A New Energy Innovation Series

Marine Energy in Chile

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Marine energy is increasingly recognized as a viable and growing source of sustainable energy. According to estimates, the electrical generation potential of marine energy could exceed the current worldwide consumption fourfold.[1] Other studies estimate that by 2030, the exploitable potential in hydrokinetic energy could reach 15,000 terawatt/hours (TWh), or half the globe's consumption for that year.[2] Even conservative estimates project future ocean energy installed capacity to increase sevenfold in the next five years, reaching 5.5 GW by 2017.[3]

Chile has captured the attention of marine energy proponents. Its long coastline and powerful waves and tidal currents (up to 66 kW/m and 5 m/s, respectively)[4] lead to an estimate of over 160 GW in marine energy resources, equivalent to more than 10 times the current installed capacity in the country. Harvesting this marine energy would help mitigate the energy crisis that seems imminent in the country, which results from increasing energy demand, unreliable energy imports, and decreasing hydrological levels.[5]

[1] "Marine Energy in Chile." Working paper by Sergio Versalovic, Center for Renewable Energies (CER), 2010. Figure quoted from Ecofys, 2009.
[2] Ibid, figure referenced from UNDP.
[3] "Hydrokinetic and Ocean Energy." Pike Research, 2012.
[4] "Preliminary Site Selection, Chilean Marine Energy Resources." Garrad Hassan research, 2009.
[5] Ibid.

Recent History in Chile

Between 2002 and 2011, energy consumption in Chile grew from approximately 42,000 GWh to 62,000 GWh, an increase of approximately 47 percent.[6] In the same period, installed capacity grew more than 57 percent, from approximately 10 GW[7] to 16 GW. In 2009, 28 generation companies, 5 transmission companies, and 37 distribution companies participated in 4 electricity grids:

- The Northern Interconnected System (Sistema Interconectado del Norte Grande, or SING)
- The Central Interconnected System (Sistema Interconectado Central, or SIC)
- The Aysén System
- The Magallanes System

Current installed capacity is approximately 16 GW. SIC accounts for 75 percent, SING for 24 percent, and the Aysén and Magallanes systems for less than 1 percent.[8]

In terms of installed capacity, the Chilean electricity energy matrix is composed of hydro (33 percent), followed by natural gas (26 percent), coal (20 percent), and finally diesel (15 percent).[9] In terms of generation, 37 percent comes from hydro, 26 percent from coal, 22 percent from diesel, and 10 percent from gas. While hydro and coal are indigenous, most of the diesel and natural gas is imported.

In 1998, a severe drought in Chile emptied the reservoirs and led to brownouts and energy cuts. The response was a substantial increase in the installed capacity of natural gas plants fed by imports from Argentina. Unfortunately, this arrangement did not last, and by 2008, chronic shortages led to another serious energy crisis. Chile has been trying to grapple with energy security ever since. Projections estimate that in order to maintain economic growth, installed capacity must increase by over 8 GW by 2020.[10] Although currently planned projects could deliver that additional capacity, several issues—including popular opposition, lack of environmental approval, and land entitlement disputes—have held up implementation.

[6] "Gross Generation." CNE data, 2012.
[7] "Real Production by System." CNE data, 2012.
[8] "Generation Capacity." CNE data, 2011.
[9] Ibid.
[10] Presentation by Energy Ministry of Chile, September 14, 2011

Clean Energy Legislation

In response to past and impending crises, Chile has developed a series of initiatives to diversify its energy matrix and accelerate the introduction of Non-Conventional Renewable Energy (NCRE) in the energy sector. Law 20.257 was passed in 2008, mandating that at least 10 percent of energy distributed be derived from NCRE sources by 2024, imposing fines on companies that do not comply. The law has driven much interest in incorporating NCRE to power generation. The regulation, however, only applies to systems above 200 MW (the SIC and SING systems). Hence, most of the locations with the highest marine energy potential, covered by the Aysén and Magallanes systems, are excluded.

National Marine Energy Strategy

In 2009, in response to a study commissioned by the Inter-American Development Bank (IDB),[11] the Chilean government announced its commitment to further develop its marine energy resources. The study estimated the overall potential for wave energy at approximately 160 GW, or over 10 times the current installed capacity, and found that a capacity between 500 MW and 800 MW could potentially be harnessed just from the streams in the Chacao Channel next to Puerto Montt (which is covered by the SIC grid). More recently, the current administration expressed a commitment to have at least 1 MW of installed marine energy generation initiated during its tenure.

Scotland, which has a similar level of marine energy potential and is a leader in the field, has been working in close collaboration with academia, research institutions, and industry for about 20 years. The Marine Energy Group was launched in 2003, and subsequently published its Marine Energy Roadmap in 2009, which focuses on five work streams, including finance, grid connection, infrastructure, planning, and promotion within Europe. In the case of Chile, a national marine energy strategy is expected to be unveiled soon, which will likely address the following: the regulatory framework, how agencies collaborate within government and with other stakeholders, the development of pilot projects, and mechanisms to foster research, investment, and international cooperation.

11 "Preliminary Site Selection: Chilean Marine Energy Resources." Garrad Hassan for the IDB, 2009.

Potential Stakeholders in Marine Energy Development in Chile

Government Institutions
CORFO (Corporación de Fomento de la Producción de Chile): a development corporation that promotes investment, innovation, and the national industry, including specific tools for marine energy.
CER (Center for Renewable Energies): an offshoot of CORFO focused on renewable energy.
CONICYT (National Commission of Scientific and Technological Research): a national commission that promotes scientific and technological research, including marine energy.
Ministry of Defense: Subsecretariat of the Marine (Navy): permits all production and/or research projects on the coast or in national waters. DIRECTEMAR (Directorate for Maritime Territory and Mercantile Marine) enforces the existing norms regarding any maritime operation (hierarchically under the Navy). SHOA (Oceanographic and Hydrographic Service): monitors, registers, and provides early warning of potential hazards regarding maritime conditions for any civil or military operation. National Commission for Coastal Utilization: coordinates 12 public service agencies to ensure that zoning reflects a rational utilization of the national coastline.
Ministry of Energy: sets energy policies and regulations, including the regulatory framework that provides the appropriate market conditions for the development of new technologies.
Ministry of the Environment: establishes environmental policies and guidelines, and manages the national environmental impact assessment system.
Ministry of National Public Good: responsible for recognizing, administering, and managing state-owned territory, as well as ensuring its sustainability.
Ministry of Public Works (MoP): in charge of public infrastructure, including roads, ports, and coastal protection. INH (National Hydraulic Institute): responsible for scientific and technological research on fluid dynamics for marine projects, such as bridges and potential marine energy devices.

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Potential Stakeholders in Marine Energy Development in Chile *(continued)*

Key Organizations and Stakeholders in Chile
ACERA (Chilean Association for Renewable Energies): promotes NCREs and fosters a regulatory framework to provide incentives; aims at achieving a 30 percent participation of NCREs by 2030.
ALAKALUF promotes marine energy in Chile, through the organization of workshops and seminars, site selection, environmental issues, and onsite assessment of power resources.
ASMAR (Astilleros y Maestranzas de la Armada): performs all ship maintenance work for the Chilean Navy; has the technical ability to assemble and perform maintenance work on marine energy devices in southern Chile.
Fundación CEQUA or Centro de Estudios del Cuaternario de Fuego-Patagonia y Antártica: a scientific and technological research center that focuses on environmental issues.
ENERMAR Corporation: the first private association to focus exclusively on the promotion of marine energy; convenes stakeholders to facilitate the design/implementation of energy resources, project design, and measurement and generation equipment.
Universities: some Chilean universities, such as Catholic University in Santiago and the University of Concepción, have shown great interest in marine energy development.
International Organizations
IEA (International Energy Agency): works to ensure reliable, affordable, and clean energy for member countries, and provides a focus point for a global dialogue on energy.
OES (Ocean Energy Systems): promotes research, development, and demonstration of marine energy technologies among countries (Chile is not a member yet).
IRENA (International Renewable Energy Agency): provides a hub for international cooperation and synergy for the renewable energy community.
Marine Energy Trade Groups: brings together industry, academia, government, and civil society for marine and hydrokinetic energy in various countries, including: OEG: Ocean Energy Group (UK); OREC: Ocean Renewable Energy Coalition (United States); and OREG: Ocean Renewable Energy Group (Canada).

Additional Information on Marine Energy

Wave and Tide Energy for Prize Money

Ocean Energy

The Chacao Channel

The Chacao Channel is located at the southern end of the SIC grid and very close to the city of Puerto Montt, home to approximately 175,000 people. With tidal peak flows of 3.5 to 5m/s[12] and raw kinetic energy of 674MW,[13] the Chacao Channel was identified by Garrad Hassan as the most promising area for tidal stream energy project development in the country.[14] The Ministry of Energy and the CER are looking at options to develop a project, with support from the IDB, to tap into this potential. The specific technology selected for this application will depend on variables such as wave intensity, level and variability of currents, and the flow of vessels through the channel, all of which depend on the specific location chosen for the marine device.

Chacao Channel

Source: Google Maps

Punta Arenas and the Magallanes Region

Magallanes, the southernmost region of Chile, is a remote, sparsely populated area located between the Pacific and Atlantic oceans. Its capital, Punta Arenas, has a population of approximately 120,000 people. The nearest town, Puerto Natales (20,000 inhabitants), is located 250 kilometers away (in comparison, Chiloe, the southernmost extension of the SIC system, is located over 1,500 kilometers north). The local economy is based primarily on livestock, port and shipping activities, forestry, fishing, and oil exploration. With average peak flows of 4 m/s in the Straits of Magellan, this region was also identified as one of the most promising areas for development of marine energy in Chile.

Magallanes Region

Source: Arkapatagonia.com

Regional Generation Characteristics

Power generation in the region is covered by four independent systems: Punta Arenas, Puerto Natales, Puerto Williams, and Porvenir. The rest of the demand in the region, mostly industrial, is covered by independent systems. The Magallanes systems have an overall installed capacity of approximately 100 MW. Generators in Magallanes and Aysén are integrated vertically, whereby each generation company (Edelmag and Edelaysen) is responsible for generation, transmission, and distribution. Although they are private, these companies comply with a government mandate to provide energy. Therefore, growth of renewable energies is directly linked to government policies. The government also subsidizes electric power, which is currently generated from diesel in Aysén and locally produced natural gas in Magallanes. Indigenous gas supplies are expected to run out in four to five years, rendering the locally mined coal as a possible alternative for the near future.

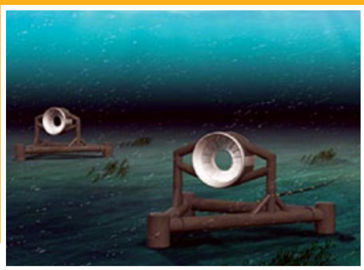
[12] Garrad Hassan, p38.
[13] Garrad Hassan, p61, Total Mean Annualized Power, after spatial correction, flood, and ebb.
[14] Garrad Hassan, p46. Selection criteria include resource levels, available depth, grid connection, nearest ports, and lack of potential conflicts with other user groups or environmental protection areas.

Available Marine Energy Devices

The following are some of the marine energy devices being considered for application in the Magallanes region. Note that this is a sample listing, as there are other viable technology options.

Open Hydro

Open center turbine: may be mounted on a platform on the seabed.



Fred Olsen

Power Buoy (point absorber): energy is produced from roll and pitch motion of the surface.

Ocean Renewable Power Company (ORPC)

Horizontal Axis Venturi Fence Turbine: different modules may be used to harness energy from small rivers, shallow tides, or deep tides and ocean currents.

Flumill

Solid helix screw turbine: can operate in ocean/tidal streams at less than 1 m/s flow; low cost and no moving parts in turbine lead to lower overall costs.

Minesto

Kite turbine: small and low weight for portability; unique ability to operate at low speeds.

Ocean Power Technologies Power Buoy

Floating Buoy (point absorber): harnesses the vertical motion due to wave energy.

Project Concepts in Magallanes

"First Narrows" (Primera Angostura)/IMPA

This project concept, developed by the local engineering firm IMPA (Ingeniería Mecánica Proyectos y Asesorías), consists of a hydrogen generation station powered by marine energy obtained from the First Narrows of Magellan. Although this area has powerful currents, it is remote (160km from Punta Arenas) and local demand is sparse. IMPA has extensive experience in manufacturing hydraulic and piping systems. The project envisions an Open Hydro type of system and would replicate the HARP (Hydrogen Assisted Renewable Power) project in Bella Coola, Canada. In addition to generating hydrogen, a marine device could potentially meet the demand of the 50 residents of Punta Delgada and the infrastructure needed for the ferries that cross the channel (mostly lighting and heating installations), which demand a capacity of approximately 250 kW.

"First Narrows" Strait of Magellan/ Primavera County

This project, developed by Alakaluf Ltd. and backed by the Primavera County in Tierra del Fuego, would generate 250 kW to provide electricity to 450 residents of Cerro Sombrero and Bahia Azul and the research center and bird sanctuary in Bahia Lomas. Possible technologies for this initiative include an Ocean Renewable Power Company, Flumill, or Fred Olsen type of device.

First Narrows in the Strait of Magellan

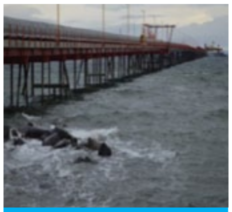
Captain Aracena Island/Salmon breeding

The concept is to provide an alternative to diesel generation for salmon fisheries, located offshore, that could eventually be standardized and applied throughout the industry. Each salmon pontoon (currently there are 200 in Chile) would require an installed capacity of approximately 250kW, including living quarters and operations. As the fisheries relocate periodically, a Minesto "kite" type of power device has been suggested.

Captain Aracena Island / Salmon breeding

Otway Channel/Pecket

Located next to the Pecket Coal Mine, the Otway Channel has high marine/wave energy potential. Though currents are fairly low, wave frequency is 15 to 21 seconds. The coal mine operators are closely tied to an engineering firm (Ingeniería Civil Vicente), which has the resources and technical capability to manage the device. Assuming coal is used to replace natural gas for most of the local energy generation requirements, the company may be interested in adding a marine energy component to improve the sustainability of the energy mix. Another advantage of this site is connectivity. The mine currently uses diesel generators to provide power for the loading ships at the pier, which is required for only a few days every month. Since the generators are connected to the Punta Arenas grid (100MW) through a substation, this could serve as the interconnection point for a wave power facility.



Coal-loading pier, Otway Channel

Oil Platforms/ENAP

Chile's national gas company, ENAP (Empress National del Petroleo), has four platforms that are not being used and may be adapted to host tidal or wave energy generation devices. An installed capacity of approximately 2 MW could supply power for platform processes (over 40 platforms in total are currently in operation in the area), and for the approximately 100 residents of ENAP's camp in the village of Posesión. This alternative would also constitute an opportunity for ENAP to get involved in renewable energies.

Fitzroy Channel/ENERMAR

ENERMAR, working with Alakaluf in Chile and Aquatera in Scotland, is considering a project in the Fitzroy Channel to supply marine energy to the 70 residents of the remote Villa Posomboy in Rio Verde, which would require an installed capacity of 100kW. An ORPC type of device would be employed.

Fitzroy Channel

Conclusions

The IDB is in continuous contact with Chile's Ministry of Energy and other key stakeholders to support the environmentally and economically sustainable generation of marine energy. The country has tremendous resources, the technical capacity to maintain or even assemble marine energy devices, and a government that has expressed a commitment to renewable energy. However, realizing the potential of marine energy will take much effort. Some of the most promising marine energy resources in Chile are far removed from the demand, and the main regulatory incentive behind NCRE development does not apply to the regions with the highest potential. Therefore, in the short term, the projects with the highest potential of reaching implementation will be the ones connected to the SIC grid, especially those in the Chacao Channel.

This is the first issue of a new series dedicated to deliver concise information on energy innovation. The series is published by the Energy Innovation Center (EIC), an integral part of the IDB's Energy Division in the Department of Infrastructure and Environment.

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