MARINE ENERGY DEVELOPMENT

TAKING STEPS FOR DEVELOPING THE CHILEAN RESOURCE

ERRAZURIZ & ASOCIADOS

British Embassy Santiago

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Acknowledgements

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List of Acronyms and Definitions

CER: Centro de Energías Renovables (Renewable Energy Centre). Part of the Chilean Ministry of Energy.

CNBUC: Comisión Nacional del Uso del Borde Costero (National Commission for Coastline Usage). Commission set up by the Chilean government for planning the usage of coastal land.

CRBUC: Comisión Regional del Uso del Borde Costero (Regional Commission for Coastline Usage). Commission set up by regional governments for planning the usage of coastal land.

Conicyt: Comisión Nacional de Investigación Científica y Tecnológica (National Commission for Scientific and Technologic Research). Reports to the Ministry of Education and advises the President in two strategic areas: the development of human capital, and supporting and strengthening the scientific and technologic base of the country.

Corfo: Corporación de Fomento a la Producción (Corporation for Production Encouragement). Chilean government organisation responsible for innovation and entrepreneurship policies in Chile.

EMEC: European Marine Energy Centre. Research and development centre located on the Orkney Islands in Scotland where an important part of the R&D for the devices has taken place in the UK.

Fondef: Fondo de Fomento al Desarrollo Científico y Tecnológico (Fund for the Promotion of Scientific and Technologic Development). A Government body set up to finance scientific and technological research and development projects.

LBGMA: Ley de Bases General del Medio Ambiente (Environment Act, General matters, Chile).

LGSE: Ley General de Servicios Eléctricos (Electrical Services Act, Chile).

IEA: International Energy Agency.

INH: Instituto Nacional de Hidráulica (National Institute of Hydraulics, Chile).

Marine or ocean energy: energy that can be extracted from the ocean. For the purposes of this report, marine energy refers to energy that can be extracted from waves and tidal currents.

MSP: Maritime Spatial Plan.

NCRE: Non-Conventional Renewable Energy.

PBI: Production Based Incentives.

PUC: Pontificia Universidad Católica de Chile. One of the main Universities in Chile.

RO: Renewable obligation.

ROC: Renewable Obligation Certificate.

SEA(1): Strategic Environmental Assessment. This is a process to ensure that significant environmental effects arising from policies, plans and programmes are identified, assessed, mitigated, communicated to decision makers and monitored, and that opportunities for public involvement are provided.

SEA(2): Servicio de Evaluación Ambiental (Chilean government Environmental Assessment Service).

SHOA: Servicio Hidrográfico y Oceanográfico de la Armada (Chilean Navy Hydrographic and Oceanographic Service). The service is part of the navy and is responsible for developing navigation charts and monitoring ocean activity. It also leads research into the ocean’s behaviour and has been a vital source of information in the estimation of energy potential.

Tidal stream energy: Energy captured from the kinetic energy of tidal water movements.

Wave energy: energy captured directly from surface waves or pressure fluctuations below the surface of the water.

Executive Summary

The Chilean coast has a vast resource for both wave and tidal stream energy production. The potentially exploitable wave resource is more attractive than the tidal stream resource, however, if harnessed, both could make a significant contribution to increasing the energy security and sustainability of Chile's future energy system.

At present, technologies that convert wave and tidal stream energy into electricity are at an early stage of development and the cost of the energy they produce is currently significantly higher than that of other conventional sources of electricity. Research has shown that there is high potential for cost reductions, however significant public and private sector support and investment will be required to facilitate the necessary cost reductions. If Chile is to capitalise on the significant opportunities presented by the marine energy sector, government support and investment will be required.

It is, however, important to bear in mind that there have been significant reductions in the cost of marine energy as technology developers move to second and next generation devices and refine and optimise their design and operation. It is envisaged that the cost will continue to decrease significantly as we begin to see the first commercial arrays of marine energy devices, and that the cost of the energy generated will reach a competitive level in the medium term.

A strong reason to support the development of marine energy technologies is the series of positive economic impacts that have been observed in countries where support has been provided, principally in the creation of a supply chain for the industry with extensive job creation.

Historically, Chile has tended to be a technology buyer rather than a technology developer. However, considering the marine energy resource that exists in Chile, this may be an opportunity to reverse this trend and for Chile to take a more active role in the development of marine energy technologies, allowing it to reap the significant benefits associated with such activities.

In Chile there is incipient activity to investigate the opportunities presented by the country's attractive marine energy resource. In recent years there have been a number of conferences and government agency funded resource assessment studies focused on marine energy in Chile, and Chilean utility companies have begun to show an increasing interest in the sector's development. However despite this interest, the conditions do not currently exist for the deployment of devices or investment in marine energy technology development in Chile.

For marine energy deployments to be possible in Chile, a number of changes to the regulatory framework are required. The two most important aspects of these are:

>> Putting in place the financial support mechanisms required to support marine energy developments.

>> Refining the Chilean regulatory framework (not used to dealing with projects of this nature in terms of factors such as the permits required for land use, environmental impact) to facilitate marine energy developments.

Chile has a strong and effective regulatory framework regarding the electricity sector. However, from a project development perspective, there are significant issues such as those associated with the financial support mechanisms for renewable energy, the environmental impact assessment of projects, obtaining the necessary marine concessions, and engaging with the coastline planning instruments in Chile. When it comes to the development of marine energy projects, these issues will have an impact on their economic feasibility and will be hampered by the heavy burden in terms of the permits required. Furthermore, the fact that the assessment for such permits would be undertaken by government agencies or ministries with limited knowledge of marine energy projects constitutes a significant obstacle to the development of marine energy in Chile.

Potential marine energy strategies for Chile

Two strategies have been identified that Chile could implement to capitalise on the significant opportunity presented by the country's marine energy resource:

>> A **development** strategy whereby the country would provide support to the sector in order to take an active role in the development of marine energy technologies and reap the associated economic benefits.

>> A **deployment** strategy whereby the country would wait for technology to be developed abroad before purchasing and deploying the devices to take advantage of the benefits associated with exploiting the country's attractive resources.

Following detailed research into the Chilean regulatory framework in the context of marine energy deployments, it is important to highlight that both the strategies presented would require regulatory changes. In general terms, the **development** strategy would require changes in the regulations governing land use, the acquisition and cost of concessions, and environmental permits. In addition to this, the strategy would also require the establishment of financial support mechanisms for marine energy, the establishment of project finance instruments, and focused collaboration between universities, private companies, and government institutions to develop the necessary human capital, technology and infrastructure, and supply chain capacity. The **deployment** strategy would require less regulatory changes. However, in order to facilitate marine energy deployments at some point in the future when the cost of the technology becomes competitive with other forms of generation, the same changes will be required with respect to the regulations governing land use, the acquisition and cost of concessions, and environmental permits.

It is important to be aware that the Chilean government has already established special conditions for permits and financial support mechanisms for other renewable energy sources, such as solar energy. If a development strategy is to be followed, the regulatory changes required are likely to be relatively closely aligned with the measures that have already been put in place.

The need for a roadmap for marine energy in Chile is highlighted as a final outcome of this study. Several promising sites for marine energy development have been identified in Chile and there is a clear need to set out the Chilean government's objectives in terms of marine energy to develop a clear vision for the future.

Bringing together important stakeholders (particularly the Chilean government) to develop a roadmap and set out a clear vision for marine energy in Chile is an important step in deciding on the best strategy for Chile to follow and determining the regulatory changes required to facilitate this.

Ultimately, there is an attractive resource in Chile and it is up to the government and the marine energy sector to decide whether this resource will be exploited and the role Chile will play in the development of the sector. However, it is important to stress the urgency for this debate to take place soon. Other countries, particularly in Europe, are increasingly focusing on marine energy and the window of opportunity for Chile to take an active role in the development of the technology is small.

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01 | Introduction

The ocean is a vast source of energy, and this energy can be exploited from thermal gradients, salinity gradients, tidal ranges, tidal currents, and waves (OES, 2011). This report focuses exclusively on energy generation from the kinetic energy of waves and tidal currents, and the term marine energy is used throughout to refer to these two types of technologies.

Chile's coastline is over 4,000 km long and has significant wave and tidal current resources. There is considerable interest amongst the Chilean authorities and energy producers in the potential to exploit these resources for the production of electricity.

Globally there have been relatively fragmented efforts to develop marine energy technology to convert the energy in waves and tidal currents into electricity. However, interest in the sector has been growing in recent years (particularly in Europe) and a number of technologies have progressed to second and next generation devices. As the sector develops, there are many challenges that must be overcome and a key message from developments in the sector over the last decade is that putting devices in the water is expensive and reliability and cost effective maintenance constitute important challenges.

In 2003 the European Marine Energy Centre (EMEC) was established in Orkney, Scotland, a test centre that has provided significant support to technology developers working to increase the reliability of marine energy devices. As well as funding the establishment of this test centre to support the marine energy sector, both the UK and Scottish governments have shown significant commitment to the sector and put in place a number of financial support mechanisms to support technology development and cost reductions.

The main objective of the significant and sustained support for the marine energy sector in the UK and Scotland is to bring the technologies to a stage of development whereby they can produce energy at a commercial scale and cost. However, there are also significant additional benefits associated with developing and deploying marine energy technologies that represent an incentive for government investment to support the sector. These include increased energy security, emissions reductions, and the economic benefits and job creation associated with the development of a new industry and the required supply chain capacity.

In this context, one of the aims of this study is to perform a complete and comprehensive review of the potential for developing marine energy in Chile, similar to that undertaken in other countries such as the UK. This is an important first step to capitalising on the large opportunities presented by Chile's marine energy resources in terms of energy security, emissions reductions, and the development of a new industry in Chile, all of which could result in significant benefits to the country's development.

The methodology followed for the preparation of this report consisted of:

>> An extensive bibliographic review of analyses of marine energy resources, generating devices and costs, marine energy development experience in other countries, the economic and environmental impacts of marine energy, and the Chilean regulatory framework.

>> A range of meetings with stakeholders from the Chilean government, power generation companies, and marine energy specialists, including:

- **Government:** Ministry of Energy, CER, Corfo, Conicyt, SEA, and CNBUC.
- **Power generation companies:** AES Gener, Endesa, International Power – GDF Suez, and HydroChile.
- **Marine energy specialists:** Baird & Associates, and PUC.
- **Chilean Navy:** SHOA.

This methodology was used to obtain a broad and comprehensive picture of all of the issues surrounding the development of marine energy in Chile. The information was then used as the basis for the production of the report, focussing on:

>> The natural potential of the Chilean coastline where energy from waves and tidal currents can be transformed into electricity.

>> The current stage of development of technologies within the developing sector for generating electricity using energy from waves and tidal currents.

>> The Chilean regulatory framework, including existing mechanisms and pieces of regulation that could be used to support and incentivise the development of the marine energy sector in Chile.

>> Analysis of the policies and support mechanisms in place for the development of marine energy technologies in Europe and around the world to assess which of these could potentially be appropriate for adoption in Chile.

>> The socio-economic impacts in Chile if the regulatory and financial apparatus to incentivise the development and deployment of marine energy technologies in Chile is implemented, and the potential for the establishment of a local industry and supply chain to facilitate this.

>> Measures the Chilean government could implement if it decides to support the development of the marine energy industry or if it decides it would be useful to ensure the existing regulatory framework is modified to facilitate potential marine energy developments in the future.

The report conducts a detailed review of the potential of marine energy in Chile, with a significant focus on the parallels with the Scottish experience. Scotland is used as an example of a country where the government has put in place a number of policies and support mechanisms to support the development of the marine energy sector. As a result, there have been significant successes at EMEC and a high degree of cooperation exists between the government and private technology developers.

The report will culminate with assessing the potential strategies the Chilean government could implement to support the marine energy sector, and will present a number of public policy recommendations.

02 | Use of marine energy for electricity production

>> This section provides a review of the literature concerning the potential of wave and tidal stream energy on a global scale. It also gives an overview of the state-of-the-art devices for electricity production from these energy sources, detailing their costs and the current potential for their reduction.

2.1 Global wave and tidal energy potential

There are several studies and assessments of the potential available around the world for producing electricity from both wave and tidal stream energy. The sources of these studies are quite varied (including NASA (2006), Joao Cruz (2008), AVISO (2000)), but on a global scale their assessments make it clear that the potential marine energy available for development is vast.

Figures 1 and 2 show global maps of wave and tidal energy, these maps were published by Ocean Energy Systems (2011) using data from external sources.

Figure 1 shows the average annual wave power in kW/m. This value indicates the power distributed on a wave front. The global theoretical potential of wave power has been estimated as 29,500 TWh/year (OES, 2011). It is clear from the map that Chile has an excellent wave power resource, especially the central and southern areas of the country's coastline.

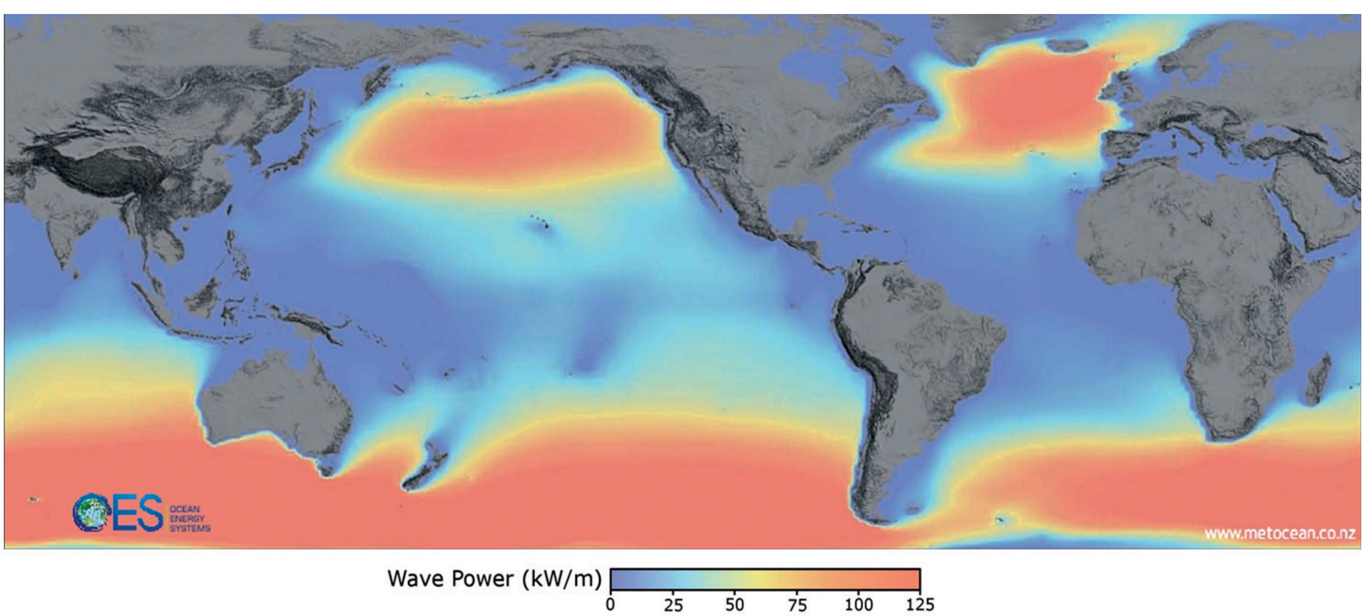


Figure 1: World map of wave power (OES, 2011).

In terms of tidal stream energy, Figure 2 shows a global map of tidal range. The specific information shown is the global pattern of the M2 tidal constituent, which is the main lunar semidiurnal component (OES, 2011) and represents about 60% of the total tidal range (NASA, 2006).

The worldwide theoretical potential of tidal power, for both tidal range and tidal currents, has been estimated at around 7,800 TWh/year (OES, 2011). It must be noted that although on a global scale the potential in Chile appears to be limited, on a more local scale, there is significant potential for development, particularly in a number of specific locations in the south of Chile (see Figure 9).

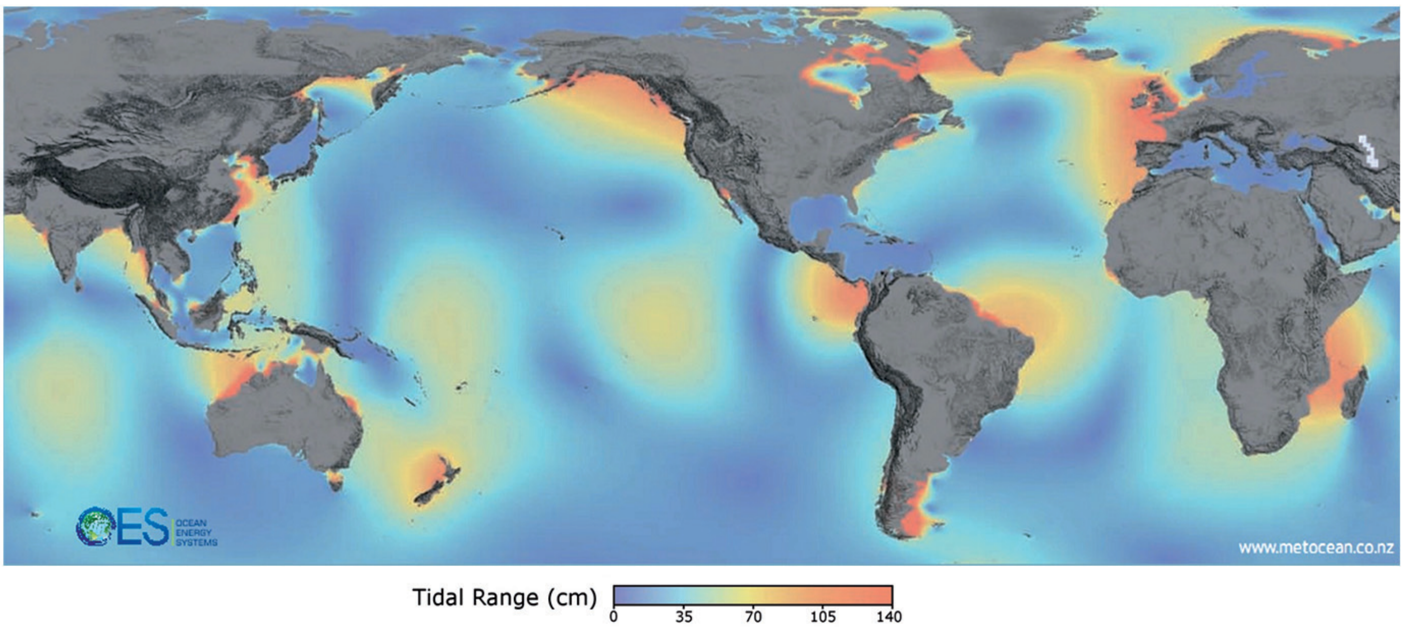


Figure 2: World map of tidal range (OES, 2011).

It can be observed from Figures 1 and 2 that on a global scale tidal energy shows less potential than wave energy. This is also true in Chile, where the wave energy resource is significantly larger than the tidal current.

2.2 Overview of available technologies for converting wave and tidal stream energy into electricity

This section provides an overview of the available technologies for converting wave and tidal stream energy into electricity. Other technologies such as tidal range, ocean thermal energy conversion, and salinity gradient lie beyond the scope of this study and are therefore not included.

There are a number of engineering concepts for harnessing wave energy, including oscillating water columns, overtopping devices, point absorbers, terminators, attenuators, and flexible structures. There is less variety in tidal current energy devices: there are number of prototype designs based on horizontal axis turbines, although vertical-axis rotors, reciprocating hydrofoils, and Venturi effect devices are also being developed.

A breakdown of different technology types within the marine energy sector is provided in Figure 3 below.

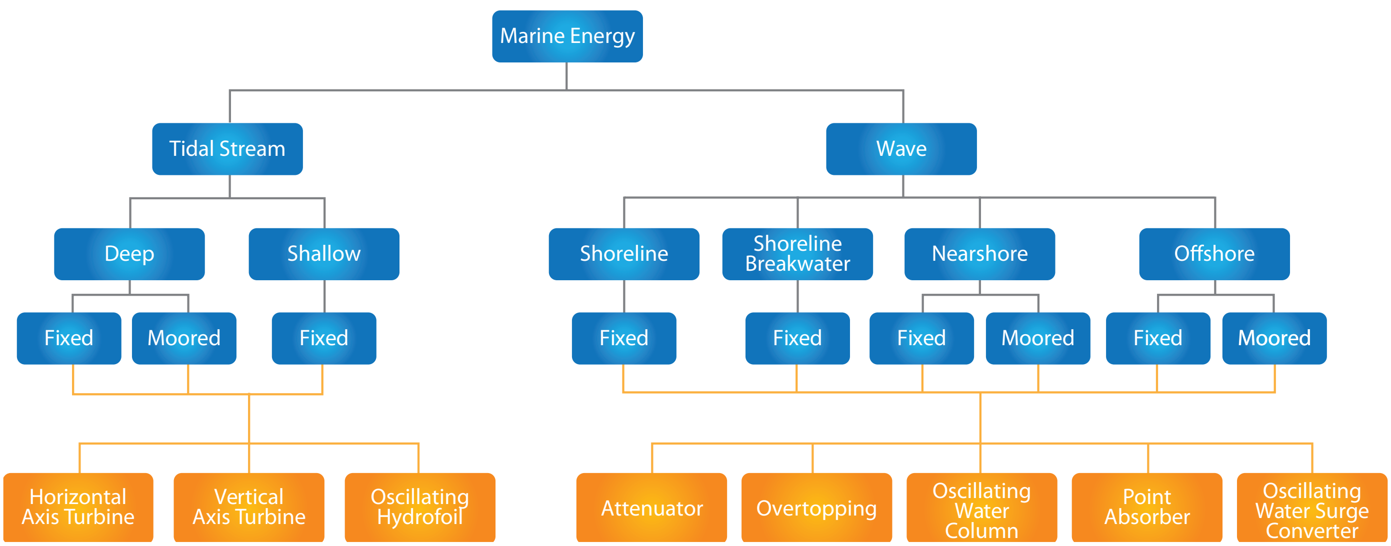


FIGURE 3: DEFINITIONS OF MARINE ENERGY TECHNOLOGY (ADAPTED FROM BOUD, 2009).

The following section provides an overview and explanation of the operation of the varying types of wave and tidal current device concepts along with examples of current device developments.

2.2.1 Wave energy device types

There is significant variety within the wave energy sector and at this stage it is not clear whether an increased design consensus will be reached in the future, as has been the case with tidal stream devices. Devices proposed or under development for capturing energy from waves can be grouped into the following categories:

- Attenuators
- Overtopping devices
- Oscillating water columns
- Point absorbers
- Oscillating wave surge converters

A brief explanation of each of the types is provided below.

Attenuator

Attenuator devices are generally long floating structures aligned with the wave direction, which then absorb the movement. Their motion can be selectively dampened to produce energy. It has a lower area perpendicular to the waves in comparison to a terminator device, so the device can experience reduced forces.

Sector Example:

Technology: Pelamis P2
Company: Pelamis Wave Power
Stage: Commercially available
Nameplate capacity: 0.75 MW
Country of origin: Developed in UK and tested in UK and Portugal

© Pelamis Wave Power

Overtopping

Overtopping devices are wave surge/focusing systems, and work by using a ramp over which waves travel into a raised storage reservoir. This creates a head of water in a reservoir which is then released through low-head hydro turbines as the water flows back out to sea. An overtopping device may use focusing arms to concentrate the wave energy.

Sector Example:

Technology: Wave Dragon (US DOE, 2009)
Company: Wave Dragon Ltd.
Stage: Full scale prototype
Nameplate Capacity: 11 MW
Country of origin: Developed and tested in Denmark

© Wave Dragon Ltd.

Oscillating water column (OWC)

An OWC consists of a partly submerged, resonantly tuned collector that is open to the sea below the water surface and contains air trapped above a column of water. This column of water moves up and down with the wave motion, acting as a piston, compressing and decompressing the air. This air is channelled through an air turbine, making use of the airflow as it is forced out and sucked back into the collector. A significant advantage of this type of technology is that it can be integrated into the shoreline (e.g. incorporated into existing or new-build breakwaters).

Sector Example:

Technology: Limpet
Company: Voith Hydro Wavegen Ltd.
Stage: Full scale, grid connected prototype
Nameplate capacity: 500 kW
Country of origin: Tested and developed in UK (Scotland)

© Voith Hydro Wavegen Ltd.

Point absorber

A point absorber is a floating structure that absorbs energy from all directions of wave action thanks to its small size with respect to the wavelength. The absorber can be designed to resonate with the natural wave periods to maximise the power it can capture. The power take-off system may take a number of forms, from hydraulics through to linear generators.

Sector Example:

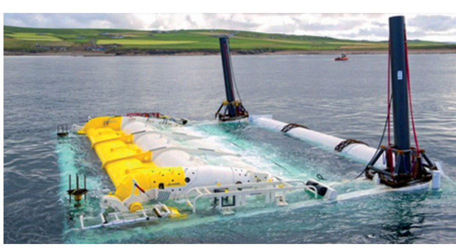
Technology: Powerbuoy PB150
Company: Ocean Power Technologies
Stage: Full scale prototype
Nameplate capacity: 150 kW (500 kW under development)
Country of origin: Developed in US and will be tested at EMEC (UK, Scotland)

© Ocean Power Technologies

Oscillating wave surge converter (OWSC)

An OWSC extracts energy from the surge motion in the waves. They are generally seabed mounted devices located in nearshore sites. The device collector is driven by the surge action of waves resulting in a pendular like motion which is then converted to useful power.

Sector Example:



Technology: Oyster 800
Company: Aquamarine Power
Stage: Full scale prototype
Nameplate capacity: 800 kW
Country of origin: Developed and tested in UK

© Aquamarine Power

2.2.2 Tidal stream device types

A number of different technology concepts for tidal current energy converters (TECs) have been proposed in recent years. The major differences between the concepts lie in the method of securing the turbine in place, the number and orientation of blades and rotors, and how the pitch of the blades is controlled. TEC devices are generally modular and intended to be deployed in 'arrays' for commercial operation in order to achieve a significant combined energy output (similar to the onshore and offshore wind approach). Devices proposed or under development for capturing energy from tidal currents can be grouped into the following categories:

- Horizontal axis turbines
- Vertical axis turbines
- Oscillating hydrofoils.

Horizontal axis turbine

These devices have two or three blades mounted horizontally to form a rotor; the kinetic motion of the current creates lift on the blades causing the rotor to turn and drive an electrical generator.

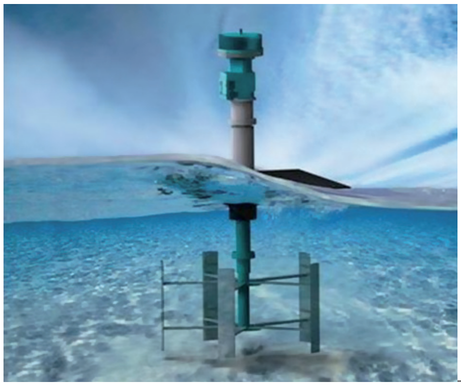
Sector Example:

Technology: SeaGen Turbine
Company: Marine Current Turbines
Stage: Commercial scale, grid connected 2nd generation device.
Nameplate capacity: 1.2MW (Strangford Lough Device)
Country of origin: Developed and tested in the UK (Ireland)

Vertical axis turbine

These devices generally have two or three blades mounted along a vertical shaft to form a rotor. The kinetic motion of the current creates lift on the blades causing the rotor to turn and drive an electrical generator.

Sector Example:



Technology: EnCurrent (US DOE, 2009)
Company: New Energy Corporation Inc.
Stage: Full Scale Prototype
Nameplate capacity: 5 kW, 10 kW, 25 kW (125 kW, 250 kW under development)
Country of origin: Developed and tested in Canada

Oscillating hydrofoil

This device operates like an aeroplane wing but in a fluid. Control systems alter their angle relative to the water current, creating lift and drag forces that cause the device to oscillate. The physical motion from this oscillation feeds into a power conversion system.

Sector Example:

Technology: Pulse-Stream 100
Company: Pulse Tidal
Stage: Full Scale Prototype
Nameplate capacity: 100 kW
Country of origin: Developed and tested in UK

© Pulse Tidal

Venturi effect devices are also being developed, but at present they are at an earlier stage of development than the device types presented.

2.2.3 Stage of development of marine energy devices

All the technologies shown, both wave and tidal, are under development and have been deployed on a prototype scale. Some of the technologies are at a more advanced stage of development than others and have already moved on to second and next generation devices in which their designs have been refined and steps are being taken towards the development of the first arrays of devices. The deployment of second generation devices includes design and assembly enhancements derived from the experience gained with the first generation prototypes, and it is an important step towards achieving significant cost reductions.

With the different technologies at different stages of development, some are already experiencing significant cost reductions, which is an encouraging sign for the industry.

At present, due to the stage of development of the marine energy devices under development, it is still too early to select a specific technology for tests at given sites in Chile. Likewise, it is also too early to rule out any of the devices. The technical aspects of different devices are under continuous development, and if they were to be installed in Chile, it would be important to adapt them to site conditions such as water depth, distance to the shore, shape, and the number of devices in the arrays.

Devices deployed as of late 2011 have not shown themselves to be currently competitive in terms of the cost of energy alone in comparison with other generation sources such as conventional fossil fuel generation or more developed technologies for the production of renewable energies. One of the key challenges for the marine energy sector and the individual technology developers is to reduce costs in order to make the cost of marine energy technology competitive with other forms of electricity generation.

2.3 Marine energy test centres around the world

International interest and development activity in the marine energy sector has grown rapidly in recent years and there are now over a dozen countries with specific support policies for the marine energy sector. Additionally, a number of full scale marine energy test centres have been established in the UK, continental Europe and North America, as detailed below. The present nascent status of these technologies creates considerable scope for its future development and cost reductions in the sector.

The establishment of these test centres has been a key element in the development of different devices, as they have provided the infrastructure needed for technology developers to carry out their research. Test centres for marine energy devices and technology development include (as presented by Mueller at al. 2010):

- The European Marine Energy Centre (EMEC). Opened in 2004 on the Orkney Islands in Scotland. Extensive research and full scale testing of both wave and tidal stream devices is conducted in this centre.
- The Northwest National Marine Renewable Energy Centre (NNMREC). Established in 2008 at the University of Washington in Seattle in the USA, with a focus on developing a full range of capabilities to support wave and tidal development in the United States.
- The Hawaii National Marine Renewable Energy Centre (HINMREC). Part of the University of Hawaii, and focusing on accelerating the development and testing of ocean thermal energy conversion technologies. This test centre is not relevant for the purposes of this report but is nonetheless included as an example of an active test centre.
- Fundy Ocean Research Centre for Energy (FORCE). Receives funding from the Canadian government, the province of Nova Scotia, Encana Corp, and participating developers. Located in the Bay of Fundy, Nova Scotia, in Canada, and aims to develop tidal stream technologies.
- New and Renewable Energy Centre. Located in Blyth, Northeast England, and dedicated to accelerating the deployment and grid integration of renewable energy and low-carbon generation technologies using wind, wave, tidal, solar photovoltaic, and thermal power.
- Wave Hub. Located in Cornwall, South West England, the centre's main objective is to provide an offshore facility for arrays of wave energy converters. The intention is that after single prototype devices have been tested at other facilities such as EMEC or Galway Bay, developers can test arrays at Wave Hub.
- Marine Institute. Based in Galway in Ireland, this Institute focuses on supporting the introduction of ocean energy (wave and tidal) to the Irish renewable portfolio and hence the development an ocean energy industry in Ireland.
- Nissum Brending. Offshore test facility in western Limfjord in Denmark, opened in 2000 with more than 30 wave power plants tested there to date.
- Wave Power Project. Established in 2002 in Lysekil in Sweden for the purpose of verifying that basic wave power technologies are successful, testing arrays of buoys, and developing an understanding of the environmental impacts of the technologies being tested.

- Florida Atlantic University Center for Ocean Energy Technology. Located in southern Florida in the USA, the centre carries out research, testing, implementation, and development of all ocean energy technologies (ocean current, thermal, wave, and tidal).
- New England Marine Renewable Energy Centre. Located in Massachusetts in the USA, with a focus on the development of ocean-based renewable energy (wave, tidal current, and ocean wind) through research, development and demonstration.
- Marine Energy Test Centre. Located in Karmøy in Norway, and providing infrastructure and conditions for full-scale testing of wind and wave energy technologies under various depth conditions. (Note, this test centre is not included in Mueller et al. (2010) but also constitutes an example of an active test centre.)

These research and test centres play a vital role in reducing the costs of prototypes and early stage devices as they provide the means to develop different technologies and increase their efficiency and reliability, hence speeding up the process of "learning by doing"

The next section provides a review of cost levels.

2.4 Costs and potential for cost reduction for different technologies

Section 2.2 provided a discussion of a number of electricity generation technologies based on wave and tidal energy that are currently under development, however, the cost of the energy produced is not yet competitive in its own right when compared to other energy generation technologies. As an example, in the International Energy Agency's World Energy Outlook 2009 shows that the generating cost of wave and tide energy is in the range of two to four times the cost of generating electricity from hydropower, with the authors of the report even adding that this may be a conservative estimate.

It is assumed the capital investment costs of renewable energy technologies will decrease over time, especially for those which have not yet reached a commercial stage of development, such as wave and tidal current energy technologies. This assumption is based on the sector learning in line with progressive deployments, where cost reductions have been, and will continue to be, achieved through innovation and research, as well as learning by doing.

Greater deployment accelerates technological progress and results in economies of scale in manufacturing the associated equipment, in turn leading to lower costs. The extent of the reductions depends on the maturity of the technology in question, although falling unit investment costs are roughly proportionate decreases in power-generating costs.

The International Energy Agency (IEA) (2009) shows that wave and tidal current energy technologies are currently among the most expensive when compared to conventional fossil fuel electricity generation or other renewable forms. However, the projected decrease in their costs is highly significant, both in terms of investment and generation costs and it is estimated they will become comparable with other renewable technologies in the medium term.

It should also be noted that the reduction in costs for mature technologies, such as hydropower, is small and marginal, whereas for wave and tidal power these cost reductions are highly significant (IEA, 2009).

According to available studies, in terms of investment and annual operation and maintenance (O&M) costs, wave power is more expensive than tidal power. This is shown in Table 1, which specifies the available costs and performance parameters for these technology types.

Ocean energy technology	Investment costs (USD2005/kW)	Annual O&M costs (USD2005/kW)	Capacity factor (%)	Design life (years)
Wave	6,200-16,100	180	25-40	20
Tidal Current	5,400-14,300	140	26-40	20

Table 1: Summary of core available cost and performance parameters for ocean energy technology subtypes (IPCC, 2011). The table has omitted some information present in the original source.

When investing in the development of marine energy technologies with a focus on increasing reliability and performance, and decreasing costs, it is important to strike a balance between demonstrative trials of the most advanced wave and tidal prototype devices(both for single devices and arrays), and also research into more radical but less developed designs and components. For effective development, the marine sector needs to explore new concepts as well as improvements as to existing designs.

In practice, this means a carefully considered balance between technology push and market pull support measures. The Carbon Trust (2011) has suggested long-term learning rates for wave and tidal energy of approximately 10% for both technologies, but highlights the importance of taking advantage of step-change improvements, as well as learning by doing. The projected cost curves from the Carbon Trust are shown in Figure 4.

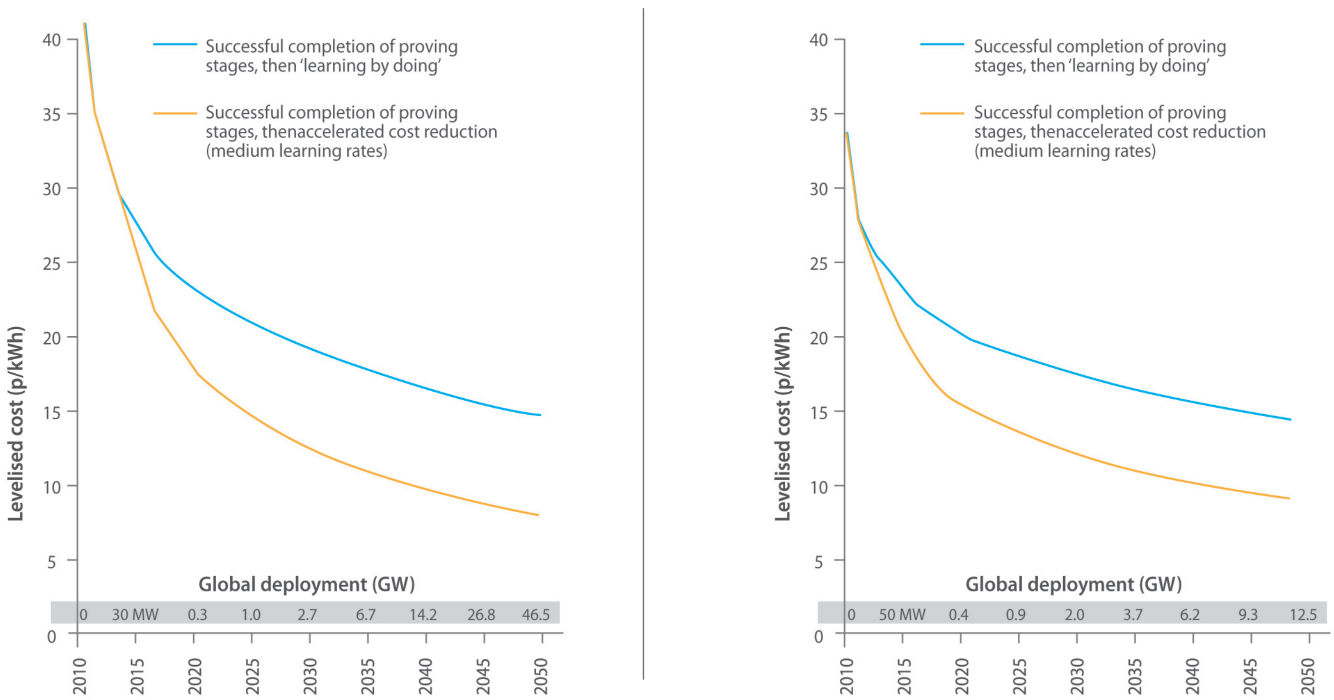


Figure 4: Projected cost reduction curves for the wave (left) and tidal stream (right) energy sectors under a business as usual and accelerated cost reduction through innovation scenarios (Carbon Trust, 2011).

It is important to clarify that the learning rates and projected cost reductions in Figure 4 will only be achieved if there are significant deployments of wave and tidal energy technologies. The horizontal axis gives the global deployments in GW of current wave and tidal technology required to achieve the cost reductions shown in the graphs.

Cost reductions will not be achieved unless there are significant deployments at higher costs in order to facilitate the learning and economies of scale required to bring them down.

A real example of cost reductions in the sector is illustrated by a case study of Aquamarine Power, a British technology company that has developed the Oyster device (Section 2.2.1) which produces electricity from wave energy.

The first generation of this product, Oyster 1, was operational during the winters of 2009–2010 and 2010–2011, with an investment cost of more than £35 m per MW, as shown in Figure 5. However, the cost of the second generation of this product was under £10 m per MW, i.e. a price reduction of more than 60%. The projected cost reductions for future generations of the device are shown in Figure 6.

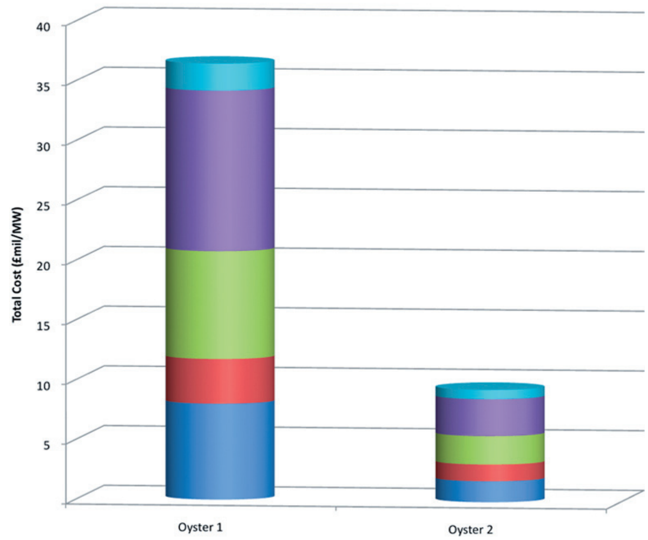


Figure 5: Projected Oyster cost reduction between first and second generations (Aquamarine Power, 2011).

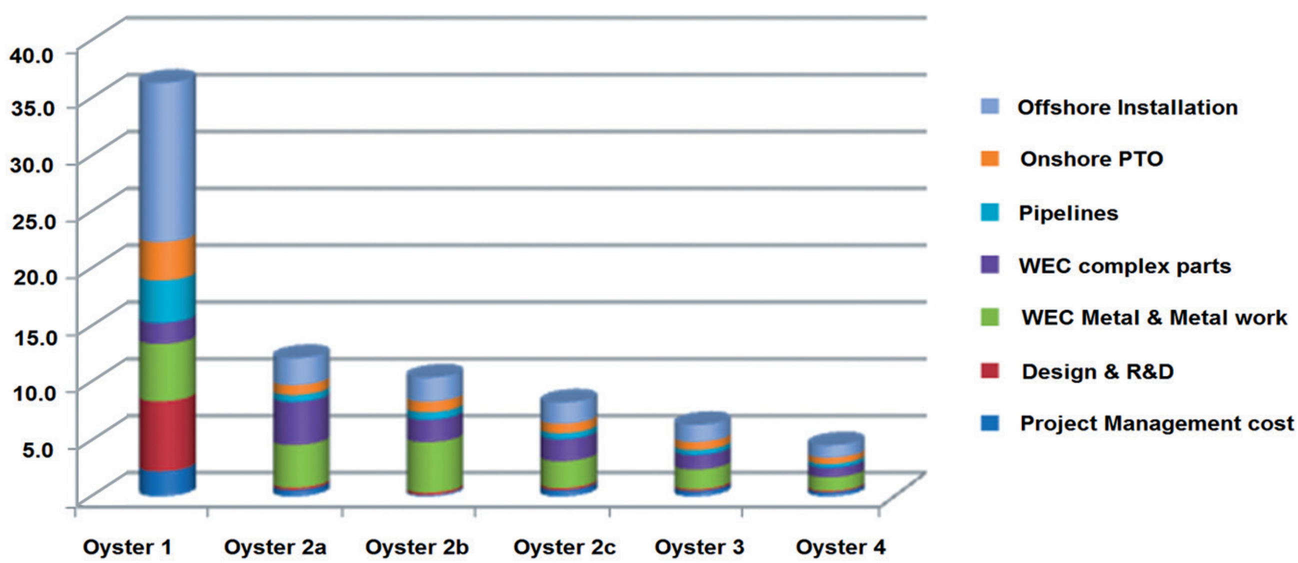


Figure 6: Projected Oyster cost reduction for future device generations (Aquamarine Power, 2011).

The cost reduction for the Aquamarine Power Oyster device is an interesting example to consider and presents a clear example of how costs can reduce as devices progress to more advanced stages of development.

The first generation Oyster used four piles in order to be fixed to the seabed, its complete structure was made of steel, and it was transported in a special vessel for installation, equipped with cranes and a highly sophisticated assembly system (Aquamarine Power, 2011). However the second generation Oyster required only two piles to be fixed to the seabed (instead of four), had an enhanced hydrodynamic design and was installed using standard vessels, such as commonly used tugs. Both these and further enhancements in the design of the device have played an important role in achieving the cost reductions in question (Aquamarine Power, 2011).

For the next generation, Aquamarine Power is evaluating more changes to the Oyster design, including attempting to use a single pile and starting to use materials for the device that are lighter and cheaper than steel.

All these changes and optimisations are expected to contribute to significant cost reductions, and it is expected that similar developments will be seen across the industry, with all device developers making progress in their devices and reducing costs.

It is important to highlight that at present all the marine energy devices being developed are being produced on a prototype scale, and there is therefore still no serial production or defined supply chain for this specific industry. When permanent industrial production on a large scale is reached, the costs of the special parts used by these devices should also come down.

Currently, it is still not possible to deploy a large scale array of wave or tidal power generation devices that can provide energy at competitive cost. However, the cost reductions achieved by developers are a strong and clear indication that the market is maturing and developing at a fast pace, making the outlook for the future of marine energy highly promising.

03 | Chile at present: available resource and current activity

>> In the marine energy sector it is widely acknowledged that Chile has significant potential for future development. Several studies and global potential maps have been made, all of which show that the long Chilean coast has a high potential for marine energy.

This section gives an overview of some of the potential studies carried out for Chile's coast, alongside general activity of the sector at present in the country.

3.1 Potential of wave and tidal energy in Chile

Global maps for wave and tidal energy were provided in Figures 1 and 2. These were taken from general and broadly known sources, and showed that on a global scale there is considerable wave energy resource along Chile's coast, whereas tidal stream energy is not so high (although on there may be possibilities for this type of energy to be developed a smaller scale).

This section provides a review of the available potential of these two energy sources along the Chilean coast. No calculations will be made for the potential, instead the report will be limited to discussing references to existing studies.

3.1.1 Wave energy

As stated previously, there are several studies and calculations on a global scale that show a great potential along the Chilean coast, however this report will focus on three studies deemed to be of particular relevance for their assessment of the potential of wave energy for development in Chile. The studies in question are: Monárdez, Acuña, and Scott (2008); Garrad Hassan (2009); and Monárdez, Acuña, and Zimmer (2011).

The study by Monárdez, Acuña, and Scott (2008) is based on a long-term (20 years), 2D spectra wave hindcast of the entire Pacific Ocean every 3 hours. It is validated using 22 wave measurement stations from the Chilean Navy Hydrographic and Oceanographic Service (Servicio Hidrográfico y Oceanográfico de la Armada, SHOA) and the North American Atmospheric Administration Office, as well as satellite measurements from Topex and Poseidon. The study also includes general comparisons between the conditions in Chile and the UK.

In general, the study shows that wave energy in Chile has several benefits for power production compared to the north-east coast of the UK, one of the most energetic sites in the world and where the majority of the world's research and development of devices has taken, and is taking, place.

The main conclusions from this study are:

- >> Wave power along the Chilean coast increases exponentially from north to south and ranges from 25 kW/m at the north end to close to 110 kW/m in the south.
- >> Seasonal variation of wave energy is very low compared with the UK (less than 6%).
- >> The capacity factor of plants in Chile would be a lot higher than in other parts of the world due to low variability throughout the year. Values close to 50% were estimated, compared with capacity factors of 30% for other parts of the world (Aquamarine, 2011).
- >> Wave power is greater than 5 kW/m at least 95% of the time (based on the 20 year hindcast data).

It should be noted that as a general rule, the minimum wave power resource considered technically feasible for generating electricity is 5 kW/m (Dennis, 2005), meaning that the whole Chilean coast has enough resource to generate electricity.

In summary, the natural conditions for Chile to develop wave energy are excellent and in several ways, even better than the conditions in the UK or in other parts of the world, where development has thus far taken place.

Garrad Hassan (2009) bases its potential assessment on a study by Baird & Associates for SHOA. It should be noted that the authors of the study mentioned above (Monárdez, Acuña, and Scott, 2008) work for Baird & Associates, and the study on which Garrad Hassan (2009) is based is a previous version of the study described above.

The main difference between the studies from Baird (2008) and Garrad Hassan (2009) is the shape of the energy distribution: the former shows an exponential distribution, whereas the latter shows a linear energy distribution that higher in the south than in the north of Chile. Both distributions are shown in Figure 7.

Nonetheless, in both studies it is noted that wave energy is of a sufficient level to install electricity generation devices along the entire length of Chile's coast. Hence for the purpose of this study the difference is small, because in both cases wave energy in Chile is shown to be very high and to have a promising potential for development.

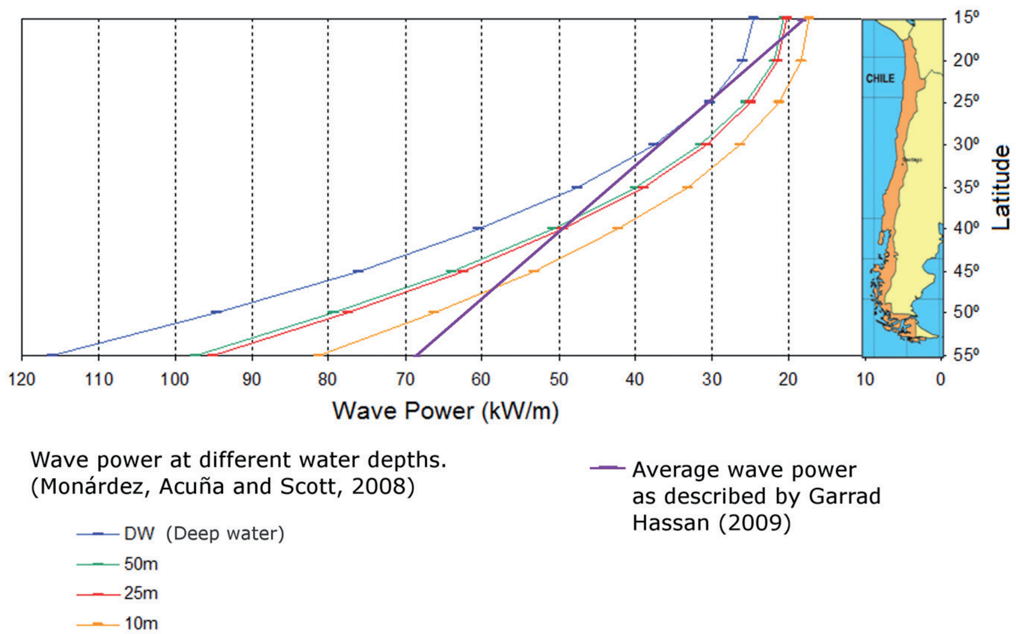


Figure 7: Distribution of wave power along the Chilean coast as a function of water depth (Monárdez, Acuña and Scott, 2008) and average wave power as described by Garrad Hassan (2009).

The study by Monárdez, Acuña, and Zimmer (2011) consists of the development of a continuous wave energy map of central Chile, based on 30 years of 2D wave spectral hindcast every 3 hours, validated with 30 wave measurements on intermediate waters (25–10 m water depth) along the country's coast. The methodology of the study is unique since it propagates 2D wave energy spectra into intermediate waters using linear models.

This assessment was prepared for Endesa (the largest utility company in Chile) by Baird & Associates in 2010. The complete findings of the project are not publicly available, although the work was presented at a local seminar in Chile (SOCHID, 2011) and is expected to be presented in English at the 4th International Conference on Ocean Energy.

Essentially, this latest study confirms the primary findings of the first assessment undertaken by Monárdez, Acuña, and Scott in 2008.

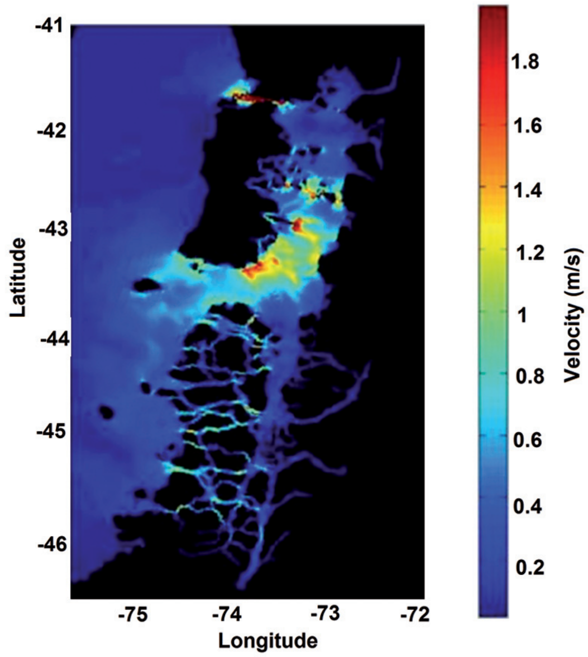


Figure 8: Map of tidal speed, potential for tidal energy production, in the south of Chile, around the island of Chiloé (Map produced by Aiken, 2008, and taken from Garrad Hassan, 2009)

3.1.2 Tidal stream energy

In terms of tidal energy, Chile has a high enough potential to be developed, although not to the same extent as wave energy.

Tidal energy is more relevant for specific sites where tides and their high volumes of water are channelled through narrow straits or channels at high flow velocities.

A global map of tidal potential was provided in Figure 2, although Chile was not a promising zone. Nevertheless, Figure 8 shows that on a more local scale there are zones in the south of Chile (from latitude 40° south) where tidal speeds are relatively high, and could thus be used for tidal energy production.

Figure 8 shows a map of the average tidal current velocities in the channels around the island of Chiloé. It should be noted that the tidal current velocity is extremely high in the Chacao Channel to the north of the island and hence, it may be worthwhile evaluating the potential of that area in detail. Furthermore, all the areas shown in yellow and red may also merit further study (the north of the island and several areas in the south-east). In some of the channels south of the main island of Chiloé there may be other hot spots, although these should be studied on a more local scale.

It is worth noting that areas where the velocity of peak flow exceeds 3 m/s are considered excellent for the development of tidal energy, areas where the velocity is greater than 2 m/s are considered good, and those with flows greater than 1.8 m/s are considered of interest for investigation (Garrad Hassan, 2009). These figures are complemented by those from the Northwest Marine Renewable Energy Center at the University of Washington, provided in the graph shown in Figure 9.

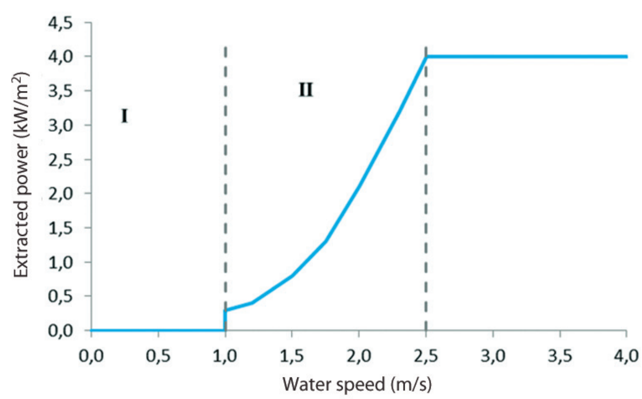


Figure 9: Representative turbine power curve: graph showing the relationship between speed of water in tides and extracted power. Region I is below the cut-in speed and the turbine extracts no power. In region II, power is extracted in proportion to the kinetic power acting on the rotor sweep area. Region III is above the rated speed and power extraction is constant (NNMREC, University of Washington).

Figure 10 shows the results of a numerical model developed in order to study the potential of the Chacao Channel for developing tidal energy. This study was carried out by Herrera et al. (2010), and reinforces the fact that the channel has an excellent potential for development, with power density in most of the zones exceeding 10 kW/m².

Considering the results of this numerical model and the typical turbine curve from Figure 9, it can be concluded that almost the entire Chacao Channel is a promising location for the development of tidal energy.

Together with the Chacao Channel, there is another specific zone in Chile where tidal stream energy is known to have high potential and development of tidal energy could take place. This is at the Strait of Magellan (Estrecho de Magallanes), in the deep south of Chile (Garrad Hassan, 2009), where there are already plans for project development in the short term.

The Strait of Magellan has not been studied as extensively as the Chacao Channel and as such, there are no results from power output simulations, as is the case with the channel. Nevertheless, the strait is considered an important and feasible location for tidal energy development by Garrad Hassan (2009).

This section has shown that tidal energy in Chile is not as broadly available as wave energy, but it nonetheless represents a significant source of energy available for development in certain locations.

3.2 Present activity and ongoing studies in Chile

At present there are a number of ongoing studies and potential measurements for both wave and tidal energy that are being carried out by the National Institute of Hydraulics (Instituto Nacional de Hidráulica, INH) and the private company HydroChile, in cooperation with Pontificia Universidad Católica de Chile (PUC).

Although there is information available on the resources for energy production using both wave and tidal energy in Chile, only a few studies have been carried out, and all have been based in simulations and modelling with calibration and validation of the measured data.

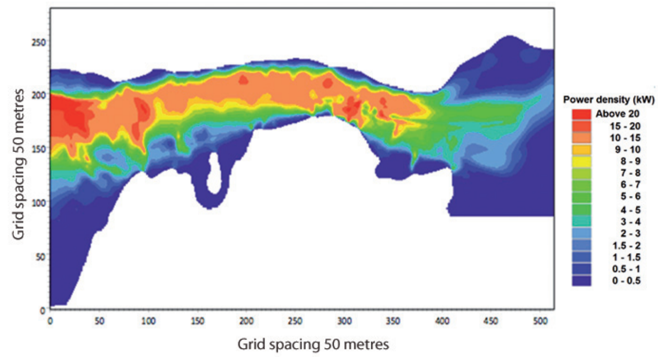


Figure 10: Power density in the Chacao Channel (Herrera et al., 2010).

The main sources of information on the resource in Chile have previously been discussed, although these are supplemented by information continuously produced by SHOA from its buoy monitoring system stationed along Chile's coast. The information from the SHOA system is available from the institution, although it should be kept in mind that the purpose of this institution is to develop navigation charts and, as such, while the information it produces is useful for assessing energy potential it is not specifically generated for its assessment.

As a result of this, the available literature is rather limited and has not been extensively verified with in-situ measurements of the resource (the studies by Baird & Associates being an exception). However, the ongoing studies are focused on providing measurements to assess the resource directly in order to provide highly important information for the development of power generation projects using marine energy.

Both these studies have been financed by Government agencies (Corfo and Fondef) in partnership with the private sector and a brief description is provided below.

3.2.1 Wave study: Innova Corfo and Instituto Nacional de Hidráulica (INH, 2011)

This study is funded through Corfo's innovation and technology transfer fund (Innova Chile) to the value of approximately MM$740 (£925,000 approx.).

The study is being led by INH with the participation of a significant number of universities and private companies, and a strategic partnership has been established for its purpose.

This study is entitled A Cadastre of the Energetic Resource related to Waves for the support the Evaluation of Energy Generation Projects using Wave Power and entails an assessment of wave power potential along Chile's coast.

The main objective is to obtain a valuation of the wave resource, long-term field campaigns, and calibrated numerical modelling in several zones of the sea surrounding Chile.

Specific objectives include: generating relevant information to allow the production of energy maps for specific locations; determining relevant geo-spatial parameters; improving environmental regulations; and creating tools for being able to evaluate the installation of devices that produce electricity from wave power (both from a technical and financial perspective). In addition to this, INH seeks to build technical and human capacity to facilitate the expansion of these studies to other areas, and also to maintain the monitoring of systems in the long term (INH, 2011).

In order to meet these objectives they will install buoys for measuring wave properties and work on monitoring them, as well as beginning to form a panel of experts to lead this development in the long term.

The results of this study will be available to the public in 2016.

3.2.2 Tidal study: Fondef, HydroChile and Pontifica Universidad Católica (Cienfuegos, 2011)

This study is funded by Fondef, the government funding body for promoting scientific and technological development, through its Pre-Competitive R&D Fund, which funds the research and development of general technologies not mature enough to reach competitive market prices. The value provided by Fondef was around MM$390 (£490,000 approx.).

The study is titled The Evaluation of the Energetic Resource related to Tidal Streams for the Selection and Implementation of Power Generation Devices, and the contract was awarded to HydroChile, who is workeing in partnership with PUC to carry out the technical studies, together with other parties.

The aims of the study set out in Cienfuegos (2011) are to:

- Perform the bathymetric, wave, and tidal studies required to obtain specific knowledge of the seabed and profile the tides in the Chacao Channel area. The specific aim is to determine specific areas where the first test devices for converting tidal energy into electricity could be installed and operated in Chile.
- Combine the field measurements with numerical modelling to reduce the uncertainty surrounding the available and usable energy resource in the Chacao Channel.
- Provide advanced models of the interactions of tidal stream devices.

Once the study is complete, it will be possible to quantify the effect of the devices on the hydrodynamics of the Channel, generating parameterisations that can be used in larger-scale models and making progress towards the development of tools that allow the pre-design of arrays of devices, considering the location and optimal distribution.

The results of this study will be available to the public in 2016.

04 | The environmental and socio-economic impacts of marine energy

>> In today's world, reducing CO_2 emissions, increasing energy security, and using natural resources in a sustainable manner are all important goals for almost every country in the world. However, it is necessary to assess and attempt to measure the social, environmental, and economic impacts that may be produced by the development of new technology, such as marine energy devices, that helps to reduce emissions. This section provides a review of such aspects.

4.1 Environmental impacts

At present, the development of marine energy around the world is still at pilot stage and there is a small number of devices under commercial operation. This means that experience or certainty about the effects of different devices on the marine environment is limited, and this remains the subject of ongoing research and merits further focus in the future. Nevertheless, the progressive and incremental nature of the development of the sector (first prototypes, then small arrays, then larger arrays, etc.) means that it lends itself particularly well to an adaptive management approach.

In Chile there are several projects and activities that work with and modify the seabed for industrial purposes (such as small offshore oil & gas operations, fisheries, or ports) although it is still not possible to determine the effects on the coastline as a result of the development of marine energy in advance.

However, there are some studies that provide a general picture of the impact to be dealt with. One of these studies was carried out by the Intergovernmental Panel on Climate Change (IPCC, 2011) and it includes details of the potential effects of generating devices on the environment.

The IPCC study (2011) gave consideration to the following aspects:

>> Wave energy

- Emission of noise, vibrations (especially during construction and commissioning), and electromagnetic fields that could affect marine fauna. Specific impacts will be related to the communication systems of animals that use noise and vibrations to navigate and locate food.
- Negative effect on the biota (habitats and/or water quality due to potential leaks and pollution).
- Chemical leaks from abrasion (paints and anti-fouling chemicals).
- The visual impact of wave converters is likely to be negligible.

>> Tidal currents

- Environmental effects could be somewhat lower than for wave devices as tidal devices would be located in zones that already have high energy, moving water environments, with low diversity and numbers of species.
- While current technologies have moving parts (rotating rotor blades or oscillating hydrofoils) that may harm marine life, to date there is no evidence of current devices harming marine life (e.g. whales, dolphins, seals, and sharks) This may be partly due to the limited number and duration of device deployments, although it may also be due to slow rotation speeds (relative to escape velocities of marine fauna) compared to ship propulsion.

4.2 Social and economic impacts

The impact of the development of the marine energy industry on society can be studied from several points of view, with the economic point of view being highly significant.

Important economic impacts arise from the creation of an industry for supplying both products (parts and general supplies) and services (housing, transport, boat and vessel rentals) to the marine energy industry.

One of the most important economic impacts in this matter is also a social one, specifically in terms of employment since job creation has a highly positive impact on society.

However, in addition to employment, there is also another impact resulting from the development of knowledge and expertise for specific operations that can subsequently be exported. One example of this is the development of technology on the Orkney Islands in Scotland, which has led to the formation of research units at several universities throughout the UK. The case of Orkney is explored in greater depth in Appendix 1, however for now, it is important to note that together with the economic impact, there is also an element of knowledge creation that can be considered an important social impact.

4.2.1 Marine energy supply chain

The marine energy supply industry (wave & tidal) is related to different sectors of production that must be developed in order to provide the industry with the correct supplies. These sectors include:

>> Steel industry: required for the support and anchoring structures for the different technologies.

>> Ports: upgrade of existing infrastructure and the construction of new ports with the capacity to handle the equipment and structures that will be needed.

- Assembly contractors: these companies are required for the installation and commissioning of the main equipment for both wave and tidal energy converters. Vessels, tugs, diving apparatus, and services are needed for the assembly of the machines, their supporting structures, underwater cables, etc.

- Materials R&D: up to 2012, steel has been the most commonly used material for almost every marine and tidal energy technology due to its reliability and strength. However, steel is also expensive and heavy, and as such, research and development must be undertaken to consider the possibility of using other materials. It is worth mentioning that technology developers are looking for alternatives to steel for future versions of their prototypes as a way to make them lighter and cheaper (Aquamarine, 2011).

- Expertise and qualified professionals: the training of specialised professionals is needed for them to perform the following tasks:

    - Measure the available resource in order to reduce uncertainty and locate the most suitable areas for project development.

    - Carry out planning and design work for the projects (e.g. optimum layouts for arrays of machines or transmission lines).

    - Carry out environmental impact assessments. Since there is still limited knowledge of the impact of this type of energy, it is important to have professionals with knowledge of the local marine flora and fauna, and the conditions of the ocean (biological and chemical) to facilitate the identification of impacts.

Figure 11 shows how these synergies are developed and how they interact with different sectors.

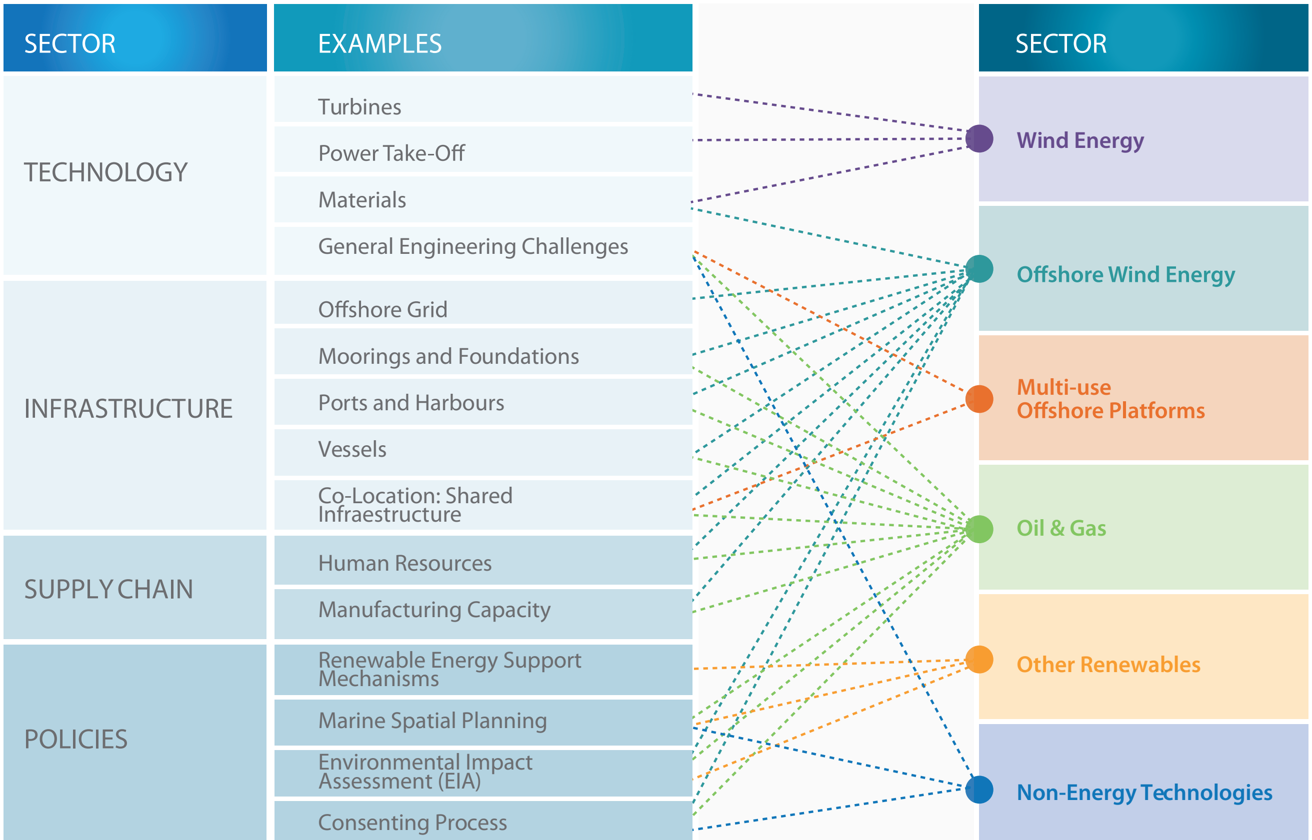


Figure 11: Synergies between different sectors of production. The left columns show the different sectors involved in marine energy, which are linked to the related sectors in the right column (OES, 2011).

It is important that these sectors are able to interact freely, however it is also important to point out that there are a significant number of different actors in this market, meaning that the marine energy industry creates opportunities for other related activities, creating a supply chain that can result in important benefits for many companies.

4.2.2 Observed and projected positive impacts of marine energy development in the UK

Appendix 1 provides a case study of the impact of marine energy development on the Orkney Islands, where EMEC was established in 2003. Benefits can be seen in several areas, the most important being job creation and the local economy. This section discusses some specific figures for these impacts, as well as those projected for the British economy as a whole in light of future plans.

One of the main impacts to be assessed is job creation. In this respect, at present the marine energy industry provides 800 full-time jobs in the UK (Renewable–UK, 2011). Figure 12 shows a breakdown of the direct jobs created by this industry, although it should be kept in mind these are only direct, full-time jobs; indirect jobs are not included.

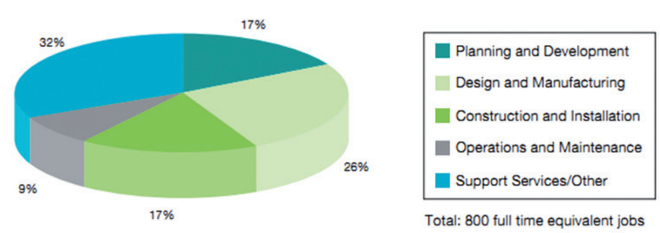


Figure 12: Direct employment in marine energy in UK (Renewable–UK, 2011).

Figure 13 presents a breakdown of the number and type of jobs per MW of marine energy deployed. The majority of these jobs represent the supply of main equipment and its assembly (devices, foundations, electrical equipment, etc.).

The figure provides a separate account of the number of direct and indirect jobs created, direct jobs being those specifically created for qualified employees in enterprises focused on marine energy, and indirect ones being the job opportunities that happen to arise as a result of the investment made in the marine energy sector, including jobs created when an industry/enterprise creates jobs beyond the direct employment for the specific company/ industry.

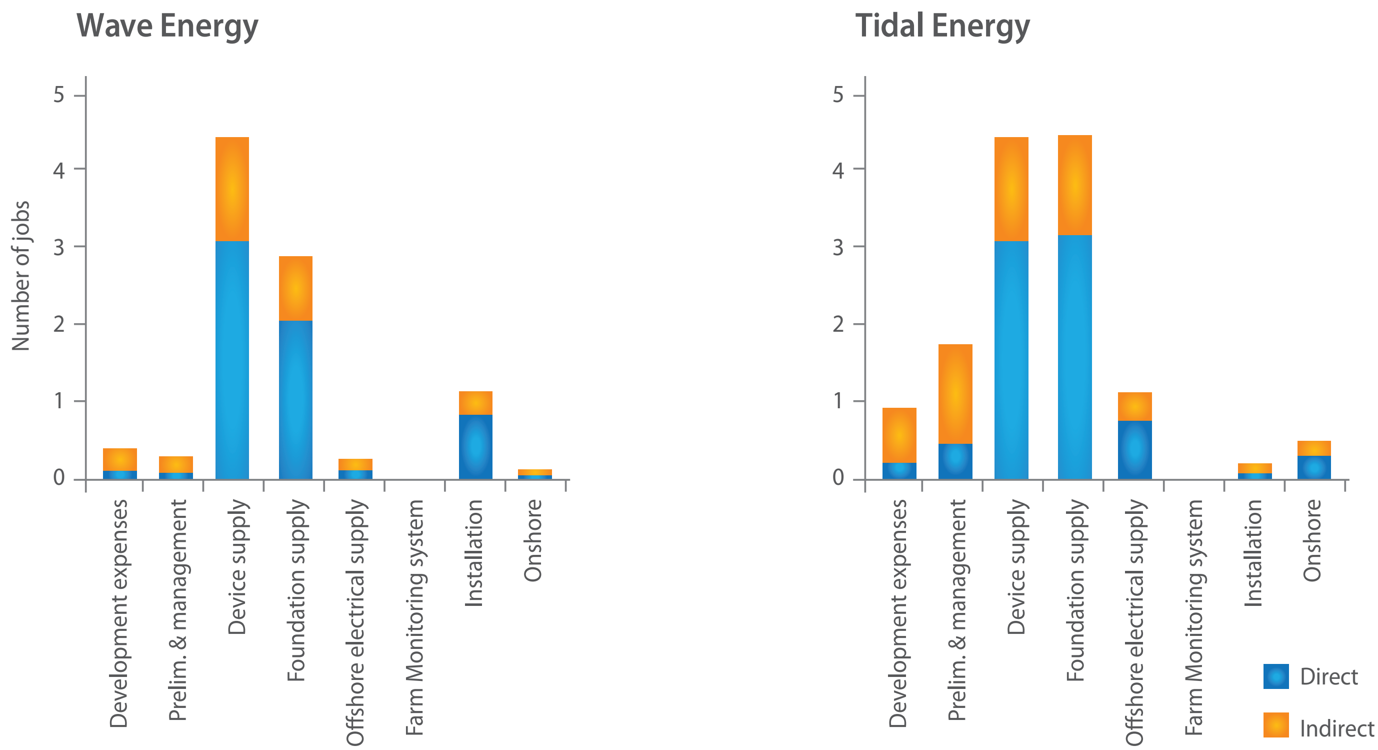


Figure 13: Job creation per MW of installed capacity of ocean energy (EU-OEA, 2011).

Several institutions have made their own estimations of job creation prospects for the future:

- >> The European Ocean Energy Association (EU–OEA, 2010) estimates that before 2020 around 40,000 jobs will be created in Europe, and that in the period 2010–2050, the Industry will create more than 400,000 jobs in Europe. This figure considers the complete supply chain required for the commissioning of these devices.
- >> The Scottish Government (MEG, 2009) estimates that the Industry may create around 2,600 direct jobs in Scotland by 2020, and approximately 12,500 jobs could be created when indirect and induced jobs are taken into account.
- >> Ocean Energy Systems (2011), an initiative of the International Energy Agency forecasts that by 2030, the marine energy Industry will have created around 160,000 jobs around the world, both direct and indirect.

Summarising, EU–OEA (2010) estimates around 10 to 12 direct and indirect jobs created per installed MW of marine energy and, given the gross estimates of potential in Chile of 165 GW for wave power (Garrad Hassan, 2009) and 500 MW for tidal (Atlantis Resources Corp.), and bearing in mind this is a gross estimate and the feasible potential could be significantly lower, at this rate of job creation it is clear that the possibilities for Chile in terms of employment are extremely high.

Nevertheless, it must be considered that the potential estimates are a theoretical assessment of the available resource and these must be complemented by further evaluations of the technical resource and any other constraints, such as protected marine areas where, for shipping or military reasons, grid and port constraints, etc., it may not be possible to develop the potential. In light of this the practical resource available for exploitation may be significantly smaller than the theoretical resource, although it is still expected to be large enough for the creation of an industry and a significant number of jobs.

The economic impact of marine energy development is also an important aspect and some countries already have extensive plans for marine energy. A case in point is the study carried out by Allan et al. (2008) which assessed the impact on the Scottish economy from the installation, operation, and maintenance of 3 GW of wave energy converters in Scotland.

The base case of the study considers the installation of 4,000 Pelamis modules (750 kW each) between 2007 and 2020. Its results show a positive impact on GDP, with the impact peaking at over £400 million in 2020. Furthermore, the net present value of the additional GDP is calculated to be £5,466.2 million.

The results show a positive impact on GDP that continues for over 50 years after the expenditure has been completed. The study also projected that the installations would create over 15,000 jobs by 2020.

This study includes other cases that consider the installation of different devices. In some cases, better results are observed, but for the purpose of this study the base case is presented as a good option, and a means of demonstrating the significant positive effects investment in marine energy technologies can have on an economy.

4.2.3 Projected economic impacts in other countries throughout the world

Many countries have become interested in the development of marine energy technology and the process of assessing the economic impacts of this development has been completed in several of these countries, good examples being France, Ireland, Portugal, Canada, the USA, and New Zealand.

The approaches taken by individual countries differ in terms of the extent of planning and analysis, yet all reach the same conclusions: the potential for job creation and economic activity is real and warrants being pursued further.

In this respect, there are studies available that discuss the plans and benefits for different locations, some of which are described below:

>> Canada and the USA have detailed roadmaps for marine energy development (both issued in late 2011). These roadmaps set out plans and goals, although the economic benefits that arise from the development are not further assessed or considered.

In the USA case, a study by ECONorthwest (2009) estimates the economic impacts of wave energy for the state of Oregon, showing that when taking account of factors such as tax revenues, job creation, and the impact on fishing industry, wave energy offers significant economic potential if the technological and cost barriers can be addressed to allow the industry to progress to a commercial stage.

>> In Ireland the Department of Communications, Marine Energy and Natural Resources (2005) has set out the country's strategy for development.

Together with this, a study from SQHenergy (2010) assesses the economic impacts, concluding that:

- For the scenarios studied, the cost-benefit ratios were highly similar for wave and tidal technologies.
- For all scenarios for wave and tidal technologies, it is clear that benefits in terms of value created are significantly greater than the subsidy costs required.

The approaches taken differ from country to country, with some countries adopting a more comprehensive approach than others according to the impact on local economy, at least in terms of the documentation available. Nevertheless, regardless of the size of the economy, there is a consensus that the impact of marine energy development in local economies is positive and significant.

4.2.4 Overview of the possible effect of marine energy development on the Chilean economy

A significant part of the industries mentioned in Section 4.2.1 are already present in Chile, although they tend to be focused on other sectors of production such as fishing, oil & gas, and ports. There are nonetheless terms and conditions that would facilitate the development of this new marine energy industry. In fact, Chile has good port facilities and a wealth of marine experience along the length of its coast.

As will become clear in Section 7.2, according to preliminary studies of the marine resource in Chile, the main locations with potential for the development of such projects are next to ports and cities with large industrial capacities, which would create a favourable situation for the development of marine energy in Chile.

On the other hand, Chile also has large companies in the steel industry and shipbuilding, and manufacturing maintenance depots that would facilitate the manufacture of devices for use in marine energy, or at least a large part of their constituent parts, hence further favouring the development of the industry, job creation in Chile, and even suggesting potential scenarios in which the country could be a regional pioneer.

However, it is essential that Chile promotes and gives priority to its own technological development through research and activities in partnership with universities, government agencies, and private companies. This is fundamental to the development of the marine energy industry since it is the major technological developments that pioneering countries have made in marine energy, together with their significant resources, that has enabled them to achieve this status.

The effects on Chilean economy in terms of industrial activity and job creation could be as extensive as those described by Allan et al. (2007), although this would be dependent on the extent to which technological development is encouraged by the government, an issue discussed further in Chapter 7.

4.2.5 Opportunities for creating South American supply chains

Although Chile has a large industrial potential that could be used for the development of the marine energy industry, neighbouring countries such as Brazil and Argentina, which have more developed manufacturing industries (particularly Brazil), could participate in the development of a marine energy industry through the creation of consortia and cooperation links.

Both countries (Brazil and Argentina) have a significant potential marine resource, particularly in terms of tidal stream projects (see Figure 2), meaning that developing a marine energy industry may also be attractive to them.

This cooperation could be comparable with the case for certain European countries, which, through the European Ocean Energy Association (EU-OEA) represent the interests of the sector through regular contact with European institutions (the European Commission, the European Parliament, etc.). Furthermore, the association is focused on promoting the development and use of these technologies through political, legislative, educational, and communication activities (EU-OEA website, 2012).

In this way, thanks to the existence of large industries in the area, combined with the resource that is present, the European model may be applicable in South America, for the joint development of the marine energy generation industry.

In each of the countries mentioned (Chile, Argentina, and Brazil) there is significant industrial capacity, across a wide range of industrial sectors with direct synergies with the marine energy sector. Hence, in the future, steps should be taken in favour of regional integration for technology development.

These synergies can work in Chile and South America, and moreover, they have worked in other cases. Examples of large-scale industries and companies in the area include:

- Chile, Argentina and Brazil have well developed steel Industries. There are strong and experienced companies who sell all kinds of processed steel for reinforcement structures in the construction sector, steel structures, stainless steel parts, pipes, and shipbuilding and maintenance.

  The steel production figures published by the World Steel Association for 2011 are 1.62 million tons for Chile, 5.7 million tons for Argentina and 35.1 million tons for Brazil; taken together, the countries represent around 3% of the total global production.

- Mining is a major activity in Chile, and there are several industries that service the mining companies. With respect to marine energy, mining could represent synergies and a major energy consumer.

  The annual production of metallic minerals for 2011 was around 20.5 million tons, copper being the main mineral, with a production of 5.5 million fine metric tons, with a value of more than USD $45,000 million (The Chilean Ministry of Mining, 2011 production).

- Chile has limited oil & gas resources and operations, however Brazil and Argentina have developed significant expertise in this area.

  Oil & gas production for the countries is as follows:

  - Chile: 244 thousand m³ of oil and 1,793 million m³ of gas. (Chilean Ministry of Mining, 2011 production).
  - Argentina: 35,268 thousand m³ of oil and 47,097 million m³ of gas (Argentinean Oil and Gas Institute, 2010 production).
  - Brazil: 122,177 thousand m³ of oil and 24,000 million m³ of gas (Brazilian National Oil, Natural Gas and Biofuels Agency, 2011 production).

- Brazil and Argentina have large companies that produce hydropower, wind, and steam turbines. These companies have the highest quality standards and compete with the major European companies, meaning their capacity and expertise is highly significant and could potentially be used in the development of marine energy.

- The development of IT companies is also significant in these three countries and it is envisaged they will be able to design and operate all the control systems required for the marine energy sector, as they have successfully built these systems for other energy projects.

05 | Regulations and permits: the Chilean system and the UK experience

>> This section provides an overview of the consenting procedure followed in the UK for awarding benefits, and the existing regulations in Chile and the UK for use of seabed and coastal land are compared, together with the different approaches for environmental impact assessments.

5.1 The consenting process

Incentive measures for more expensive energy sources, regardless of their type, can result in significant levels of resources being invested at government level. In this respect, for incentive measures to be established or for regulations to be changed in favour of a new technology, there must be a consenting process that agrees the national interests and discusses financing policies for renewable energies, as well as regulatory changes.

Before the incentive measures are discussed, the consenting process in Europe is described in order to explain the rationale behind the policies they have implemented for the development of marine energy.

There is legislation at the European Union (EU) level in the form of EU Directives which is applicable to marine energy developments. Each member state within the EU is responsible for transposing EU-level legislation into their respective legal system, as well as implementing their own licensing processes for the consenting of projects. This means that the regulatory and legislative landscape varies largely across countries and while the national legislative frameworks may reflect the EU Directives for marine energy, there are often variations in how countries administer such legislative requirements and many associated policies are at different stages of development in different countries.

As identified by the recent EU-funded coordination action project, Offshore Renewable Energy Conversion platform Coordination Action (Orecca), there are three principal factors that illustrate how developed the regulatory/legislative frameworks are in each country, and these are detailed in Table 2. The table shows that some countries (such as Scotland and Ireland) are at further stages of putting a Maritime Spatial Plan (MSP) in place, implementing a 'one-stop-shop' for marine consenting, and establishing a Strategic Environmental Assessment (SEA(1)) for the marine energy sector. These are important factors in facilitating its development.

Country	SEA(1) in place for marine energy?	MSP in place?	Streamlined or 'one-stop-shop' marine consenting process?
Belgium	No	Yes	No
France	No	Partially	No
Germany	Partially	Yes	Yes
Ireland	Yes (provisionally)	Preparatory steps	Pending
Italy	No	No	No
Netherlands	No	Yes	No
Spain	No	Preparatory steps	No
UK (excl. Scotland)	Pending	Partially and pending	Partially
Portugal	Partial	Under development	No
Norway	No	Partially	No
Denmark	No	Partially	Yes
Scotland	Yes	Partially	Yes

Table 2: National policy landscape across Europe: matrix showing three important factors for supporting the development of the marine energy sector analysed across Europe (Orecca, 2011).

An SEA(1) is important prior to commercial-scale development to ensure that the environmental effects of significant deployments on regional and national scales are taken into account. Similarly, having a detailed MSP in place, developed in consultation with all stakeholders, is important to manage the interactions of marine energy deployments with other sea users in the most efficient way possible. A streamlined consenting system is important in reducing the costs and delays associated with obtaining all the necessary permits and licenses for a marine energy project (in comparison to a convoluted consenting system that could pose a significant barrier to the development of the sector).

An "adaptive management" or "deploy and monitor" approach is often advocated as important for the regulation of the marine energy sector. The offshore renewable energy sector lends itself well to this approach where data obtained from early deployments is used as a basis for regulatory decisions due to the incremental nature of deployments in the sector. Moreover, as the sector moves from prototype devices to small-sized, and eventually medium- and large-sized, arrays there is considerable scope for learning and the gathering of information. Regulators and legislators should be able to take comfort in this. In this vein, demonstration projects should be encouraged to obtain reliable information to inform future policy, regulation, and legislation.

Within the UK, there are differing degrees of devolution between the UK Government and the Scottish Government, the Welsh Assembly Government and the Northern Ireland Executive with respect to marine energy regulation and consenting. Therefore there are differing degrees of integration between the regulatory landscape and consenting schemes in each constituent part of the UK.

As illustrated in Table 2 above, the UK (and in particular Scotland) is making good progress with regards to having a fit for purpose regulatory framework and consenting scheme in place for the marine energy sector.

As of 2011, the UK Department for Energy and Climate Change (DECC) was in the final stages of developing a comprehensive UK Offshore Energy SEA(1) covering the Renewable Energy Zone and territorial waters of England and Wales, (DECC, 2011) which includes wave and tidal stream energy. This SEA(1) is important and aims to help inform licensing and leasing decisions by taking into account the environmental implications of multiple deployments. Scotland is more advanced in this respect and the Scottish Government conducted an SEA(1) specifically focused on wave and tidal stream energy deployments in Scottish territorial waters in 2007.

In 2009, the UK government established the Marine Management Organisation (MMO) which is responsible for most of the marine consenting process for wave and tidal stream deployments. However, the procedures are not fully streamlined and the responsibilities for consenting are shared with the Infrastructure Planning Commission (IPC), which is soon to be replaced by the Major Infrastructure Unit, and the Welsh Assembly Government, depending on whether a project is greater than 100 MW in size and whether it falls within territorial waters (Seaenergy 2020, 2011). Scotland is more advanced in this respect and has a streamlined, one-stop-shop system in place for marine consenting, namely Marine Scotland, established in 2009 and responsible for issuing all necessary consents/licenses for renewable energy projects in Scottish waters, both within territorial waters and in the wider Exclusive Economic Zone.

Substantial progress towards having a comprehensive MSP in place has been achieved in the UK, where the DECC has published a Marine Policy Statement (DEFRA, 2011) which will provide the overarching policy framework for the UK marine area. Similar to the rest of the UK, Scotland does not have a statutory MSP in place, however, in 2010 the Scottish Government and Marine Scotland published a non-statutory MSP for the Pentland Firth and Orkney Waters region where much of Scotland's wave and tidal stream resource is concentrated (Marine Scotland, 2010). This document was published in advance of the implementation of a statutory MSP to guide developments in the region and also provides guidance specifically focused on marine energy projects.

This consenting procedure has made incentives necessary, since it would not be possible to fulfil the national plans for marine energy if there were no schemes to offer financial support.

In Chile there is currently an early-stage consenting process: in recent years, conferences have been organised, funding has been awarded for preliminary studies (see Section 3.2), companies have been following the development of technology abroad, and Government agencies and Ministries (such as CER and the Ministry of Energy) are studying the steps to be followed to decide if and how marine energy should be developed in the country.

This process will necessarily take some time to establish concrete measures, however it is a positive sign that there is a certain activity in this respect, and that the consenting process has already started.

5.2 Land and seabed usage

Marine energy projects need to use a determined physical space in order to install the devices for energy production in the sea.

The way in which an area of seabed is made available varies from one country to another, so it must be addressed in different manners in order to comply with the local regulations and grant space on which the devices can be installed.

5.2.1 Chilean regulations and permits

Chile has not been through a consenting process such as the one described for Europe in Chapter 5. As such, this section provides a brief overview of the Chilean regulations for marine concessions and seabed useage in order to consider current legislation and the permits required, and define the extent of the changes that must be included in order to incentivise the development of marine energy.

a. Coastline usage and planning

Geographically, Chile is a coastal country whose coastline stretches for approximately 6,435 km. The country has created a National Policy for Coastline Usage (Política Nacional del Uso del Borde Costero, PNUBC), to ensure the sustainable management of coastal and ocean areas while maintaining a long term balance between environmental, economic, social, cultural, and recreational objectives. Part of the instruments established by the PNUBC to help it reach its objectives is the duty to set out Regional Coastline Planning Instruments, or Zoning.

The above is relevant to this report insofar as, prior to developing any project located on the coastline, the authority must review its compatibility and consistency with the Coastline Planning Instruments in force or under development.

Chile is divided into 15 regions (detailed in Appendix 3), of which only the Metropolitan Region does not have a coastline. To date, of all the Coastline Regions, only two (the Coquimbo and Aysén regions) have an approved and valid zoning plan. The remaining coastal regions are in different stages of drafting and analyzing their zoning plans, although it is expected that significant progress will have been made in this area by the end of 2012.

The procedure to draw up Coastline Zoning is carried out regionally through Regional Commissions for Coastline Usage (Comisión Regional de Uso del Borde Costero, CRUBC) responsible for developing a regional zoning proposal consistent with the PNUBC to be subsequently presented to the National Commission on Coastline Usage (Comisión Nacional de Uso del Borde Costero, CNUBC) which reports to the Subsecretary of the Armed Forces of the Ministry of Defence. The CRUBC is comprised of the an important number of political and social actors (see Appendix 2) such as the Regional Governor, councils, representatives from aquaculture, tourism, fishing, the ministries for the Economy, Urban Planning, National Assets and Transport, and the Navy.

Given the importance of coastline zoning in the development of the marine energy industry, it is concerning that the CRUBC does not have a representative from the Ministry of Energy and the generation companies, including hydroelectric, off-shore wind power, and marine energy generators. As will be explained further on in the recommendations in Chapter 8, it is suggested that the necessary regulatory modifications to incorporate representatives of the Ministry of Energy and industry in the CNUBC and CRUBCs are made. In this respect, an important step was taken in late 2011 and since then, a representative of the Ministry of Energy has been included in the CRUBC. Even though this representative still does not participate in the decision making process (is not entitled to vote), this nonetheless represents progress, and further steps may be taken in the future in this respect.

In order to determine the Coastline Usage Zoning the CRUBC analyzes different environmental, social, economic, political and strategic factors to finally establish areas of "Preferred Usage" for the development of certain activities or industries (e.g. conservation, aquaculture, tourism, and ports) and the criteria in order to determine compatibility with other uses in these areas. Only in very exceptional cases will the Planning Instruments determine areas for exclusive usage.

This leads to the conclusion that, although the zoning instruments in force or under development do not prohibit the development of projects such as those analysed above, they will nonetheless face the challenge of having to demonstrate their compatibility with the preferred usages in existence according to the criteria that have been established without knowledge of the specific benefits and impacts of this industry.

Furthermore, considering that regional zoning instruments are dynamic and under permanent review, active participation in these processes is recommended for the future. The designation of preferred areas to develop these types of projects should be analysed.

b. Marine concessions

The Chilean regulations establish that maritime concessions are classified by the object requested, as follows

- >> Concessions for beachfront property
- >> Concessions for beaches
- >> Concessions for rocks
- >> Concessions for water portions
- >> Concessions for seabeds
- >> Concessions interior and exterior bays.

Although there is currently no experience in this respect, depending on the technology to be used, marine energy projects must request a maritime concession for water portions (when they wish to install a stable floating element in the sea), a concession for seabeds (when the generating unit is located on the sea floor) and/or a concession for beachfront property (when a turbine is installed outside the sea on the beach). This distinction does not affect the procedure that is applicable as this is determined by the classification of maritime concessions reviewed below.

For maritime concessions to be awarded and processed, they must be classified according to their period of duration, which shall not exceed 50 years, and the amount of capital to be invested in the concessions. Hence there are four types:

>> Major maritime concession: a concession awarded for more than ten years or involving an investment of more than UTM 2,500 (£124.000 approx.) according to a formula calculated by the Ministry of Defence.

>> Minor maritime concession: a concession awarded for more than one year and less than ten, or involving an investment equal to or less than UTM 2,500.

>> Permit or authorisation: maritime concession of minor importance for transitory usage not exceeding one year.

>> Destination: maritime concession granted by the ministry to government services to fulfil a specific objective. Destinations do not entail a charge, and do not have a specific purpose, although there are certain restrictions in the sense that a government institution must execute any work carried out at the leased location.

Given the current active legal framework, it is highly likely that due to the duration of the projects (generally projected as 30 years) and the level of investment involved, it will be necessary to request a major maritime concession.

Of all the types of maritime concessions, it is worthwhile noting the "Destination" category, which applies when the request for a concession stems from a public service (e.g. the Ministry of Energy, CER). This category would become relevant if the authority in question decides to promote this type of technology by developing a testing centre and/or a pilot project on its own initiative. Nevertheless, it should be noted that the destination category only currently applies when the government is to execute any works in that area, and as such, this may have to be expanded to encompass private companies working in the Government's interest.

5.2.2 The UK case for seabed leasing

Local regulations regarding use of the seabed for this type of project depend greatly on the local governments. For the purposes of this report, the case of the UK will be explained and analysed.

The Crown Estate (CE) is the owner of the UK seabed out to the 12 nautical mile territorial sea limit and under the Energy Act 2004 has the rights to license the generation of renewable energy on the UK's continental shelf up to 200 nautical miles. The CE is committed to working to successfully exploit the UK's significant wave and tidal energy resources and to date has helped facilitate the establishment of test and demonstration facilities for wave and tidal stream energy technologies at EMEC in Scotland and Wave Hub in England. As of October 2011, the CE had already held two leasing rounds:

>> 2010: Leasing round for wave and tidal stream sites in the Pentland Firth and Orkney Waters strategic area in Scotland, resulting in 10 sites leased with 1.6 GW of planned capacity by 2020.

>> 2011: Further Scottish leasing round (to allow developers to compete for the Saltire Prize, a £10 million prize to accelerate the commercial development of marine energy (Scottish Government, 2011), resulting in sites leased in waters around Scotland.

The CE also welcomes applications for demonstration leases for projects with a capacity of up to 10 MW. Demonstration leases have recently been awarded to sites including a site in Northern Ireland and a site in Wales, and further leasing rounds are planned for the future.

The currently leased sites in Scotland are detailed in Appendix 4.

5.3 Environmental permits

At present, regardless of the nature of the resource to be exploited, every energy project has to follow strict procedures in order to show it does not represent a hazard for the environment. In this respect, determining the environmental impact assessments that must be undertaken for marine energy projects is highly relevant due to the limited experience in the area and consequently, as for other types of projects, the environmental authorities will be required to work together with the technology developers to find a solution to this problem.

This section discusses the environmental regulations in Chile and describes the procedure followed in the UK.

5.3.1 Chilean environmental regulations

Chile's environmental regulatory framework is set out in the Environment Act, General Matters (Ley de Bases General del Medio Ambiente, LBGMA) (Act 19,300), which came into effect in 1994 and was most recently reformed by Act 20,417 (2010). LBGMA sets out the Chilean environmental institutional structure whereby the Ministry of the Environment is responsible for determining environmental policy, the Environmental Assessment Service (Servicio de Evaluación Ambiental, SEA(2)) manages the environmental impact assessment system for projects, the Environmental Regulator is responsible for monitoring compliance with environmental laws, and the Environmental Courts penalise those found to have committed crimes against the environment. Here it is worth noting that the last two institutions have not yet been implemented, although the process is expected to begin during this year (2012).

The Chilean system is composed of two routes by which project representatives can submit initiatives to SEA(2): the first, and most straightforward, is the Environmental Impact Declaration; the more demanding route is the Environmental Impact Study. The main differences between the two is the degree of detail required in terms of the information provided, the time frames involved, and opportunities for public participation. The reasons a project might be required to submit an impact study to SEA(2) are set out in Article II of LBGMA and are linked to the specific effects or impacts the project or activity could have on the environment.

In addition to the environmental permit or Environmental Qualification Resolution, most projects must apply for and obtain other sector permits in order for development to proceed. Permits involving environmental matters are known as Environmental Sector Permits and the debate on environmental matters is conducted around the framework of the project's assessment by SEA(2). The resolution approving the project indicates the individual permits to be awarded to the project developer, and, since these have already been approved as part of the procedure mentioned above, they may not be denied on environmental grounds. Sector permits that do not involve environmental matters should be processed directly by the respective public service.

Environmental practice has created an instance that is not specifically included in LBGMA, but which is very common nowadays, namely the Consultation on Environmental Relevance, whereby a project developer who is uncertain as to whether their project should be submitted to SEA(2) can request opinion on the matter. In general, the need to present a consultation stems from a public service awarding a sector permit that can only be awarded directly if the project does not need to be submitted to SEA(2). This consultation requests confirmation that the project is in fact exempt from assessment.

Given the lack of precedent the sector authorities will face when called to award the necessary permits to develop the first marine energy projects, it is highly likely that they will request a relevance consultation even where the specific project does not exceed 3 MW and is not located in an area under official protection.

In this respect, it is necessary to educate the assessors and other competent public services on the particularities of marine energy so as to prevent them from requesting unjustified relevance letters and/or ensure these are resolved with a good knowledge of the industry. This will avoid projects that do not need to be submitted being presented to the SEA(2).

More details of the Chilean environmental regulatory framework can be found in Appendix 2.

5.3.2 UK procedure for environmental impact assessment for marine energy projects

As part of the consenting process carried out in the UK described in Section 5.1, decisions must be taken in order to assess the environmental impact of the deployment of any marine energy devices and ensure the operation of EMEC would not create an environmental hazard.

Given the fact that no experience of the operation of any of the devices was available, the government was faced with two choices when it came to permitting the deployment of new devices:

>> Perform a strict and detailed theoretical assessment of the possible impacts that each different device to be deployed might have on the environment, and draw up mitigation plans based on the theoretical assessment.

>> Develop guidelines and considerations for the issues related to the provision of the test facility in terms of infrastructure and site usage, together with generic considerations for the types of devices envisaged for deployment, and complement this by establishing an extensive environmental monitoring system in the area around the tested devices.

The theoretical assessment would be in line with the assessments performed for other sources of energy, however, since there is no experience for marine energy devices, the impacts considered would be only assumptions.

When assuming environmental impacts for a study, a conservative approach would have to be taken. This would mean detailed studies that may take a significant amount of time, and although several impacts may be identified, it is possible that others remain unforeseen, or even that those expected do not occur.

In this sense, taking an "adaptive management" approach for developing general guidelines and plans together with a strong system for monitoring environmental impacts appears to be reasonable, even though slightly more risky.

This approach is often advocated as being important to the regulation of the marine energy sector, and it was the approach followed at EMEC, where every site is evaluated and general considerations are made depending on the technology being tested. An extensive monitoring plan is then followed during the operation of the device in order to ensure any environmental impact can be observed, addressed, and dealt with.

Reaching an agreement on the approach involved a process of negotiating and consenting, but after reaching this point, the approach has been observed as a positive way to deal with this challenge, allowing the development of technology without causing unnecessary delays, but also giving the proper importance to studying the environmental effect of the devices' operation.

In general, the offshore renewable energy sector lends itself well to this approach, whereby data obtained from early deployments forms the basis of regulatory decisions, due to the fact that deployments in the sector are incremental.

As the sector moves from prototype devices to small arrays, and eventually to medium- and large-sized arrays, there is considerable scope for learning and gathering information. Regulators and legislators should be able to take comfort in this, and, in this respect, demonstration projects should be encouraged to obtain reliable data for the purpose of informing future policy, regulation, and legislation.

06 | Incentives and project finance tools for developing marine energy

>> To date a significant proportion of the developments in the marine energy sector have been concentrated in Europe. A number of European countries have made firm commitments to the sector and a range of support policies have been put in place. This chapter will present and analyse the current landscape for the marine energy sector in Europe in terms of production incentives, regulations, and project finance.

Particular emphasis is placed on the UK, which has shown the most significant commitment to the marine energy sector in recent years. In the following sections, the UK is considered as a case study from which Chile can potentially learn valuable insights.

6.1 Incentives for renewable and marine energy

Without government support, wave and tidal stream technologies are not currently competitive in terms of the cost of energy alone. However, the sector has the potential to deliver emissions reductions, increased energy security, and economic benefits, meaning there is therefore significant governmental interest in the sector.

This section presents an overview of the incentive mechanisms used throughout the world.

6.1.1 Current financial support mechanisms throughout the world

In order to discuss the possible incentive mechanisms that could be used in Chile, a description of the main incentives used throughout the world is presented below.

a. Feed-in tariff

This is an instrument that encourages the development of Non-Conventional Renewable Energy (NCRE) by ensuring a special fixed price for the energy sales it generates. This means that the consumers (or government) will be required to purchase renewable energy at a determined price over and above the spot price (Barrosso et al., 2010). This system allows the development of the various technologies through the differentiation of tariffs by technology, and also provides incentives for new actors to join the market (Central Energía, 2010).

This scheme is one of the most commonly used, and has been broadly implemented in countries such as Denmark, Germany, and Spain (Barroso et al., 2010).

b. Quota system

This system sets objectives/requirements for an amount of renewable energy to either be sold by the producers or bought by consumers and fines must be paid if the target is not met. In certain countries quotas can be traded, generating Renewable Obligation Certificates (ROCs), also known as Green Certificates.

The value of ROCs is proportional to their demand, which encourages free competition and the implementation of the cheaper NCRE technologies.

However, the system favours large-scale power producers who can leverage economies of scale in terms of project development, and it does not provide any incentive to new technologies, since the most developed and cheapest have more chances of being commissioned.

This system is most similar to the one implemented in Chile, and has also been implemented in the UK, and in some states in the USA (Barrosso et al., 2010).

A quotas system in its simplest form is not technology specific and therefore incentivises the cheapest NCRE technologies. However, as has been demonstrated in the UK and Scotland, and as will be explained in the following section, with the banding introduced to the Renewables Obligation, it is possible to design a quotas system that incentivises different technologies.

c. NCRE auctions

An auctions system works by setting specific targets (e.g. installed capacity and amount of energy) for given technologies over a determined period of time (usually between 15 and 25 years). Invitations are then sent to interested developers or power producers whereby they can bid with a volume of energy to be sold at a given price and by a specified delivery date. The offers with the lowest prices are awarded the contracts and must implement the associated technologies (Osinergmin, 2011).

Using this scheme it is relatively easy for a government to set targets and stimulate private sector interest in investing in technology development since the government's willingness to pay is enough to trigger private interest.

Some disadvantages of this scheme are that the resulting energy prices may not reflect generation marginal costs, and that the generators who win the auctions have limited exposure to market signals and hence lack incentives to ensure the efficient operation of their plants (Osinergmin, 2011).

Brazil and Peru are among the countries that have implemented this system.

Figure 14 below shows the mechanism for awarding contracts in a normal auction.

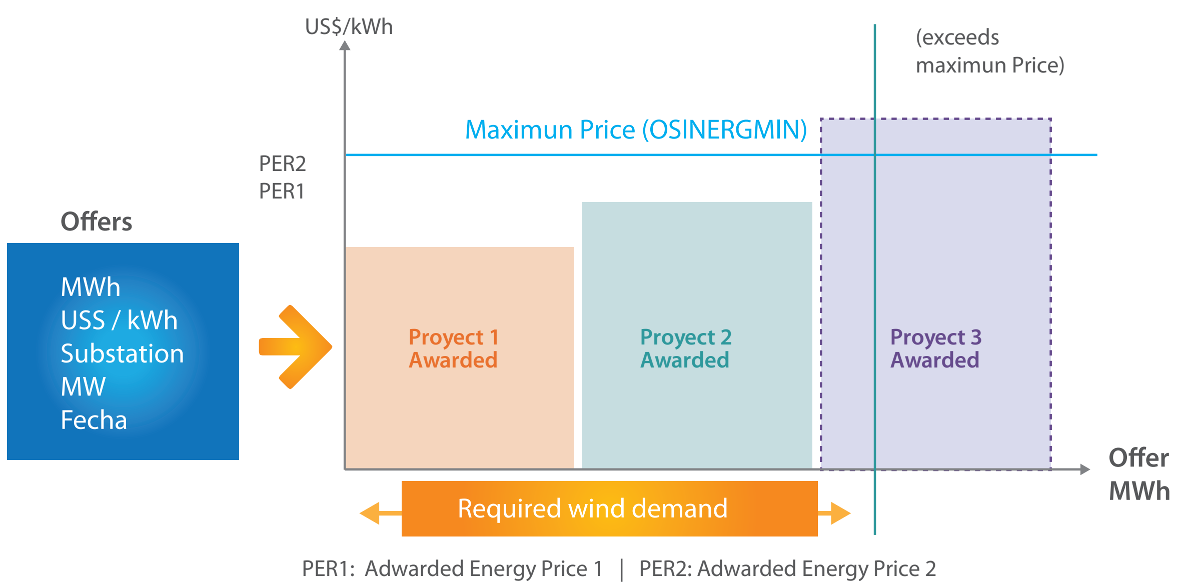


Figure 14: Example of an auction for wind power. The projects awarded are those whose price is below the maximum price set for the auction and that are within the demand established for wind power in the specific auction (Osinergmin, 2011).

In general, financial support mechanisms to support an emerging sector can be grouped into two types: technology push and market pull.

Technology push support mechanisms focus on supporting the development of promising technologies, ignoring prices and other changes in economic conditions that affect the profitability of innovations. Technology push support mechanisms (including mechanisms such as R&D programmes, research grants, etc.) focus on capital grant support.

Market pull support mechanisms focus on changing market conditions to create opportunities for firms to invest in innovation. Market pull instruments work to achieve their objective by increasing demand for technologies with particular characteristics, and this in turn is expected to result in a generally higher level of innovation in response to shifts in demand patterns. Market pull type support mechanisms (including feed-in tariffs, emissions trading schemes, and certificates such as the UK's ROCs focus on revenue support.

Many authors argue that both technology push and market pull support measures are important constituent parts of a successful innovation system to develop new technologies and they highlight the importance of striking a balance between the two types of support.

Market pull mechanisms are important to ensure the large-scale deployments necessary to build supply chains, facilitate learning by doing in terms of deployment, operations and maintenance, and leverage economies of scale to drive down costs.

Technology push mechanisms are necessary to ensure that research is also carried out for technologies that could result in significant step change improvements for the sector, both in terms of performance or cost (i.e. disruptive technologies).

Thus a successful incentive scheme should have both types of measures, ensuring there is a balance between them in order for technology to be developed with a reasonable contribution from the government or institution responsible for providing incentives.

6.1.2 Financial support mechanisms in Europe

On a European level, there is significant variation in the financial support mechanisms available for the marine energy sector, as shown in Figure 15.

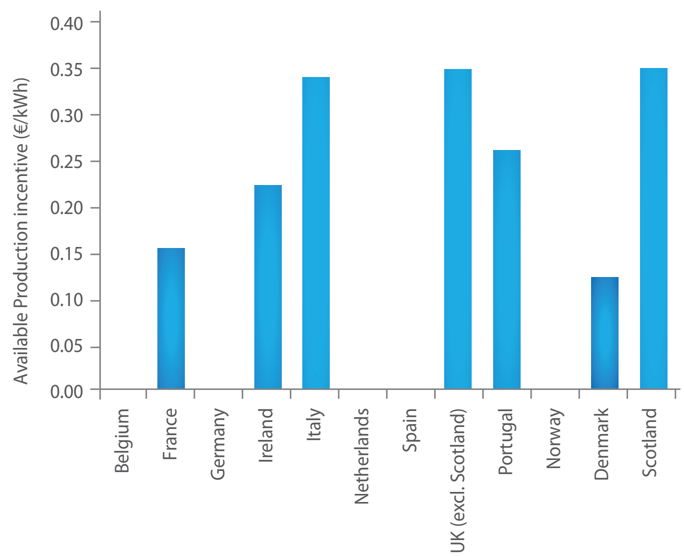


Figure 15: Chart showing PBIs for the marine energy sector in countries across Europe. Note that where appropriate, the data includes an assumed Europe-wide wholesale electricity price of €0.07/kWh. Where there is no production incentive available above the wholesale price, the graph reports zero. (Orecca, 2011)

It is clear that not all countries in Europe have a Production Based Incentive (PBI) in place for marine energy, however it is also important to note that not all countries have a significant marine energy natural resource available. A large majority of the wave and tidal stream resource in Europe is concentrated in a relatively small number of countries, particularly the UK, Ireland, Norway, France, Italy, Portugal, and Spain.

In addition to the fact that not all countries have a PBI in place for marine energy, the variation in the level of the PBIs in place across Europe is also significant. The UK, Scotland, Italy, Portugal, and Ireland all have a high PBI, taking account of the emerging status of the ocean energy sector and setting a strong market signal for the sector which will help to attract investment and accelerate development. The funding landscape, particularly in terms of available production based incentives, is an important factor in determining how attractive the sector is as an investment target and for capitalising on the opportunity it presents.

In the UK the incentive system for renewable energy is based on certificates that may be traded on the green obligations market.

The UK Renewables Obligation scheme provides a supplementary payment to renewable electricity generators over and above the market price for energy. The scheme is market based, with energy suppliers being required to obtain an increasing percentage of their electricity from renewable sources. The current average price of a ROC approximately £48/MWh over and above the wholesale price of electricity.

The UK government has banded the obligations scheme to ensure both wave and tidal stream projects are eligible to receive 2 ROCs/MWh of electricity generated (a recent banding review will see this rise to 5 ROCs/MWh for both wave and tidal stream technologies from 2013). In Scotland, the Renewables Obligation (Scotland) has altered the banding so that wave and tidal stream energy projects are eligible to receive 3 and 5 ROCs/MWh, respectively (planned to rise in line with the UK banding of 5 ROCs/MWh for both wave and tidal technologies from 2013). In both the UK and Scotland, renewable electricity generation from all sources is supported by the obligation scheme, although wave and tidal stream energy technologies receive additional support.

6.1.3 Financial support mechanisms in Chile

A complete description of the Chilean regulatory framework for energy and NCRE is included in Appendix 2 and a brief description of the system of incentives for NCRE is provided below.

The main tool for promoting NCRE in Chile is the legal imposition of a quota or minimum percentage of energy from NCRE sources. The main features of this instrument are set out in Article 150 bis of the Electrical Services Act (Ley General de Servicios Eléctricos, LGSE) and are summarised below:

- Mandated companies: Electricity companies that make withdrawals from the system in excess of 200 MW.
- Contracts signed after 2008: The obligation of the percentage or quota is only applicable to energy contracts signed after 2008.
- Gradual minimum percentage 2008–2024: The NCRE quota is to increase gradually over time, starting at 5% in 2014 and rising to 10% in 2024, as shown in Figure 16.

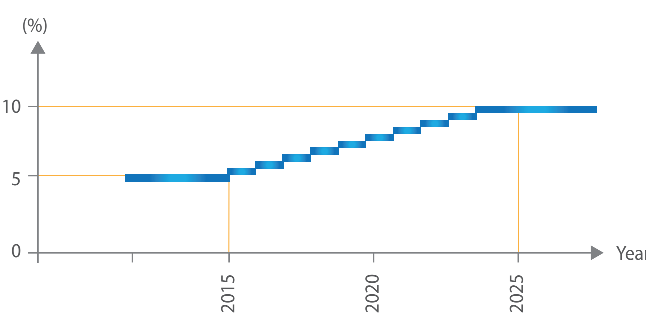


Figure 16: Gradual increase of legally required % of NCRE in Chile.

>> Form of compliance: Can be through direct or indirect generation from NCRE sources, an important aspect of the regulations that allows small NCRE generators to sell their production and/or NCRE attribute to electricity companies with withdrawals above 200 MW.

>> Possibility of selling NCRE surplus.

>> Charge or fine for failure to comply: UTM 0.4 (£20.30 approx.) per MWh of deficit based on the entity's obligation, with the charge increasing to UTM 0.6 (£30.50 approx.) per MWh if the company repeatedly fails to meet its obligation over the next three years.

Figure 17 includes a table prepared by the Economic Load Dispatch Centres for the grids of Chile's Central and Norte Grande regions (CDEC–SING and CDEC–SIC) in partnership with the Corfo CER. It shows the behaviour of injections into the grid by NCRE sources in relation to the legal percentage or quota in the past year (2011).

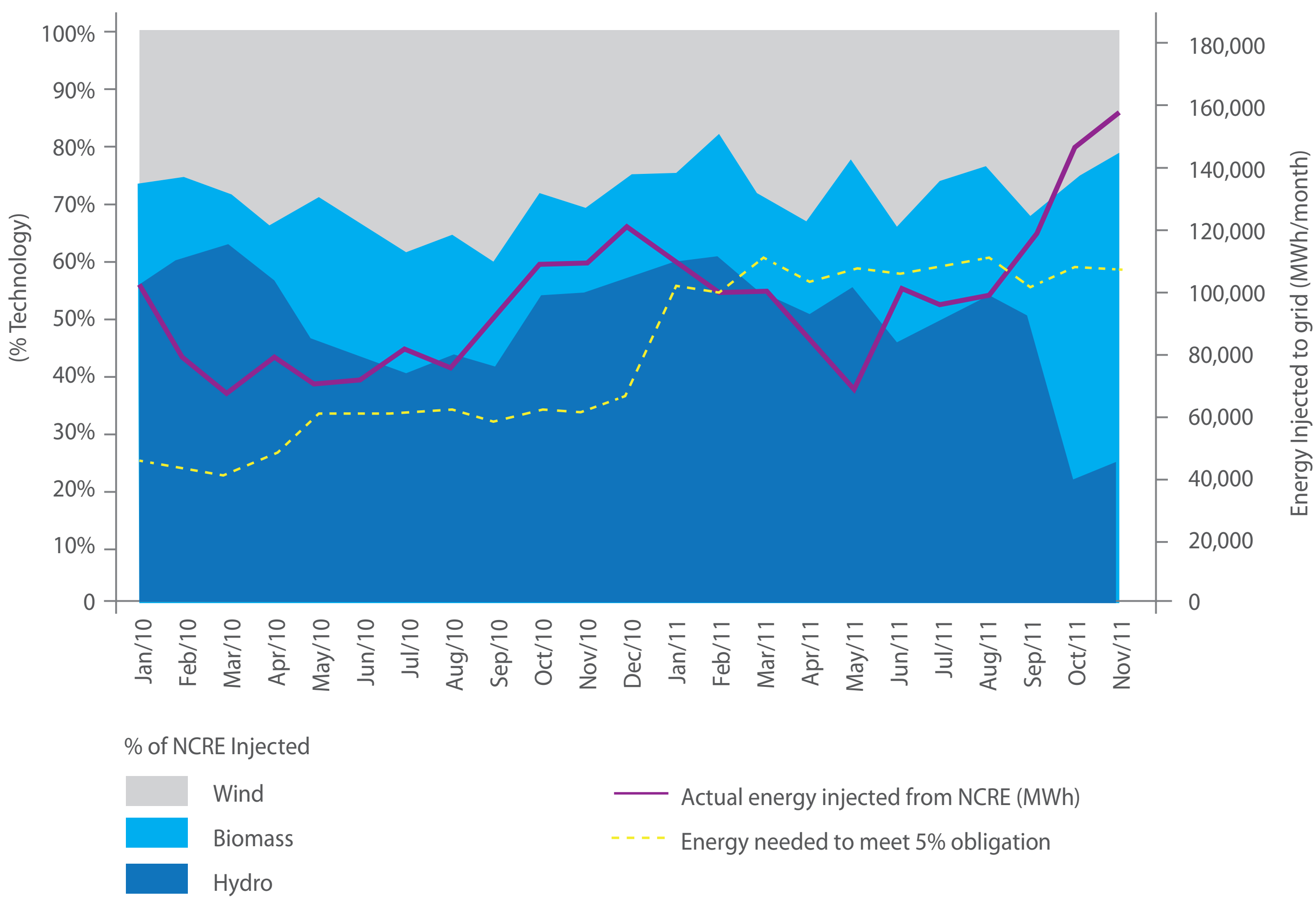


Figure 17: NCRE injected to the grid between January 2010 and November 2011 (CDEC SIC/SING, CER, 2011).

Future marine energy projects can take advantage of this legal incentive by signing energy supply contracts and/or selling the NCRE attribute to companies required to meet a minimum generation percentage using NCRE sources that cannot meet this obligation using their own sources.

A few years have passed since the implementation of the instrument and it is under continuous review in order to determine its effectiveness in terms of accelerating NCRE development. Congress is considering a bill that looks to increase the obligation set out in Article 150 bis of LGSE from 10% by 2024 to 20% by 2020 (the 20/20 goal). Specialised entities such as CER are considering whether the charge established in the law has had the desired effect of promoting NCRE, or whether it has failed to make the industry more dynamic due to its low value relative to the alternative cost of developing NCRE projects.

Another tool established by LGSE to increase the feasibility of NCRE projects and small- and medium-scale projects is the exemption from the payment of trunk transmission tolls, with a benefit of up to 20,000 kilowatts applicable to NCRE projects. Projects with a power surplus between 0 and 9,000 kilowatts are entitled to the full exemption; projects with power surpluses between 9,000 kilowatts and 20,000 kilowatts, are entitled to a partial exemption.

6.2 Project finance

At the present stage, technology development projects for marine energy devices require a significant amount of resources in order to carry out the significant levels of R&D that are required, activity that is generally undertaken by small companies that do not necessarily have strong finances.

6.2.1 Project finance in Europe

Technology developers have three main options for financing marine renewable energy projects, which are both capital intensive and require the developer to raise large amounts of finance well in advance of the start of operations (DTI, 2000):

1. balance sheet finance;

2. co-development of the project with a financially strong partner that has greater access to the necessary finance;

3. project financing where bank loans are secured against the future cash flows of a project rather than the physical assets of the borrower.

Due to the fact that the required amounts of capital are large, many developers are unable to use balance sheet financing to fund projects, resulting in a strong trend in the sector whereby technology developers form partnerships with partners that include utility companies and original equipment manufacturers. Generally speaking, these partnerships have tended to fall into two categories:

- **Strategic investment partnerships:** Strategic investment in a technology development company by a larger company whereby a larger partner acquires the company or acts as a key investor to provide finance.

- **Joint venture partnerships:** The technology development company forms a project partnership joint venture with the larger partner to provide finance.

Project finance is an important source of finance for the marine renewable energy sector and this importance will increase as the sector matures and moves towards deployments of large arrays of devices. However, at present, due to the emerging status of the sector and the relatively large uncertainty associated with project developments, project finance remains difficult to obtain for marine energy projects. Reliable data on returns on investment and device performance is limited, especially for the initial deployment of new technologies.

Increasing access to capital for marine energy projects is quoted frequently mentioned priority for the sector. A wide variety of actions contribute to this, from putting policies in place to ensure a long term market signal for the sector and developing international standards for device verification, to obtaining reliable performance data from continued deployments and developing measures to mitigate environmental impacts.

6.2.2 UK project finance experience

Continued political support for the marine energy sector, particularly in the UK (especially policies such as the banded Renewables Obligation and the Marine Supply Obligation in Scotland) have provided a long term-market signal and created the certainty required to facilitate investment in the sector. This has encouraged the previously described situation whereby large utility companies and Original Equipment Manufacturers (OEMs) enter the sector and form partnerships with technology development companies through investment, acquisition, and joint ventures. A non-exhaustive list of examples of significant partnerships between technology developers in the marine energy sector and large Utility companies and OEMs are presented in Table 3.

Sector	Technology developer	Strategic investment partners	Joint venture partners
Wave energy	Wavegen	Voith Hydro	EVE
	AWS Ocean Energy	Alstom	
	Aquamarine Power	ABB, SSE	SSE Renewables, ESBI
	Pelamis Wave Power		Vattenfall, Scottish Power Renewables, E.ON
	Ocean Power Technologies	Lockheed Martin Corp.	Iberdrola
Tidal stream	Tidal Generation Ltd.	Rolls Royce	MeyGen Ltd. (Morgan Stanley, International Power, Atlantis Resources Corp.)
	Hammerfest Strom	Scottish Power Renewables	
	Marine Current Turbines	Siemens	RWENpower Renewables, EDF
	Open Hydro	DCNS, Emera	EDF, SSE, Nova Scotia Power
	Atlantis Resources	Statkraft	Lockheed Martin Corp.

Table 3: Table showing some major partnerships between technology developers in the marine energy sector and large utility companies and OEMs. Note that the list of technology developers is by no means exhaustive, nor is the list of partnerships

There are encouraging signs that the sector is beginning to reach a stage of development where it is possible to obtain project financing for projects. A recent loan of £3.4 million to the UK technology developer Aquamarine Power by Barclays Corporate to fund the development of a 2.4 MW array of wave energy devices in Orkney in Scotland is indicative of this and has been hailed as the first time a marine energy company has secured bank debt finance. This development signals increasing investor confidence in the emerging marine energy sector, particularly in the UK.

6.2.3 Existing project finance tools in Chile

Together with the legal incentives, the Chilean government has developed financial tools for NCRE projects, most of which are channelled through Corfo. Table 4 summarises the existing financial instruments, although updated information on the funds used from these mechanisms was not available for this report.

Sector	Incentive	Descripción
Current financial incentives	Corfo funding for basic and advanced pre-feasibility studies	Funding of pre-feasibility studies of NCRE projects for up to 50% of their cost up to CLP $33.000.000. (£43.000 approx.).
	Corfo creditlines	Funding of NCRE projects through long-term loans (12 years for a maximum of USD $15 million). Corfo has not allocated new funds to this instrument.
Other current incentives	Project is rated as Clean Development Mechanism (CDM)/Carbon Bond Sale	In accordance with the Kyoto Protocol, NCRE projects that show the technologies to be used are capable of reducing greenhouse gas emissions produced by conventional energies can be certified as CDM and sell Emissions Reduction Certificates.

Table 4: NCRE funding instruments in Chile.

Technology	No. of projects	Installed capacity (MW)	Investment (MUSD)
Biomass	6	42	112
Wind	17	881	1.802
Mini-hydro	21	174	380
Solar	4	26	140
Total	48	1.123	2.436

Table 5: NCRE initiatives facing funding problems in Chile (CER, 2012).

The adequacy of the funds committed by the government for either research or construction and operating stages of NCRE projects is under continuous review. As an example, CER conducts periodic reviews of NCRE projects that face funding problems. The results of the latest assessment (July 2011) are presented in Table 5.

According to CER (2012) the main gaps for securing funds for developing technologies are linked to the difficulty of securing a bank loan or a power purchase agreement with an available client.

There are other funding instruments available within Chilean institutions, such as Corfo's special Innova and Invest funds, and others managed by Conicyt (e.g. Fondef and Fondecyt). Some of these funds are used in the studies presented in Section 3.2, however it has been established that the resources made available by these instruments would not be enough to fund extensive testing or technology development.

07 | Plans for marine energy development in Chile

>> This chapter provides a general discussion of the suitability of the Chilean regulatory framework for the inclusion of marine energy projects, followed by a consideration of the most attractive areas for marine energy development in Chile.

Following this, the chapter will end with the presentation of two potential strategies that could be implemented by the Chilean government to provide support to the marine energy sector, accompanied by a number of public policy recommendations required to implement these strategies.

7.1 General comments on Chile's regulatory framework and its suitability for marine energy projects

As highlighted in Chapter 6, there are currently no marine energy projects in Chile, nor are they explicitly mentioned in the current regulations (environmental regulations or those governing marine concessions and the use of coastal zones). However, the current legal and regulatory framework is not incompatible with the development of marine energy projects since this type of development can fit within the current guidelines defined in each regulation. As an example, it would be possible to consider the development of electricity generation projects from waves or tidal currents within the zoning process, including the declaration of areas as zones for preferred use.

However, none of the applicable Chilean regulations are explicit regarding this type of development, meaning that developers who wish to begin development of a marine energy project are faced with several legal black holes and must deal with authorities that are not prepared or qualified to assess this type of project in terms of the current regulatory framework. In this regard, it is important that, in order to facilitate future marine energy deployments, marine energy should be explicitly mentioned in future government plans and regulations.

In this respect, an important first step in facilitating marine energy developments within the legal framework is to explicitly include marine energy within government regulations, in line with the provision in place in the existing legislation. This should not be a complicated task, but it is vital that authorities that need to grant permits or make decisions with respect to marine energy developments have the necessary regulatory tools to effectively assess the situation and issue a well-founded opinion.

The legal frameworks for renewable and marine energy and the approaches they follow are different for each country. This is normal and to be expected, however, it is important that these legal frameworks are either flexible enough to accept projects focused on exploiting new sources of energy, or that the sources of energy that can be developed are explicit.

As highlighted earlier in the report, the current financial support mechanism for NCRE projects in Chile is a quota system, which requires energy suppliers to obtain a certain percentage of the energy they supply from renewable energy sources (the quota is set at 5% until 2014, increasing by 0.5% per annum to 10% by 2024). However, in order for this system to be successful (i.e. for investment in NCRE deployments and technologies to be promoted) it is essential that the cost of complying with the law is lower than the fines imposed for non-compliance, which is not necessarily the case at present (Galetovic and Muñoz, 2008). Nevertheless, as shown in Figure 17, renewable energy production in Chile has currently met the legally required quotas and to date no company has been required to pay fines for non-compliance. It is expected that the quota will continue to be met for at least a further 2–3 years.

Although this system for encouraging the development of NCRE is similar to the system established in the UK, in Chile the system is technology neutral, with all eligible technologies attracting the same level of support. Therefore, the system incentivises the development of the least expensive NCRE technologies (biomass, small-scale hydro, and wind power) and does not encourage investment in the development or deployment of technologies such as marine energy, which are at an earlier stage of development and still have some way to go before becoming commercially viable.

In order to avoid this situation and promote a diverse mix of mature and emerging technologies, a banding structure has been introduced into the UK Renewables Obligation scheme, under which a different number of ROCs are awarded to different technologies per MWh of electricity generated. This system therefore provides a different level of support to different energy generation technologies depending on their maturity, with technologies at an earlier stage of development, such as marine energy technologies, receiving a higher level of support.

The banding system introduced into the UK Renewables Obligation scheme creates an additional incentive for the development of marine energy by increasing the level of revenue support provided. This is an important measure to ensure increased market pull for marine energy in the UK and sends out an important signal that the government has a long-term commitment to the marine energy sector.

7.2 Attractive areas in Chile for marine energy development

This section provides a brief overview of some issues deemed important with regard to marine energy developments in Chile (i.e. earthquake and tsunami risks), before turning to the specific areas that are most attractive for marine energy developments in Chile.

7.2.1 Natural hazards in Chile: earthquakes and tsunamis

It is important to note that Chile is located in a seismic zone (one of the world's most active areas) and sometimes large earthquakes can produce tsunamis in the region.

This natural hazard must be taken into account when considering the development of marine energy in Chile as it poses a risk to any facilities built in the nearshore region. In this respect, a detailed hazard analysis should be performed on a case by case basis for marine energy developments. Notwithstanding this point, it is possible to make some general preliminary observations:

>> Tidal stream devices are usually installed underwater and as such tsunamis do not pose a significant risk. Nevertheless, tsunami conditions could cause extreme water speeds and this should be taken into consideration when designing the foundations of tidal devices.

>> The impact of tsunamis on wave energy converters is likely to be different for the different types of energy conversion devices currently under development in the sector:

- Floating devices such as that developed by Pelamis Wave Power Ltd. should not have major problems and simply require a system to anchor them to the seabed and that can withstand the large deformations produced by rapid and significant changes in sea level during a tsunami.
- Oscillating wave surge converters such as Aquamarine Power's Oyster device may have problems caused by the rise in the water level that must be addressed.
- All facilities to be installed onshore should have appropriate protection or should be located in a safe area. Along much of Chile's coastline, the relatively abrupt topography near the shore makes it relatively straightforward to find a safe and elevated site.

While tsunamis may represent the natural hazard posing the greatest risk to marine energy devices, the individual risks should be assessed on a case by case basis since it is clear that risks vary when considering different technologies and types of devices.

It is important to highlight that although tsunamis can occur in Chile, they are not common or regularly occurring and it is quite possible that a marine energy device with a lifespan of 25–30 years may never experience a tsunami. Therefore, a risk-based tsunami hazard analysis is likely to be suitable for assessing the hazard.

Seismic activity is another issue that should be studied in greater depth to assess the potential impact of seismic loads on energy devices. At present, although seismic areas such as the west coast of Canada and New Zealand have been involved in the development of marine energy, there is still no significant volume of information available in this respect. Despite the fact that the effects could be immaterial, the issue nonetheless merits further investigation.

7.2.2 Attractive areas in Chile

Studies focused on Orkney in the UK (the location of EMEC and currently the area with the highest number of marine energy developments on a global scale) have identified that the principal attributes making it highly attractive for marine energy deployments are:

>> a good resource for both wave and tidal energy;

>> an existing and close transmission grid;

>> existing ports.

Another important factor is the presence of professionals and qualified workers for industrial activities. In the case of Orkney, prototype construction, assembly, and port works were particularly important activities and drew on the strong experience existing as a result of the presence of the oil & gas industry in the region.

In Chile there are several zones where all the attributes which make an area attractive for marine energy deployments are present. According to Garrad Hassan (2009) the best locations for wave energy are in the proximity of a number of ports in the Valparaíso, Bio Bio, and Los Lagos regions, with the most attractive resources lying in regions further to the south. Table 6 shows the study of potential sites.

Region	O&M base	Average distance to nearest substation (cable routing in km)	Closest electrical grid (SIC)	Average local wave climate (kW/m)	Estimated energy yield for 30 MW wave farm (GWh/annum)
Valparaíso	Ventanas (seaport)	6	220 kV	37	54,55
Valparaíso	San Antonio (seaport)	16	66/110 kV	37	54,55
Bío Bío	San Vicente (seaport)	13	66/220 kV	44	64,75
Bío Bío	Coronel (seaport)	10	66/220 kV	44	64,75
Los Lagos	Corral (seaport)	17	66/220 kV	51	75,05
Los Lagos	Puerto Montt	27	66/110/220 kV	58	85.35

Table 6: Priority locations for the development of wave energy projects and estimated annual energy yield of a 30 MW Pelamis wave farm covering 1 km^2 (Garrad Hassan, 2009).

An important case is the ports in the Bio Bio region, mainly in the area of Lota and Coronel, some miles south of Concepción. In this region economic activity peaked at the end of the eighteenth century and the beginning of the nineteenth due to activity of the coal industry in the area. After the coal mines were closed at the end of the 1900s, several facilities were abandoned, creating unemployment and poverty in the area, but leaving a strong legacy of industrial work and qualified labour.

In this sense, the ports of San Vicente and Coronel are considered strong candidates, not only due to the quality of the resource nearby, but also due to the potential for the regeneration of the area as a result of the economic benefits associated with marine energy deployments.

Furthermore, it should be noted that an important part of the Chilean steel industry is located in that area of the Bio Bio region and this could be a significant factor when considering where to locate developments in terms of nearby supply chain capacity.

Regarding tidal current energy, the most convenient locations are in the south of the country. Garrad Hassan (2009) has studied the locations with the highest potential and these are summarised in Table 7.

It should be noted that the most attractive location for this type of project is the Chacao Channel, which in addition to having an excellent resource, is also located near transmission lines and ports.

Zone	Water depth (m)	O&M base	Average distance to nearest substation (cable routing in km)	Closest electrical grid (SIC)	Average local tidal resource (kW/m2)	Estimated energy yield for 30 MW tidal farm (GWh/annum)
Canal de Chacao	30–100	Cabo Forward o Pto. Montt	0–10	110/–220 kV	3,8–5,2	101–152
Golfo Corcovado	20–100	Cabo Forward o Pto. Montt	~60	66/–110 kV	0,72	19
Estrecho de Magallanes	50–70	Austral	none	none	3,6	99–126

Table 7: Priority locations for the development of tidal stream energy projects and estimated annual energy yield of a 30 MW generic tidal farm (Garrad Hassan, 2009).

Most other locations where the development of tidal projects could be feasible are rather isolated and, while there may be some complications in the development of the projects, development of marine energy could be seen as a strategic issue in terms of energy independence for isolated islands that depend on oil shipped from the continent for their energy generation.

Chacao is near Puerto Montt, the capital city of the Los Lagos region and home to a significant local supply chain capacity that supports the fishing industry by producing cages and sea structures, and provides a range of services for fisheries and processing plants. As such, it is considered that it would be feasible to develop an industry for marine energy services in this area, and that this would complement the existing local industry.

On the other side of the Chacao Channel, the island of Chiloé was one of the places in Chile with the highest unemployment rates prior to the development of the fisheries market. With the fisheries, this area has shown its ability to build an industry from scratch, and hence it is also considered feasible to develop a new industry to support marine energy deployments in the area.

At present, the best and only tool for that provides an assessment of the most suitable sites is Garrad Hassan (2009), although the studies currently underway (mentioned in Section 3.2) could provide crucial information regarding the potential present at a number of sites.

Building upon the results of these existing studies and those currently in progress, a study to give further priority to the most attractive areas for marine energy projects would be a useful step to start focusing on sites where potential development projects could be feasible and beneficial.

7.3 Potential Strategies for the development of marine energy in Chile

Historically, in terms of energy (and many other sectors, although with a number of notable exceptions), Chile has tended to be a technology receiver rather than a technology developer. The culture in the country has been focused on buying or adapting technologies developed abroad rather than investing in R&D and playing a more active role in technology development.

Studies have shown that the marine energy resource in Chile is amongst the best in the world. This is an opportunity that could be exploited, allowing Chile to develop (and potentially export) leading expertise in this field on an international level.

Putting policies in place to incentivise foreign companies to develop marine energy projects in Chile or to incentivise the establishment of a national industry for the development of marine energy technologies will require significant regulatory changes and support mechanisms to be put in place by the Chilean government. However, the industry presents significant opportunities in terms of economic benefits both to the Chilean economy as a whole and, more specifically, to the local economy and population at sites where the industry is developed or the devices are deployed.

This section discusses what the government could do in order to promote marine energy development and gives an overview of the environmental, economic, and social impacts that have been observed in the UK and are considered to be positive.

The approaches the Chilean government can take regarding marine energy development can be classified into two strategies:

- **Development strategy:** focused on supporting the implementation of an industry for developing and deploying marine energy technologies in Chile. This strategy will require significant commitment and support from the Chilean government, but will result in significant benefits for the country.
- **Deployment strategy:** focused on putting the conditions in place to support the deployment of marine energy technologies in Chile at some point in the future. This strategy will result in significant benefits for the country and will allow its resources to be used. However, the opportunities for supply chain development, the export of technology and expertise, inward investment, and capitalising on economic benefits are much less than with the development strategy.

It is important to highlight that, whilst the latter strategy involves an element of waiting for the technologies to be developed abroad and the right time for Chile to invest in importing technology and expertise, there are nonetheless important steps which must be taken. These actions are essential to ensure that the regulatory and legislative frameworks are ready to facilitate the envisaged deployments when the time comes.

In the following sections, both approaches are described, together with the recommended actions the government should take to ensure their implementation. It also provides an overview of the social, economic, and environmental impacts, which are complemented by the case study of the Orkney Islands in Scotland (the home of EMEC) presented in Appendix 1.

7.4 Development strategy

This strategy involves Chile taking steps to assume an active role in marine energy technology development. A number of changes will be required to the present regulatory framework in Chile and these are set out in the following sections.

The changes presented are not the only ones that could be implemented but illustrate the potential opportunities for Chile to support marine energy technology development and deployment by making certain modifications to its laws and procedures.

7.4.1 Required regulatory changes

To incentivise marine energy development, regulatory changes should be made in several fields. Some of these changes are proposed below (although the list of suggestions is not exhaustive).

a. Environmental regulations

In general, it is observed that Chile has a relatively strong environmental assessment system that works well. As such, no major changes should be required to incorporate the assessment of marine energy projects. Nevertheless, some flexibility in the regulations may be required upon the implementation of the first projects, as the lack of information may cause significant difficulties for the SEA(2) to approve the project.

Together with this initial flexibility, it is essential to engage with qualified environmental professionals to improve our understanding of the effects of marine energy projects on the environment. With the correct personnel in place, it would be possible to create the full environmental support structure and regulations for this type of project and define the evaluation criteria.

A practical approach of strategic environmental assessments is identified, similar to that used in the UK, where a general environmental hazard analysis is carried out considering the potential of different areas and declaring priority areas for marine energy development. This approach means that priority zones and their environmental profiles are better known and understood, making the development of that area simpler and faster in terms of issuing permits for putting devices into the water. However, despite this approach, it is still of critical importance to carry out detailed monitoring of the operation of the individual deployments and their impacts.

Flexibility with regard to applying regulations to early-stage projects, engagement with environmental professionals to define the criteria for the environmental evaluation of marine energy projects, and implementing a strategic environmental assessment process for marine energy are all important changes for the Chilean regulatory framework that would help it support marine energy developments. However, these changes are not exclusive and could all be implemented together, along with a range of other options.

In line with this, and as highlighted above, there are significant benefits to employing an adaptive management approach for the regulation of the marine energy sector, with data obtained from early deployments forming the basis for informing future regulation, legislation, and policy decisions. Such an adaptive management approach is particularly appropriate in the face of uncertainty regarding the environmental impacts of marine energy technologies.

b. Use of land and seabed

i. Marine concessions

As was the case with the environment, Chile has a strong system that works well in this area. The only changes required would be to make marine energy explicit in the concession framework and lower the cost of concessions for the research period of a marine energy project, potentially even extending this to the operational period.

Similar to the environmental aspect, it is essential to train those who will be responsible for granting the marine concessions, specifically the Subsecretary of National Defence of the Ministry of National Defence. This will ensure that when applications for marine concessions are submitted, there will be some knowledge of this type of project available, hence avoiding delays in granting the concession caused by the evaluator's lack of familiarity with the type of project, requiring them to first understand it.

A marine concession implies payment for the use of the land in question and as such, developing an instrument whereby developers could be made exempt from payment for a certain period of time would provide a significant support mechanism for the sector. In this respect, there are a number of potential options that could be implemented in line with the legislative framework in Chile. These include:

- Using the marine destination category to lease areas to project developers, although some changes to the current law would be required. At present the destination category is only applicable to government institutions, whereas in this case it would be awarded to private companies.

  The marine destination category could be awarded to private companies working on the development of marine energy technology for government interests (at least for the development period until a competitive cost of energy is achieved).

- Following an approach similar to the mining concessions. According to the Chilean regulations there are two types of mining concessions: exploration and operation concessions. An exploration concession covers the exploration of an area, whereas an operation concession is awarded for putting a mine into operation in a specific area.

  Of the two types of concession, the exploration concession has a significantly lower cost and lasts for two years (extendible for an additional two year period for half of the area requested), whereas the operation concession has an unlimited duration.

  A similar approach could be followed for marine energy: awarding companies a short and cheap concession to carry out research in a specific area, then, once the company is able to develop a project, the concession is granted in a similar manner to current regulations, although the cost would need to be assessed to ensure the project is still feasible after the fee charged by the government.

The cost of the concessions during the operation of marine energy projects may also need to be revised, although this will come at a later stage, some years from now.

In this respect, the actions taken by the Ministry of National Assets for wind projects may be adapted and used. In a recent case where the ministry realised the fee charged by the government for land usage was too high, hence making wind projects economically infeasible, action was taken to lower the land usage fee when the land was to be used for a wind project.

A similar approach could be followed for marine concessions, differentiating fees by the type of project to be developed. This means the current fees could be still used for activities such as building ports, however they could be reduced for marine energy projects.

ii. Coastline usage

No major changes are expected to the Chilean regulations for coastline usage, although it is important that marine energy is included in regional land usage plans.

It is important that offshore energy projects (both wind and marine energy) are given specific consideration in the zoning plans for coastline usage. Although at present these types of project are not incompatible with the zoning already carried out (Coquimbo and Aysén regions), they must nonetheless prove they are compatible with the previously determined preferred uses. In addition to this, there are areas with attractive conditions for marine energy projects that could practically be designated as zones of interest for this type of project.

As highlighted in Section 6.1.1.a, despite recent changes whereby a Ministry of Energy representative has been invited to sit on the Regional Commission for Coastline Usage, it is worrying that the representative does not have voting rights, and that power generation companies are not represented.

The inclusion of a representative from the Ministry of Energy on the regional commission constitutes a significant step towards ensuring marine energy developments are considered the future. However, it is important that greater emphasis is given to the representation of the marine energy sector in Chile's spatial zoning procedures.

c. Incentives and financial support mechanisms for renewable energy

One of the most important issues in the decision to encourage the development of marine energy is related to the electricity market in which any project would operate. As was previously discussed, Chile uses a quota system to encourage investment in renewable energy, facilitating ROC trading in order to allow actors to comply with mandatory obligations. However, because it does not differentiate by technology, the system does not encourage the development of less mature and more expensive technologies.

A potential financial support mechanism to support technology at an earlier stage of development, such as marine energy technology, is to follow a similar path to the UK, where marine energy projects receive more ROCs per MWh of electricity generated than other more developed energy technologies. One of the advantages of this method is that it produces less market distortion than other schemes, such as feed-in tariffs.

Another alternative would be to implement an auction system, such as the ones implemented in Peru and Brazil, although one specific to marine energy projects. The benefit of a system of this kind is that, as the auction is for a limited number of projects, it is possible to assign tariffs to ensure the feasibility of the project, which, due to the relatively small scale of the energy produced, will not have a significant impact on the market. This is a good mechanism for encouraging investment in pilot projects to allow the expansion of the knowledge and experience associated with the technologies and their deployment and operation.

From another perspective, the auction system also aligns well with the plans of the Ministry of Energy, which, in recent years, has run tenders and pilot projects for other energy technologies. However, it is important to highlight that using a mechanism of this kind will focus on developing a limited number of projects and will not therefore allow Chile benefit from the same supply chain creation, cost reductions, and technology development as in some of the other support mechanisms outlined.

In other countries certain conditions must be met for projects to be eligible for incentives (or additional incentives). A case in point is Canada where there is a feed-in tariff system with different rates for different renewable energy technologies and the tariff structure has been carefully designed to ensure projects are eligible for a higher tariff if they are developed using local resources (Ontario Power Authority, 2011).

Carefully designing any support mechanisms put in place to equip them with features of this nature could be a useful way of promoting the development of a marine energy supply chain in Chile, and encouraging developers to use supplies from the local industry or manpower from a certain area of the country.

7.4.2 Discussion of the development path, pilot projects, test centres and other options

It is important to highlight that, even if the Chilean government decides to implement the **development** strategy described and make the necessary regulatory changes, there are still a large number of alternatives when it comes to the policies to be put in place to support the sector. These include establishing a test centre, pilot projects, targeted R&D programmes, and national market pull mechanisms. The following sections consider the available development path and support policy options. Furthermore, it is important to note that the different options presented are not mutually exclusive, and the best way forward for Chile is likely to be to select and develop a combination of policies designed to support the sector through various stages of development.

The main support mechanisms to incentivise investment in renewable energy projects have been presented and discussed in previous sections. These systems are mainly focused on encouraging investment from the perspective of the electricity market. However, it is also important to highlight that, in parallel to mechanisms providing national market pull support (such as the UK Renewables Obligation), which result in significant market distortion, there are a number of models that do not necessarily imply a structural change in the incentives system. These include development through pilot projects or test centres, both of which encourage the development of marine energy projects and the generation of knowledge of the application from these emerging technologies in Chile.

Section 6.1 discussed the importance of striking a careful balance between technology push and market pull support mechanisms. In this respect, it is important to highlight that, whatever the strategy for marine energy development in Chile, this balance must always be present to ensure the effective development of the sector towards being cost competitive with other forms of energy generation.

The following sections provide a brief overview and discussion of some of the different available support mechanisms.

a. Pilot projects

Supporting the development of pilot projects is an important way in which the Chilean government could support the marine energy sector and incentivise the development of marine energy projects in Chile. Given the stage of development of marine energy technologies, these projects will require financial support from the government. However, there are a number of ways of providing this support, including capital grants and enhanced revenue support based on the electricity generated.

Given that the regulatory entities involved do not have any experience of this type of project and considering these would be the first projects to be implemented in Chile, it would be advisable for permits for pilot project locations to be obtained by the government, or for significant support to be provided to help developers obtain them.

It is worth mentioning that the goal of implementing pilot projects is to increase awareness of the technology in the market, meaning that pilot projects generally entail limited development of the supply chain. Hence it follows that if only a small number of projects are to be deployed, this is not a strategy that will result in the development of local industry since a larger number of projects are required to produce industrial development.

One model that may possibly be followed, and that may be presented as a future plan for these pilot projects, is that future auctions or tenders (assuming this was the procedure for assigning developers to sites) begin to increase the installed capacity of the projects in order to generate economies of scale and increase knowledge for future stages of development. To achieve this, the auctions must include a certain volume of projects to ensure a supply chain is developed and the costs of supplies start to decrease.

In this respect, a pilot project strategy that includes at least several tens of MWs to be installed will possibly translate into significant benefits on a local scale, and some development in the local supply chain.

With this mechanism, a requirement could also be implemented for the participants involved in the auctions to work with local providers. This would focus more activity on local industry and generate knowledge among the related services.

b. Test centre

As was observed for the Orkney case study in Appendix 1, the implementation and commissioning of a test centre for both wave and tidal devices requires a significant level of initial investment, together with subsidised operation until the centre can become self-sustaining. Several years may be required for this to occur (approximately seven years for EMEC), meaning that the entity financing the centre must be willing to make a medium or long-term commitment in terms of resources.

This may not be suitable for a country such as Chile, given the high risk of the implementation of the test centre due to:

- the high level of initial investment;
- uncertainty in how long it would be necessary to finance the operation of the test centre.

The scale of resources needed for the establishment of a test centre are considerable, and a country like Chile may have other priorities for its available funds.

It is clear that the EMEC test facility has required significant and sustained government support, and that the facility comprehensively covers testing, demonstration, and accredited verification in the marine energy sector. Despite the fact there is likely to be limited value in Chile replicating this test facility, there are certainly useful lessons to be learnt and that can be applied to a potential deployment centre in Chile.

Rather than duplicating functions which are already well established and covered by other facilities, it is important for any Chilean initiatives to complement activities already taking place in the sector.

In this respect, establishing a test, research, development, or deployment centre in Chile could be a positive option in the sense that it would increase the opportunity for a supply chain to be developed and the challenges of a location with higher energy than where devices have been tested so far would provide an important opportunity for developers. Furthermore, providing technology developers with the opportunity to test their devices in new locations with higher energy resources, different setups and different challenges, could provide an important opportunity to test and refine the adaptability, reliability, and durability of the devices.

Establishing a research centre is also related to the development of expertise, R&D capabilities, and human capital. In this respect it would be both beneficial and important to establish cooperation agreements with other countries or research centres in order to continue the development of the technology rather than replicating what has been achieved at other centres.

c. National market pull financial support

Putting in place a comprehensive national market pull support mechanism for marine energy is a possibility that may work and the most common way to do this is by establishing a feed-in tariff system. A significant issue for this option is that doing so could create uncontrolled demand for marine energy, costing the government important resources and making the market focus more on deployment speed than technology development.

While this may be a viable option, it is arguably not the best, since it fails to address the balance between market pull and technology push.

d. R&D programmes

There are many ways in which marine energy technology development could be encouraged. The purpose of this report is not to advocate one of them but to highlight the benefits of investing in technology development and, in this respect, while test centres or pilot projects are the most common development options, they are not the only ones that could be considered or implemented.

Implementing a targeted R&D programme represents a valuable support mechanism, following an approach similar to that which the Ministry of Energy has implemented for the development of biofuels in Chile, consisting of forming research consortiums for the development of second generation biofuels.

The Ministry of Energy, in partnership with Corfo, is investing over USD $30 million in financing the research of three consortia in this area, largely made up of private companies working in partnership with universities. These consortia receive government support for pursuing R&D for these fuels, and they have a period of five years to complete all their research and finish their programme with the production of second generation biofuels (Electricidad Interamericana, 2010).

This approach may also be implemented in the case of marine energy, although it should be tailored in order to meet its specific requirements, particularly in order to produce development across a range of technologies, and not just those promoted by the consortia successful in attracting financing.

It is important to note that these development strategies are not mutually exclusive and a combination may well represent the best option. Consider the case of the UK, where the government has opted to invest in test centre infrastructure, as well as establishing a UK-wide market pull financial support mechanism specifically for marine energy, and funds a significant number of R&D programmes specifically focussed on marine energy.

As a preliminary conclusion, several paths may be followed in order to permit Chile to play a more active role in marine energy technology development and implement a **development** strategy. Should the Chilean government decide to implement this strategy, it provides an important opportunity to further study the development options and to develop its own combination of support measures to take Chile down the chosen development path.

7.5 Deployment strategy

This strategy involves Chile playing a passive role in technology development and implementing marine energy technologies at some point in the future when the cost of energy becomes competitive with other forms of generation.

If Chile decides to implement this **deployment** strategy and wait until marine energy reaches a development level that makes it competitive with other energy sources, it will still be necessary to make a significant number of the regulatory changes proposed in Section 7.4.1. Despite there being no marine energy projects in Chile, regulatory changes will still be required to facilitate the implementation of these projects in the future.

7.5.1 Required changes to regulations and permits

This section provides a summary of the proposed changes, discussed in detail in Section 7.4.1.

a. Environmental

It is important that the SEA(2) is technically capable of evaluating the projects presented by developers. In this respect, qualified environmental professionals are needed in order to determine the foundations of the requirements to be met by future projects. It will be necessary to work with Chilean universities on a significant scale to achieve the level of expertise required.

Environmental guidelines for developers should be produced by CER, as per small-scale hydro and wind power, although these guidelines should be developed at a future stage when extensive project deployment has been carried out and experience accumulated abroad, meaning there is more information regarding the impact the different technologies have on the environment.

By the time projects reach a market cost there will be a wealth of experience in other countries upon which to base the impact assessments, so flexibility for the initial projects will not be as important as acceptance based on analyses of foreign experiences.

b. Use of land and seabed

i. Marine concessions

In this case, changes to the present marine concessions scheme would not be urgent from a project development point of view, although could nonetheless be beneficial from the perspective of research into resource.

As such, the implementation of some modifications may be beneficial in the near future:

- The institutions that handle marine concessions should be informed and educated to ensure they are familiar with marine energy projects and are able to grant the correct portions of seabed for developments and/or research.

- The cost of a marine concession should be reviewed. The cost of a marine concession is currently determined by the type of activity and may be too expensive for an energy project. In this respect, the cost of such concessions should be reviewed in terms of the area used by a marine energy project, its costs, load factors, incomes, and the expected return on investment for a standard energy project.

  The solution of the Ministry of National Assets for land usage for wind power projects could be an example to follow in this respect.

- Other marine concession schemes could be implemented, such as more extensive use of the marine destination scheme (with the necessary changes), or a scheme similar to mining concessions (both explained in Section 7.4.1).

ii. Shoreline usage

If the decision is to wait until a competitive cost of energy is reached then it would be important to study and understand the resource available along Chile's coast in greater depth in order to keep attractive locations available for marine energy projects. In this respect, recommendations include:

- Carry out more detailed studies of the resource along Chile's coast in order to identify and preserve potential locations for marine energy projects. The location of projects should consider the resource and the country's future plans for energy infrastructure (e.g. in terms of new projects near the shore, transmission lines, substations, and new demand centres).

- Grant voting rights to the Ministry of Energy representative on the Regional Commission for Shoreline Usage and include power generation companies on the commission.

- As a result of the previous point, include marine energy projects in the regional zoning plans.

c. Incentives and financial support mechanisms for renewable energy

In this case no changes would be needed to be implemented to the electricity market, specifically in terms of financial support mechanisms, as it is assumed these projects would enter the market once their costs are competitive with conventional or other renewable sources.

In summary of this section, Table 8 provides the key recommendations presented in this report for both development and deployment strategies.

	Development strategy	Deployment strategy
Strategy outline	Chile becomes a technology developer, implements support mechanisms for marine energy and benefits from the significant associated positive economic impacts on the economy.	Chile waits for technology to develop abroad and imports devices when the cost of energy becomes competitive with other forms of generation.
Key recommendations	1. Modify regulations for: >> marine concessions; >> coastline usage; >> the environment (specific to marine energy). 2. Implement financial support mechanisms for marine energy production. 3. Establish a development strategy based on a combination of financial support mechanisms, targeted R&D programmes, pilot projects, a potential test centre, and/or other measures.	1. Modify regulations for: >> marine concessions; >> coastline usage; >> the environment.

Table 8: Summary of actions to be taken for development and deployment strategies.

08 | Conclusions and recommendations

>> This report has brought together and discussed a wealth of information regarding the potential offered by marine energy, the current status of the development of the technology and costs, the regulatory framework in Chile and the ways in which energy projects can be incorporated, foreign regulations and incentives that may be used in this respect, and general development schemes.

Several conclusions have been drawn in terms of the potential ways in which marine energy could be developed in Chile. This section will present a number of general conclusions regarding the further development of marine energy in Chile:

- Chile's coastline has one of the world's highest potentials for marine energy production and it represents a promising opportunity for the development of these technologies. In specific terms, the potential for wave power is higher than that of tidal stream, although the potential for tidal stream is still high.

- There is already some activity in Chile to evaluate the potential through a number of ongoing studies. Although these studies are necessary and represent a good starting point, they are nonetheless insufficient if the potential is to be developed in the short term.

- Around the world there is active development of devices for converting marine energy into electricity. The devices in question have been shown to work, however their costs remain higher than conventional technologies.

- >> The cost of the devices is envisaged to decrease significantly in the short term, however for the cost of the energy they produce to reach a competitive level, more time may be required to allow the deployment and research required to achieve this. It is envisaged that energy produced by marine devices should become cost competitive with other forms of generation in the medium to long term.

- >> While the costs are presently high, in several countries (specifically in the UK and Scotland) it has been observed that putting in place systems to support the development of these types of technologies results in significant positive social and economic impacts. These impacts are principally related to the industry built around marine energy, which involves the creation of jobs and a supply chain for the products and services required by the industry.

- >> Although government financial support would be required for Chile to take a more active role in marine energy technology development, such support should not be ruled out as the positive impacts on local industry and job creation are significant. Different countries' experiences of such benefits have been presented in this report and may serve as a baseline.

- >> The Chilean regulatory framework is observed to be sufficiently flexible to be able to incorporate marine energy projects (both wave and tidal). Nevertheless, some modifications should be implemented in order to facilitate this process, and familiarise the different regulatory institutions and processes with marine energy projects in order to facilitate deployments. Different countries' experiences of such benefits have been presented in this report and may serve as a baseline.

- >> Chile has strong industrial capacity in a number of industries which could provide significant resources to a marine energy supply chain, if this were to be developed in the country. Where the necessary industrial capacity does not exist locally, Chile can also draw on strong industrial capacity across a number of important sectors from neighbouring countries in the region, particularly Argentina and Brazil.

- >> Considering all the issues presented, the Chilean government must decide whether to support marine energy developments and/or deployments in Chile. If it decides that Chile should take an active role in technology development and marine energy should be supported, several changes to the regulatory framework should be implemented and the support mechanisms to be put in place to support the sector should be assessed. If the government decides not to invest in supporting the development of a marine energy industry in Chile, an opportunity still exists to make some changes to the regulatory framework in order to better accommodate marine energy projects (at present they are not considered in the regulatory framework). This will be important if Chile is to capitalise on the benefits of marine energy deployments in the future.

- >> If a decision is made to put financial support mechanisms in place to support marine energy, the Chilean government should consider:

  - The support mechanisms required to ensure sufficient market interest to create a supply chain. If support is insufficient, the industry will not develop and the concomitant social and economic benefits associated with the technology outlined in this report will not materialise in Chile.

  - The support mechanisms should be designed to avoid permanent commitments with regard to specific technologies. For example, designing support mechanisms to reduce support when costs in the sector are reduced or once a certain amount of installed capacity of marine energy has been deployed could avoid the risk of overspend and providing more support than is required.

- There are a number of different potential support mechanisms which could be used to support the sector, some of which have been outlined above. However, it is important to have a comprehensive understanding of investments in the sector so that any support mechanisms introduced provide the right amount of support to make projects feasible.

>> A number of possible support mechanisms and development paths for marine energy (including pilot projects, test centres, targeted R&D programmes, and national market pull mechanisms) have been presented in the report. All these options have individual benefits and drawbacks and hence it is important to investigate the different support options in greater depth to determine the optimum combination for supporting the marine energy sector in Chile.

These conclusions lead to a number of recommendations for the Chilean government in order to assess whether it would be beneficial for Chile to support the development of marine energy:

>> In order to complement the ongoing marine energy resource studies, a detailed site selection for the development of the first projects should be made. An initial attempt is made in Garrad Hassan (2009), however this should be complemented with the resource measurements already in progress and future government infrastructure development plans.

This detailed selection may also follow the approach in New Zealand in the Power Projects Limited study (2008), which develops plans for the country in terms of the resource they have and local and foreign technology development, drawing up a short list of potential sites. This study may be of particular interest to Chile, as the country is geographically and economically similar in size.

>> Government staff, especially in SEA(2) and the areas responsible for assigning marine concessions, should be trained to familiarise them with the nature of a marine energy project, ensuring they are able to make sound assessments and judgments when a project is applying for the necessary permits.

>> The regulations mentioned in this report should be modified in order for them to better accommodate marine energy projects. The changes outlined are not considered to be major, but should be made in order to facilitate the incorporation of these projects. Further modifications beyond those outlined are likely to be important, but the changes proposed represent a solid starting point.

>> The cost of marine concessions for energy projects should be revised, and possibly lowered. The example of the Ministry of National Assets' reduction in the cost of land usage for wind projects could be followed in this respect.

>> Marine energy should be included when planning the usage of coastal areas. As such, a representative from the Ministry of Energy should sit on the National Commission on Coastline Usage and should have voting rights. Furthermore, marine energy should be considered in the regional plans for coastline usage.

>> A social and economic impact assessment could be carried out for specific areas. Possible candidate areas are the ports around Concepción (San Vicente, Lota, Coronel) and cities close to the Chacao Channel (Puerto Montt and Ancud). This would provide the Government with an important tool for deciding whether supporting marine energy technologies is an attractive investment in terms of the potential benefits to Chile.

- Financial support mechanisms to support the sector should be analysed in relation to the outcomes of the social and economic impact assessment. If the impact is higher than the financial support required from the government, a scheme should be implemented for the development of marine energy technologies. It is important to stress that the financial support mechanisms implemented would need to be analysed to consider the priorities of the country and its circumstances. In some other countries, the design of support mechanisms for renewable energy generation has caused significant market distortions, resulting in government overspend and, in some cases, liquidity problems.

- A roadmap for the development of marine energy should be produced by the government; this should set out the objectives and role the government would play in the development of marine energy, should it opt to encourage its development.

All these conclusions and recommendations are the result of broad information gathering and may serve as guidelines for the development of marine energy in Chile.

The main finding of this assessment is that there is an opportunity for development in marine energy, an opportunity for Chile to change its historical tendency to be a technology adopter/buyer and take a more active role in technology development. Although there are uncertainties regarding the cost of producing electricity from marine energy, the potential for cost reductions is high and the socio-economic benefits in the sector could create for Chile are significant. At the very least, there is a significant opportunity to create the conditions to facilitate marine energy deployments in the future and the exploitation of the vast resource which exists in Chile. However, going beyond this, there is a significant opportunity for Chile to take an active role in the development of marine energy technology, and this should be the subject of an in depth, serious, wide-reaching and nationally-focused evaluation.

Ultimately, the potential is there: it is for Chile to decide on the strategy it wishes to implement in light of the significant opportunities presented by this resource.

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A N E X O S

Appendix 1:
Orkney Islands case study

Appendix 2:
Regulatory framework applicable to marine energy in Chile

Appendix 3:
Political map of Chile, including its 15 administrative regions

Appendix 4:
Maps of leased areas in Scotland

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Appendix 1: Orkney Islands case study

The case of Orkney Islands, where EMEC is located, is worthwhile studying, as it shows the potential economic and social impacts that provide an incentive to develop marine energy in a specific area.

1. Introduction to the Orkney Islands

Orkney is an archipelago located to the north of Scotland (Figure 1); it is composed of 70 islands, 17 of which are inhabited. Orkney has a population of 20,000 inhabitants and its main sources of income are agriculture, tourism, and general services, although renewable energy development has become significant in recent years (Orkney Islands Council, 2010).

Orkney has excellent infrastructure and intellectual capital, which have their roots in the 1970s when the Islands played an important role in the oil & gas industry, specifically with the construction of the Flotta Terminal (Orkney Islands Council website).

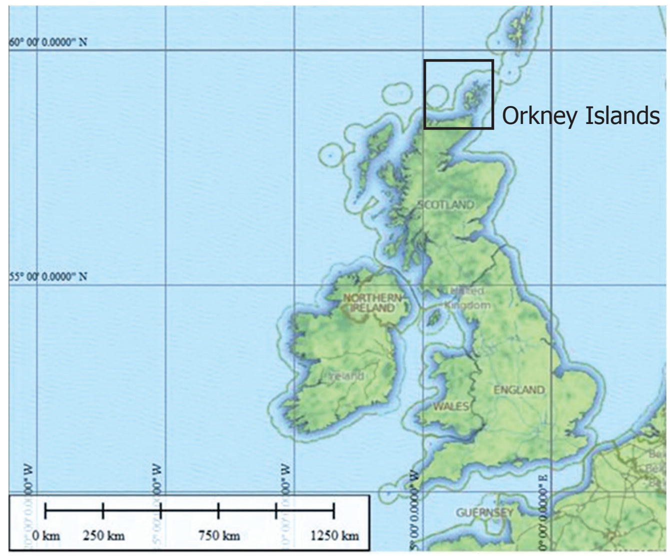


Figure 1: Location of Orkney Islands. Map (OpenStreet Map).

2. Renewables and EMEC in Orkney

Orkney has historically played an important role in the development of renewable energy. Between the 1950s and 1980s wind power was extensively developed there and turbines were installed along almost the complete length of the Islands. Nevertheless, Orkney has the highest per capita CO_2 emissions in the UK (Aquatera, 2010), possibly because of oil & gas operations.

In 2003 EMEC was established on Orkney, with the mission of guiding and supporting the development of marine energy. The initial investment to set up the Centre was in the region of £20 million, provided by the Scottish Government, Highlands and Islands Enterprise (HIE), the Carbon Trust, the UK Government, Scottish Enterprise, the European Union, and the Orkney Islands Council. (HIE website).

EMEC facilitates the development of technologies for wave and tidal devices by dealing with all the permits required to install and test a device. In this respect, EMEC has:

- Obtained a concession from the Crown Estate in order to be able to use a certain areas of the seabed.
- Negotiated with the environmental impact assessment authorities in order to be able to install devices and closely monitor their operations to discover their real environmental impact.
- Built the transmission lines required to allow the devices work in a grid-connected fashion.
- Coordinated device developers and local suppliers to meet all the requirements of the devices tested.

Device	Developer	Country of origin	Type of energy used	Type of device
Pelamis	Pelamis Wave power	UK	Wave	Attenuator
Oyster	Aquamarine Power Ltd.	UK	Wave	Oscillating wave surge converter
Penguin	Wello Oy	Finland	Wave	Other
	Seatricity	UK	Wave	Oscillating wave surge converter
Tidal turbine	Tidal Generation	UK	Tidal	Horizontal axis turbine
Tidal turbine	OpenHydro	Ireland	Tidal	Horizontal axis turbine
AR1000	Atlantis Resources Corp	UK	Tidal	Horizontal axis turbine
HS1000	Hammerfest Strom	Norway	Tidal	Horizontal axis turbine
SR250	Scotrenewables	UK	Tidal	Horizontal axis turbine

Table 1: Devices tested at EMEC (EMEC website).

As a result of this, nine different technologies have been deployed and tested and there are plans for the centre to increase its operations (Aquatera, 2011). The technologies that have been tested are shown in Table 1 below.

Essentially, EMEC deals with the permits and administrative issues for the locations for testing devices, allowing the technology developers to concentrate on their most important function, i.e. investigating how to use energy from waves or tides in the most efficient and lowest cost manner in order to produce electricity.

This means the development of technology proceeds at a faster pace than it would do without a test centre, where the developers would be required to obtain permits for testing on a specific site, assess the environmental impacts, negotiate with transmission companies to sell the electricity they produce, negotiate with land owners to install devices and build power lines, alongside several other tasks that would consume a great deal of valuable time and that could be undertaken by another party not involved in an activity as important as the development of the devices.

Economies of scale also apply to common services used by all (or several) device developers. Having a test centre means local services are used to meet the requirements of certain "families" of devices, and not just on an individual basis. As an example, a vessel can be rented by different device developers at a lower cost than if only one developer had to rent the vessel.

Having the test centre has made it possible to create a supply chain among the local community for providing the services required for technology development. The scale of activity in Orkney is still not enough to build a supply chain that lowers the costs of the main supplies, but on a local scale development has definitely resulted from the activity of EMEC and technology developers. This development includes the upgrading of three existing ports and the development of the supply chain, which, in spite of the scale limitation referred to above, nonetheless has global potential (Aquatera, 2011).

3. Investment required for EMEC and main source

EMEC was established in 2003 with almost £20 million of public investment from a range of UK government organisations. The establishment of the facility required a significant amount of upfront capital investment due to the high costs of the infrastructure required, such as the cables and substations.

In addition to the initial start up costs, around £8 million has subsequently been invested in upgrading the EMEC site to install additional cables, test berths and developing a quarter-scale test site to test scale devices alongside the full-scale test facilities.

EMEC's principal income stream is from the charges it levies on technology developers to occupy its test berths (annual charges are in the region of £200,000–£250,000 per berth), however additional revenue is supplied from consultancy work and the accreditation of devices. EMEC has only very recently become self-sustaining (i.e. it generates sufficient income to cover staff/operational costs and produces a small operating surplus). However, it is still unclear whether the centre will generate enough surplus to cover the costs of replacing depreciating capital assets (e.g. cables). Moreover, it is important to highlight that for over seven years after being established, the centre was operating at a loss and required continual government support.

4. Social and economic impacts on Orkney from the establishment of EMEC

The establishment of EMEC has produced an important impact on the population of Orkney and its activity.

Some available figures for the levels of investment made on Orkney are provided below (Aquatera, 2011):

>>	Investment in renewables	£200 million
>>	Investment in marine activity	£150 million
>>	Investment by Orkney	£20 million
>>	Revenue secured by Orkney so far	£10 million

These investments and revenues must also be considered alongside other development indicators that provide information about the education and employment opportunities created for local people (Aquatera, 2011):

>>	MSc graduates in Orkney	250
>>	PhD graduates	10
>>	Employees in marine renewables	150
>>	Employees in sustainable energy	250
>>	Employees in energy sector	500

From a local point of view, the establishment of EMEC has represented a source of development for Orkney that has provided the local community with education and job opportunities, together with several infrastructure enhancements.

This local perspective is the one that can make a difference when considering the implementation of incentives. While it may seem that a government spends significant amounts of money, the revenues and benefits for the region can be considerable.

Appendix 2: Existing regulations, permit requirements, project finance, and incentives opportunities in Chile

Regulatory framework applicable to marine energy in Chile

In order to review the regulatory framework that applies to marine energy projects in Chile, the projects must be analysed from different angles.

First, marine energy projects are electricity generation projects and as such are subject to the regulations of the Chilean electricity sector, particularly Decree with Force of Law (Decreto con Fuerza de Ley, DFL) No. 4 and the Electrical Services Act (Ley General de Servicios Eléctricos, LGSE), and their regulations.

Marine energy is considered a Non-Conventional Renewable Energy (NCRE), and is thus subject to certain special regulations and incentives, most of which were introduced into the Chilean legal system through Act 20,257.

The development of this type of project can cause environmental impacts that must be regulated based on the appropriate assessments and permits as per the Environment Act, General Matters (Ley de Bases Generales del Medio Ambiente, LBGMA) (Act 19,300) and the Regulations of the Environmental Assessment Service (Servicio de Evaluación Ambiental, SEA(2)).

Finally, there are laws and regulations that specifically apply to marine energy projects due to the resource they use for generation, namely the force produced by the movement of the waves, tides and currents, and their coastal location. This has made it necessary to review those that apply to processing and obtaining the maritime concessions needed to use the resource and the coastal planning instruments that determine the uses and industries permitted along the Chilean coastline.

The sections below present a brief analysis of applicable laws and regulations for each of the following areas applicable to marine energy projects: (1) the regulatory framework for the electricity sector; (2) the environmental regulatory framework; (3) regulations applicable to obtaining the applicable sector permits, such us marine concessions and zoning coastal usage; and (4) the regulatory framework for NCRE projects.

1. The regulatory framework for the electricity sector

The regulatory framework for the Chilean energy sector is based on DFL No. 4 (Ministry of Economy, Development and Reconstruction, 2008) that establishes the revised and coordinated text of LGSE. This regulation, which was introduced in 1981, pioneered the introduction of competition and privatisation in the Chilean energy sector.

LGSE separates the industry into generation, transmission, and distribution segments, allowing free access and competition in the generation segment. The model is based on operating at minimum overall cost and encourages generating companies to freely enter into supply contracts with unregulated customers and distribution companies (regulated customers).

Conceptually, the Chilean model has been defined as a “public service in private hands” since the state delegates and awards management concessions to private entities for economic and scarcity reasons while safeguarding the public interest in this activity and taking on the role of regulator through its regulatory and supervisory powers (Evans, 2007).

2. Environmental regulatory framework

Chile's environmental regulatory framework is set out in LBGMA, which came into effect in 1994 and was most recently reformed by Act 20,417 (2010). LBGMA sets out the Chilean environmental institutional structure whereby the Ministry of the Environment is responsible for determining environmental policy, SEA(2) manages the environmental impact assessment system for projects, the Environmental Regulator is responsible for monitoring compliance with environmental laws, and the environmental courts penalise those found to have committed crimes against the environment. Here it is worth noting that the last two institutions have not yet been implemented, although the process is expected to begin during this year (2012).

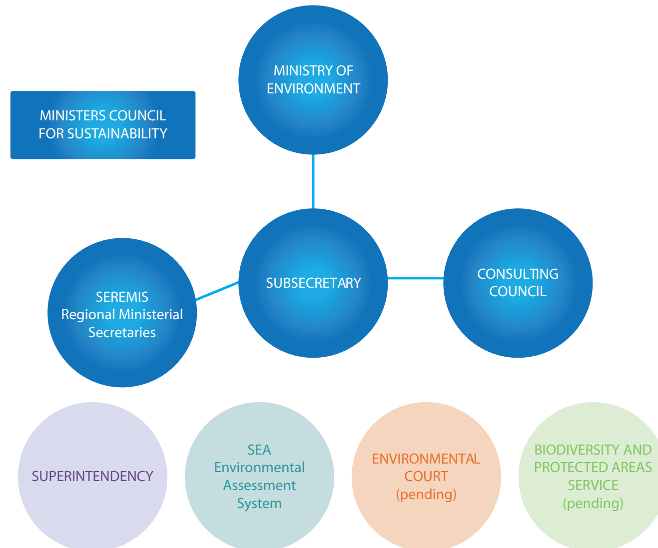


Figure 1: New environmental institutional framework (MMA website).

The section below discusses the Environmental Impact Assessment System (Sistema de Evaluación de Impacto Ambiental, SEIA), to which future marine energy generation projects will eventually be subjected if the provisions established in the law come into effect.

2.1 Environmental impact assessment system

LBGMA establishes the SEIA, to which all products or activities described in Article 10 must be subjected. The environmental assessment process is administered by SEA(2) although all public services that have any involvement in the project must take part in it under the principle of coordination and a "single point of contact" system.

According to LBGMA, projects or activities subject to the SEIA must obtain an Environmental Rating Resolution prior to being executed. Once this has been obtained, the development and operation of the projects must strictly adhere to its provisions.

2.2 Environment assessment instruments

The Chilean system is composed of two routes by which project representatives can submit initiatives to SEA(2): the first, and most straightforward, is the Environmental Impact Declaration; the more demanding route is the Environmental Impact Study. The main differences between the two is the degree of detail required in terms of the information provided, the time frames involved, and opportunities for public participation. The reasons a project might be required to submit an impact study to SEA(2) are set out in Article II of LBGMA and are linked to the specific effects or impacts the project or activity could have on the environment.

2.3 Environmental sector permits

In addition to the environmental permit or Environmental Qualification Resolution, most projects must apply for and obtain other sector permits in order for development to proceed. Permits involving environmental matters are known as Environmental Sector Permits and the debate on environmental matters is conducted around the framework of the project's assessment by SEA(2). The resolution approving the project indicates the individual permits to be awarded to the project developer, and, since these have already been approved as part of the procedure mentioned above, they may not be denied on environmental grounds. Sector permits that do not involve environmental matters should be processed directly by the respective public service.

2.4 Grounds which require generation projects to be subject to SEIA

LBGMA, Article 10, Items b) and c) establishes the specific grounds which require for generation projects and their associated works to be subject to SEIA:

b) high voltage power **transmission lines** and their substations;

c) **power generating plants larger than 3 MW.**

Likewise, the same article establishes other general grounds that require projects to be subject to SEIA that apply to generation projects, depending on their location or impact such as, for example, in Item p):

p) Execution of works, programs or activities in national parks, national reserves, natural monuments, virgin areas, nature sanctuaries, **marine parks, marine reserves** and any other area placed **under official protection**, in cases allowed by applicable legislation.

SEIA is the set of rules that define how to interpret the applicability of SEIA in LBGMA, Article 10. It can be concluded that there are no specific provisions for marine energy in SEIA except for those applicable and common to all power generation projects (i.e. having to assess whether it is greater than 3 MW and whether it is located in an area placed under official protection). Whether a project must submit either a an environmental impact study or declaration to SEA(2) for any of the aforementioned provisions will depend on its specific impacts (e.g. tourism, scenery, local communities).

At the time of writing, no marine energy generation project has been submitted to SEA(2) for assessment and hence there is no practical experience in this respect. For this same reason, based on the experience acquired over the last few years from developing other NCRE projects (wind, mini-hydro and geothermal), it has become imperative to start training the evaluators regarding this type of power plant and to define, for future reference, the permits and minimum requirements of environmental impact declarations and studies for these technologies. This has been done in the case of other technologies such as mini-hydro, wind and geothermal plants, where SEA(2) created assessment guidelines. We recommend the same be done for marine energy projects in order to prepare the evaluators and increase certainty for project developers regarding the requirements they must meet to have their projects approved.

2.5 Consultation on Environmental Relevance

Environmental practice has created an instance that is not specifically included in LBGMA, but which is very common nowadays, namely the Consultation on Environmental Relevance, whereby a project developer who is uncertain as to whether their project should be submitted to SEA(2) can request opinion on the matter. In general, the need to present a consultation stems from a public service awarding a sector permit that can only be awarded directly if the project does not need to be submitted to SEA(2). This consultation requests confirmation that the project is in fact exempt from assessment.

Given the lack of precedent the sector authorities will face when called to award the necessary permits to develop the first marine energy projects, it is highly likely that they will request a relevance consultation even where the specific project does not exceed 3 MW and is not located in an area under official protection.
In this respect, it is necessary to educate the assessors and other competent public services on the particularities of marine energy so as to prevent them from requesting unjustified relevance letters and/or ensure these are resolved with a good knowledge of the industry. This will avoid projects that do not need to be submitted being presented to the SEA(2).

3. The regulatory framework applicable to maritime concessions

As previously mentioned, marine energy projects use the energy produced by the movement of waves, tides, and sea currents to generate power. In Chile, this resource can only be used when a maritime concession has been applied for and obtained according to the rules that described below.

3.1 Applicable regulations

The regulations that apply to requesting and obtaining a maritime concession can be found in:

>> DFL No. 340 (1960), Maritime Concessions Act (DFL No. 340);

>> Supreme Decree No. 2 (Ministry of Defence, 2005), Regulation on Maritime Concessions (DS No. 2);

>> Supreme Decree No. 475 (1994), National Policy on the Use of the Coastal Border (DS No. 475).

3.2 Competent Authority

DFL No. 340, Article 2 stipulates:

the **Ministry of National Defence, through the Subsecretary** of the Armed Forces, has the exclusive authority to grant the private use, in any way, of state beaches and beachfront land within a strip of 80 meters wide measured from the highest line of tide water of the coastline, as well as the concession of rocks, sea beds, portions of water inside and outside of bays, and also the concessions of rivers or lakes that are navigable by vessels of more than 100 tons, or in those that are not, provided that they are state-owned properties, to the extent that they are affected by tides of the beaches of one or the other, and state-owned shore land to a maximum distance of 80 meters measured from the beginning of the shoreline.

Hence, it is the Ministry of Defence, through its Subsecretary of the Armed Forces, that is responsible for ruling on the request for a maritime concession presented by a private party by decree.

3.3 Types of maritime concessions

The Chilean regulations establish that maritime concessions are classified by the object requested, as follows:

>> concessions for beachfront property;

>> concessions for beaches;

>> concessions for rocks;

>> concessions for water portions;

>> concessions for seabeds;

>> concessions for interior and exterior bays.

Although there is currently no experience in this respect, depending on the technology to be used, marine energy projects must request a maritime concession for water portions (when they wish to install a stable floating element in the sea), a concession for seabeds (when the generating unit is located on the sea floor) and/or a concession for beachfront property (when a turbine is installed outside the sea on the beach). This distinction does not affect the procedure that is applicable as this is determined by the classification of maritime concessions reviewed below.

As stipulated by DFL No. 340, Article 24, in order to be awarded and processed, maritime concessions are classified according to their period of duration, which shall not exceed 50 years, and the amount of capital to be invested in these concessions. Hence there are four types:

>> Major maritime concession: a concession awarded for more than ten years or involving an investment of more than UTM 2,500 (£124.000 approx.) according to a formula calculated by the Ministry of Defence.

>> Minor maritime concession: a concession awarded for more than one year and less than ten, or involving an investment equal to or less than UTM 2,500.

>> Permit or authorisation: maritime concession of minor importance for transitory usage not exceeding one year.

>> Destination: maritime concession granted by the ministry to government services to fulfil a specific objective. Destinations do not entail a charge, and do not have a specific purpose, although there are certain restrictions in the sense that a government institution must execute any work carried out at the leased location.

It is highly likely that due to the duration of the projects (generally projected as 30 years) and the level of investment involved, it will be necessary to request a major maritime concession. As such, the project will be submitted to the most rigorous procedures as set out in DFL No. 340. The procedure will be described in detail further on in this report.

Of all the types of maritime concessions, it is worthwhile noting the "Destination" category, which applies when the request for a concession stems from a public service (e.g. the Ministry of Energy, CER). This category would become relevant if the authority in question decides to promote this type of technology by developing a testing centre and/or a pilot project on its own initiative.

3.4 Applicable procedure for major maritime concessions

As stipulated by DS No.2, Regulation on Maritime Concessions, the procedure that applies to processing major maritime concessions is summarised in Table 1:

Stage	Description
Request for maritime concession	The request is presented by the interested party to the respective Harbour Master's Office in a file containing two copies of the application form and plans as required in DS No. 2, Articles 26 and 27.
Admitted and uploaded to Integrated Coastline Administration System (Sistema Integrado de Administración del Borde Costero, SIABC)	The Harbour Master, in coordination with a technical consultant from the Subsecretary of the Armed Forces, and within ten days from receipt of the application form, will confirm that the application contains all the requested information. In addition to the formal elements, they will ensure the application does not overlap other maritime or aquaculture concessions already granted and/or that the requested use falls within the sector's zoning requirements. Once admitted, the harbour master will approve the application and upload it to SIABC.
Submission to the Subsecretary of the Armed Forces	Within five days from approval, the harbour master will send the file to the Subsecretary of the Armed Forces for analysis.
Report from the General Maritime Territory and Merchant Shipping Administration	With regard to the application, the General Maritime Territory and Merchant Shipping Administration will draft a report that will consider the following items: (a) overlaps with other concessions or destinations awarded or in process; (b) project compatibility or suitability with regard to developing the sector's maritime interests and established zoning; (c) whether the concession decree may require the project to be submitted to SEA(2); (d) whether safety of navigation and human life at sea is affected; (e) the need to incorporate new information in the application.
Analysis by the Subsecretary of the Armed Forces and ruling by the Ministry of Defence	Once the above report has been received, the Subsecretary will analyse the information and the Ministry of Defence will resolve the case by issuing a decree within 180 days from the receipt of all required information.
Legalisation of the concession decree	The concession decree must be summarised in public deed within 30 days from the maritime authority officially notifying the interested party of the corresponding decree by certified post. At all times and prior to this, the concession holder must pay the corresponding annual or monthly rental and/or fee established by the decree to the treasury.
Final delivery of the maritime concession	The final delivery of the concession will be made effective by the harbour master once the legal requirements have been fulfilled.

Table 1: Procedure for applying for maritime concessions.

3.5 Elements assessed by authorities to rule on maritime concessions applications.

Considering that the first applications presented for Maritime Concessions in order to develop marine energy generation projects will face the challenge of proving their relevance and suitability, it is important to review the four criteria established in DS No. 2, Article 29 of the regulations for maritime concessions, to be analysed by the maritime authority in order for it to be granted:

- Overlaps with other concessions: The maritime authority will analyse whether the area requested overlaps with other concessions or destinations, either granted or in the process of being granted.

  Where the concession requested overlaps with a previously granted concession, it will be rejected regardless of its nature. This guarantees the rights acquired by previous holders are respected.

  However, notwithstanding this, in the event there is an overlap with a previously presented concession being processed, the application is not rejected or decided on a first come first served basis, but instead the authority undertakes a thorough analysis of the best use of the sector based on existing zoning, the industry to be developed, and national and regional interests.

  In light of the above, it is important for the marine energy industry to show its compatibility with other neighbouring uses and the social interest underlying the development of this type of renewable, non-polluting technologies that contribute to the country's energy security.

- Compatibility or suitability of the project: The zoning of the coastline plays a fundamental role in the assessment of the compatibility of the project and this will be reviewed in the next section.

- Whether the concession decree may require the project to be submitted for environmental assessment.

- Safety issues affecting navigation and human life at sea.

4. The regulatory framework for coastline usage zoning

Geographically, Chile is a coastal country whose coastline stretches for approximately 3990 miles. The country has created a National Policy for Coastline Usage (Política Nacional del Uso del Borde Costero, PNUBC), to ensure the sustainable management of coastal and ocean areas while maintaining a long term balance between environmental, economic, social, cultural, and recreational objectives. Part of the instruments established by the PNUBC to help it reach its objectives is the duty to set out Regional Coastline Planning Instruments, or Zoning.

The above is relevant to this report insofar as, prior to developing any project located on the coastline, the authority must review its compatibility and consistency with the Coastline Planning Instruments in force or under development.

4.1 Commissions and planning instruments for coastline usage

Chile is divided into 15 regions (detailed in Appendix 3), of which only the Metropolitan Region does not have a coastline. To date, of all the Coastline Regions, only two (the Coquimbo and Aysén regions) have an approved and valid zoning plan. The remaining coastal regions are in different stages of drafting and analyzing their zoning plans, although it is expected that significant progress will have been made in this area by the end of 2012.

The procedure to draw up Coastline Zoning is carried out regionally through Regional Commissions for Coastline Usage (Comisión Regional de Uso del Borde Costero, CRUBC) responsible for developing a regional zoning proposal consistent with the PNUBC to be subsequently presented to the National Commission on Coastline Usage (Comisión Nacional de Uso del Borde Costero, CNUBC) which reports to the Subsecretary of the Armed Forces of the Ministry of Defence. The CRUBC is comprised of the following political and social actors:

- regional governor, who presides over the CRUBC;
- provincial governors with territorial jurisdiction over the regional coastline;
- mayors of the municipalities with territorial jurisdiction over the regional coastline;
- Regional Ministerial Secretary of Economy, Development and Reconstruction;
- Regional Ministerial Secretary of Planning and Coordination, who acts as the commission's executive secretary;
- Regional Ministerial Secretary of Housing and Urban Planning;
- Regional Ministerial Secretary of Transport and Telecommunications;
- Regional Ministerial Secretary of National Assets;
- a representative from the navy;
- maritime governors;
- Regional Director of Port Works;
- Regional Director of the National Tourism Service;
- Regional Director of the National Fishing Service;
- Regional Director of the National Environmental Commission;
- the corresponding Zone Fishing Director;
- two representatives chosen by the regional council from its ranks;
- two representatives from the manual fishing sector;
- two representatives from the aquaculture sector;
- two representatives from the tourism sector;
- three representatives from other remaining sectors, as named by the regional governor.

Given the importance of coastline zoning in the development of the marine energy industry, it is concerning that the CRUBC does not have a representative from the Ministry of Energy and the generation companies, including hydroelectric, off-shore wind power, and marine energy generators. As explained in the recommendations in Chapter 8, it is suggested that the necessary regulatory modifications to incorporate representatives of the Ministry of Energy and industry in the CNUBC and CRUBCs are made.

In this respect, an important step was taken in late 2011 and since then, a representative of the Ministry of Energy has been included in the CRUBC. Even though this representative still does not participate in the decision making process (is not entitled to vote), this nonetheless represents progress, and further steps may be taken in the future in this respect.

4.2 Areas of preferred usages

In order to determine the Coastline Usage Zoning the CRUBC analyzes different environmental, social, economic, political and strategic factors to finally establish areas of "Preferred Usage" for the development of certain activities or industries (e.g. conservation, aquaculture, tourism, and ports) and the criteria in order to determine compatibility with other uses in these areas. Only in very exceptional cases will the planning instruments determine areas for exclusive usage.

As an example, in the Explanatory Memorandum on Zoning in force in the Coquimbo Region, as approved by Supreme Decree No. 518 (Ministry of Defence, 2005), preferred usage zones are established for port activities, manual fishing and coves, for aquaculture, tourism, industrial uses, etc. This zoning does not specifically include uses for generation and/or transmission projects, although in some cases these can be understood to be compatible with the established preferred usages.

Likewise, although the as of August 2010, the Explanatory Memorandum of Coastline Usage for the Tarapaca Region (under development) does not propose preferred uses for this type of activity, it does at least indicate under chapter IV on "Expected Results" for zoning that this must include a *"prospective study of the generation and location of alternative sources of drinking water and power supply on the rural coastline of the Region."*

This leads to the conclusion that, although the zoning instruments in force or under development do not prohibit the development of projects such as those analysed above, they will nonetheless face the challenge of having to demonstrate their compatibility with the preferred usages in existence according to the criteria that have been established without knowledge of the specific benefits and impacts of this industry.

Furthermore, considering that regional zoning instruments are dynamic and under permanent review, active participation in these processes is recommended for the future. The designation of preferred areas to develop these types of projects should be analysed.

5. NCRE incentives, project finance and the regulatory framework

Historically, the percentage of energy coming from NCRE sources has been very low in the Chilean energy matrix, as shown in Figure 2.

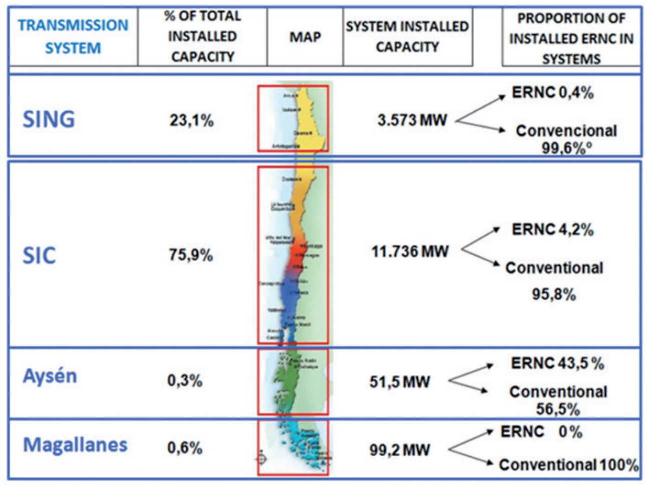


Figure 2: NCRE distribution in Chilean transmission systems (CER, 2010).

As a result, over the past few years, Chile has passed laws to provide incentives designed to promote NCRE projects. One example is Act 20,257 (2008) to reform the LGSE to account for *"the generation of electric energy using non-conventional renewable energy resources,"* also known as the NCRE Act.

5.1 Development status of NCRE industry

Prior to reviewing existing legal and financial incentives for NCRE projects, it is important to consider the current map of NCRE projects in Chile, shown in Table 2. The information is organised according to the technology used and each project's stage of development.

Status	Operation	Construction	SEIA	
			Approved, not built	Under assessment
Mini-hydro	245	64	368	93
Wind	185	6	2,269	1,041
Biomass	253	170	55	49
Solar	0	1	467	302
Geothermal	0	0	0	50
Total	683	242	3,159	1,535

Table 2: NCRE project development as of January 2012 (MW) (CER, 2012).

The table above indicates that there is growing interest in the development of NCRE projects. This is reflected in the large number of projects approved or under assessment and the entry of new technologies historically absent from the Chilean energy matrix, such as wind and solar power. However, the table also shows that difficulties persist in the effective development of these projects. This is reflected in the large number of projects that have received environmental approval but have not progressed to execution stage. Later in this report some of the difficulties that NCRE projects face in areas such as financing, land use, and permits will be analysed.

5.2 Definition of NCRE

Act 20,257 provides the legal definition of NCRE technologies in Chile and establishes the types of activities to be included in this category in order to ensure the application of existing legal and financial incentives.

LGSE, Article 225:

Non-conventional generation means are those that present any of the following characteristics:

1. Those whose primary source of energy is biomass energy, which corresponds to energy obtained from organic and biodegradable matter that can be used directly as a fuel or converted into other liquid, solid or gaseous biofuels. This is understood as including the biodegradable portion of household and other solid waste.

2. Those whose primary source of energy is hydraulic energy and whose maximum power is less than 20,000 kilowatts.

3. Those whose primary source of energy is geothermal energy, which is understood as that which is obtained from the natural heat within the earth.

4. Those whose primary source is solar energy, which is obtained from solar radiation.

5. Those whose primary energy source is wind energy, which corresponds to the wind's kinetic energy.

6. Those whose main source of energy is **marine energy,** which corresponds to all forms of mechanical energy produced by the movement of the tides, the waves, and the currents of the ocean, as well as that which is obtained from the thermal gradient of the seas.

7. Other means of generation determined based on evidence evaluated by the Commission that use renewable energies for the generation of electricity, contribute to the diversification of sources of energy in electricity systems, and have a low environmental impact in accordance with the procedures set out in the regulations.

For the purposes of this report, it is important to note that the broad definition of marine energy falls under the category of an NCRE and that its developers can therefore benefit from existing incentives for its promotion.

5.3 Quota or percentage of NCRE

Act 20,257 modified the LGSE by introducing Article 150 bis, reproduced below:

> Each electricity company that withdraws energy from electrical system with installed capacity of over 200 MW in order to sell it to distributors or end customers, whether or not they are subject to price regulation, must accredit before the respective CDEC Toll Division that an amount of energy equivalent to 10% of its withdrawals each calendar year have been injected into any of said systems by means of non-conventional renewable generation belonging to them or acquired through a contract.
>
> The electricity company may also accredit compliance with the aforementioned regulation (Paragraph 1) through injections of non-conventional renewable energy into electrical

systems over the course of the calendar year immediately preceding it as long as said injections have not been accredited for compliance with the regulation for that year.

Any electricity company that exceeds the percentage specified in the first paragraph for non-conventional renewable energy injections within the year in which the regulation is to be met with energy of its own or acquired through a contract and even if it has not made withdrawals may transfer its surplus to another electricity company. This may even be done among companies from different electricity systems. An authorised copy of the respective agreement must be submitted to the respective CDEC Toll Division so that the surplus may be appropriately accredited.

Any electricity company that does not accredit compliance with the regulation referred to in Paragraph 1 by March 1 of the corresponding calendar year must pay a charge of UTM 0.4 per MWh of deficit based on its obligation. If said company should fail to meet its obligation again over the next three years, the charge will be UTM 0.6 per MWh of deficit. Any electrical company with a deficit may postpone up to 50% of its obligation at the end of the calendar year if it has informed the Regulator prior to March 1 of the following calendar year.

The CDEC Toll Divisions for electricity systems with more than 200 MW must compile and maintain a single public record of the obligations, injections and transfers of NCRE for each electric company as well as all of the information necessary to accredit compliance with these regulations and the application of the provisions of this article.

The charges listed in the fourth paragraph will be levied on end customers and customers of distributors whose supplies meet the obligation outlined in the first paragraph of this article.

The monies collected through these charges will be distributed on a pro-rata basis in line with the energy consumed by the customers listed in the previous paragraph during the calendar year in which the obligation described in the first paragraph was not met.

The respective CDEC Toll Division shall calculate and determine both the payment of the charges that each company should make so that they may be allocated to the aforementioned clients based on the amounts collected from the companies that failed to meet their obligations as well as the transfers of money that are to take place among them. The Regulator shall require the Toll Divisions and companies involved to submit the information required to oversee the fulfilment of the obligations imposed in this section.

Any dispute that arises as a result of applying the previous section with the CDEC Toll Division brought forth by the electricity companies subject to the regulation described in the first paragraph or the distributors and end customers shall be resolved by the panel of experts. This body shall opt for one of the values proposed by the party that presents the discrepancy or the respective Toll Division. The dispute shall be formalised in the presentations that must be submitted to the panel using a sealed envelope within 15 days from the calculation issued by the Toll Division. In order to expedite the respective ruling, the panel must follow the procedure for discrepancies outlined in Article 208, Paragraph 11.

Injections from hydroelectric plants whose maximum power is less than or equal to 40,000 kW shall be recognised as well, but only for the purposes of accrediting the regulation outlined in paragraph one They will be corrected by a factor equal to one less the quotient of the excess over 20,000 kW of the plant's maximum capacity and 20,000 kW, which is expressed in the following formula:

PF = 1 - ((MP - 20,000 kW)/20,000 kW)

Where PF is the proportional factor mentioned above and MP is the maximum power of the respective hydroelectric plant expressed in kilowatts.

For clarification, it should be noted that as of January 2012, the charges correspond to:

- >> UTM 0.4 MWh (£20.3 approx.)
- >> UTM 0.6 MWh (£30.5 approx.)

The main tool for promoting NCRE in Chile is the legal imposition of a quota or minimum percentage of energy from NCRE sources. The main features of this instrument are set out in Article 150 bis of the Electrical Services Act (Ley General de Servicios Eléctricos, LGSE) and are summarised below:

- >> Mandated companies: Electricity companies that make withdrawals from the system in excess of 200 MW.

- >> Contracts signed after 2008: The obligation of the percentage or quota is only applicable to energy contracts signed after 2008.

- >> Gradual minimum percentage 2008–2024: The NCRE quota is to increase gradually over time, starting at 5% in 2014 and rising to 10% in 2024, as shown in Figure 3.

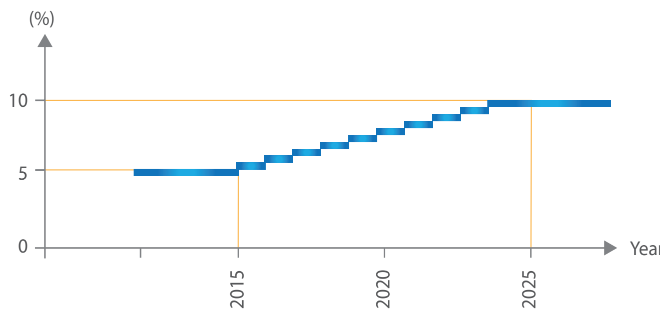


Figure 3: Gradual increase of legally required % of NCRE in Chile

- >> Form of compliance: Can be through direct or indirect generation from NCRE sources, an important aspect of the regulations that allows small NCRE generators to sell their production and/or NCRE attribute to electricity companies with withdrawals above 200 MW.

- >> Possibility of selling NCRE surplus.

  Charge or fine for failure to comply: UTM 0.4 (£20.30 approx.) per MWh of deficit based on the entity's obligation, with the charge increasing to UTM 0.6 (£30.50 approx.) per MWh if the company repeatedly fails to meet its obligation over the next three years.

Figure 4 includes information prepared by the Economic Load Dispatch Centres for the grids of Chile's Central and Norte Grande regions (CDEC–SING and CDEC–SIC) in partnership with the Corfo CER. It shows the behaviour of injections into the grid by NCRE sources in relation to the legal percentage or quota in the past year (2011).

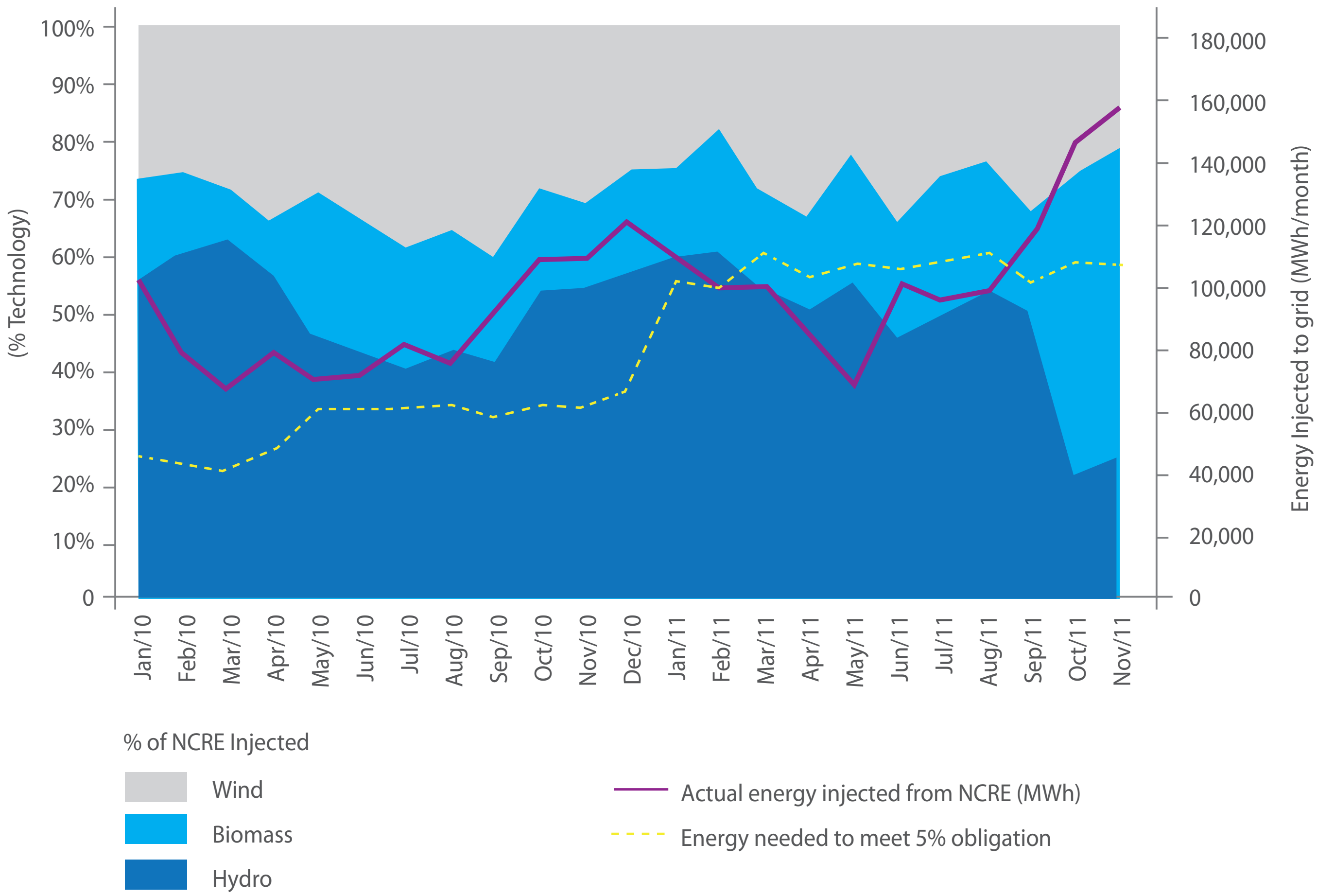


Figure 4: injected to the grid between January 2010 and November 2011 (CDEC SIC/SING, CER, 2011).

Future marine energy projects can take advantage of this legal incentive by signing energy supply contracts and/or selling the NCRE attribute to companies required to meet a minimum generation percentage using NCRE sources that cannot meet this obligation using their own sources.

A few years have passed since the implementation of the instrument and it is under continuous review in order to determine its effectiveness in terms of accelerating NCRE development. Congress is considering a bill that looks to increase the obligation set out in Article 150 bis of LGSE from 10% by 2024 to 20% by 2020 (the 20/20 goal). Specialised entities such as CER are considering whether the charge established in the law has had the desired effect of promoting NCRE, or whether it has failed to make the industry more dynamic due to its low value relative to the alternative cost of developing NCRE projects.

5.4 Trunk transmission toll exemptions.

Another tool established by LGSE to increase the feasibility of NCRE projects and small- and medium-scale projects is the exemption from the payment of trunk transmission tolls, with a benefit of up to 20,000 kilowatts applicable to NCRE projects. Projects with a power surplus between 0 and 9,000 kilowatts are entitled to the full exemption; projects with power surpluses between 9,000 kilowatts and 20,000 kilowatts, are entitled to a partial exemption.

5.5 Other incentives for NCRE projects.

Together with the legal incentives, the Chilean government has developed financial tools for NCRE projects, most of which are channelled through Corfo. Table 3 summarises the existing financial instruments, although updated information on the funds used from these mechanisms was not available for this report.

	Incentivo	Descripción
Current financial incentives	Corfo funding for basic and advanced pre-feasibility studies	Funding of pre-feasibility studies of NCRE projects for up to 50% of their cost up to CLP $33.000.000. (£43.000 approx.).
	Corfo creditlines	Funding of NCRE projects through long-term loans (12 years for a maximum of USD $15 million). Corfo has not allocated new funds to this instrument.
Other current incentives	Project is rated as Clean Development Mechanism (CDM)/Carbon Bond Sale	In accordance with the Kyoto Protocol, NCRE projects that show the technologies to be used are capable of reducing greenhouse gas emissions produced by conventional energies can be certified as CDM and sell Emissions Reduction Certificates.

Table 3: NCRE funding instruments in Chile.

The adequacy of the funds committed by the government for either research or construction and operating stages of NCRE projects is under continuous review. As an example, CER conducts periodic reviews of NCRE projects that face funding problems. The results of the latest assessment (July 2011) are presented in Table 4:

Technology	No. of projects	Installed capacity (MW)	Investment (MUSD)
Biomass	6	42	112
Wind	17	881	1,802
Mini-hydro	21	174	380
Solar	4	26	140
Total	48	1,123	2,436

Table 4: NCRE facing funding problems in Chile (CER, 2012)

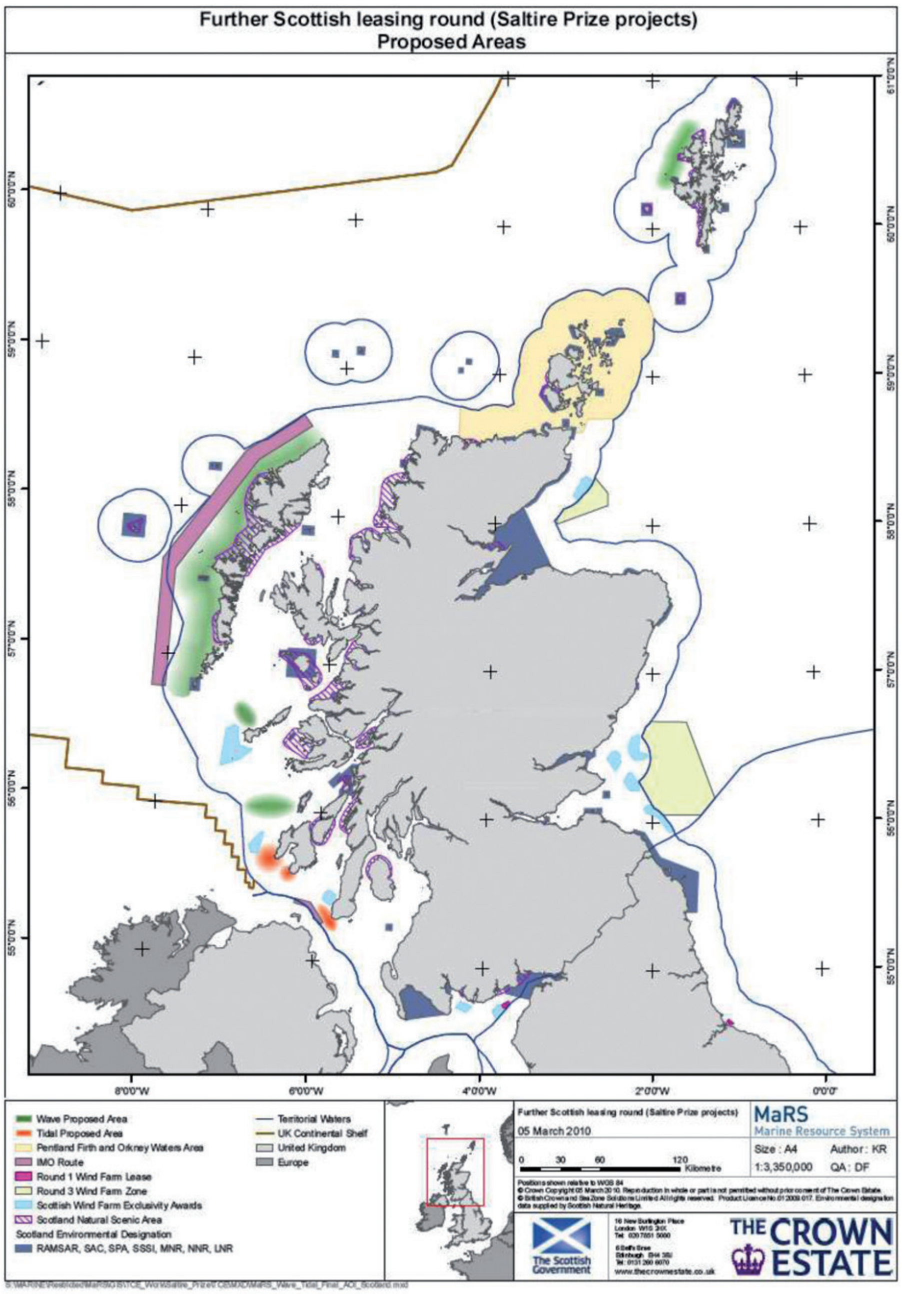
According to CER (2012) the main gaps for securing funds for developing technologies are linked to the difficulty of securing a bank loan or a power purchase agreement with an available client.

Appendix 3:
Political map of Chile

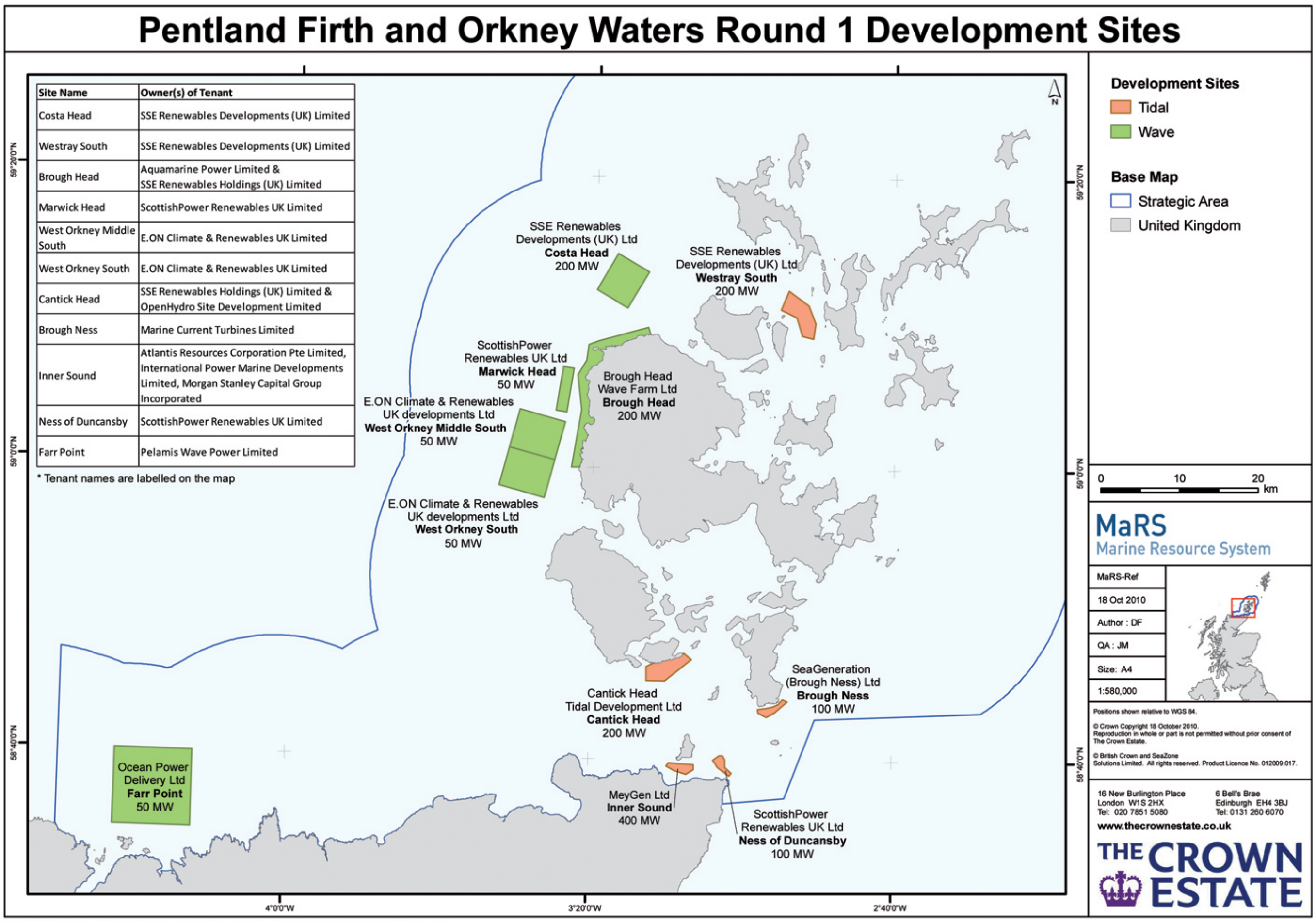
(Wikipedia commons)

Appendix 4:
Figures of leased areas for marine development in Scotland

The figure below shows the next Scottish leasing round for future projects.



Map showing the currently leased sites in the Pentland Firth and Orkney Waters strategic area.



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