, and will be imported by energy supply companies for deployment. However, further major barriers could be faced such as lack of installation equipment, specialised tug boats, and skilled personnel for the installation. Decision of where a supply company will base its wave farm will be crucial and possibly limited. 'Hotspot' areas of high energy output will be quickly identified, directly dependant on local infrastructure such as access ports and grid capabilities.

The administrative hurdles of permit acquisition as well as grid electricity compliance and planning could also prove extremely difficult to overcome, as well as time consuming. Regulatory support for wave energy from present governments is improving at the moment, with price support schemes, capital grants and proposed 'one stop shops' for permit applications, but contains the risk of uncertainty with changes of government.

Further obstacles to overcome are environmental constraints imposed by legislation as well as local opposition from fishermen, exploration companies.

Finally, but by no means least, is the cost of production. Cost of electricity for wave energy devices estimated at present is not competitive to large-scale wind. Escalating cost of materials, in particular steel, threaten to reduce any cost savings that might arise from improved device design and production techniques.

Problems faced by wave energy industry are similar in many respects to those of offshore wind (the major differences is that offshore wind is deployed in shallow and calm waters, which is not the case for wave), and should take encouragement by its recent expansion in the energy supply arena. Wave energy technology is where wind development was 20 years ago, so players entering at an early stage hopefully stand to gain later when the technology matures and the myriad of development and deployment obstacles inherent to an off-shore environment are overcome

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