

Wave Energy Potential in Chile

Identification of a preferred site & device combination with
an integration proposition

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CHILE

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Identification of a preferred site & device combination
with an integration proposition

by

Luci Dominguez van Tilburg	5109043
Roel van Eijkeren	5621607
Chanine Enthoven	5022126
Job van den Hoek	5173876
Pim Horbeek	4905970
Dirk-Jan van Ommeren	5053927

Supervisor:	Dr. C. (Catalina) Estrada Mejía
Supervisor:	Dr.ir. A. (Antonio) Jarquin Laguna
Supervisor:	Dr. J. (Jenny) Lieu
Supervisor:	Dr.ir. M. (Mauricio) Reyes Gallardo
Project Duration:	September, 2025 - November, 2025
Faculty:	Faculty of Civil Engineering and Geosciences, Delft

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Summary

Chile's ambitious renewable energy targets call for further development and innovation in the sector. In this report, extensive research is presented on the opportunities for wave energy in Chile. A detailed evaluation of three possible wave energy converters and five possible sites is performed. Out of this evaluation, a preferred combination is obtained through a Multi-Criteria Analysis (MCA) using the TOPSIS method. This method ranks alternatives in the MCA by measuring their relative proximity to the ideal best solution and their distance from the ideal worst solution.

The input for the analysis consists of factors for the social context, environmental impact, technical performance, economic feasibility, and the political & regulatory context. These categories are further divided into smaller subcategories. For the assignment of scores to all categories, research has been conducted for each specific factor. For the technical and economic aspects, desk research was conducted, and calculations were performed to evaluate the capacity factors, annual energy yield, and levelised cost of energy (LCOE). The remaining criteria (social, environmental, and political & regulatory) are essential for the long-term viability of wave energy in Chile. These aspects were explored through a stakeholder analysis, literature research, and expert interviews, providing valuable qualitative insights into the local context, environmental sensitivities, and institutional readiness for marine energy adoption. The MCA resulted in a CorPower wave farm in Concepción as a preferred combination. This outcome is a consequence of average scores on the technical criteria, relatively good scores on the social criteria, and high scores on the remaining criteria.

Research, interviews, and the financial outlook mark the necessity of combining a potential wave farm with another project. Different offshore wind farms were evaluated near Concepción. From this evaluation, the floating offshore wind farm Vento Azul BioBío was selected as the preferred combination with the wave farm. The proposed location is 22 kilometres offshore from Concepción. This location allows for 51 CorPower packs, with an estimated 510 MW of wave energy output. Intermittency issues are reduced, and energy production surpluses are created, which can be used for green hydrogen production.

Due to the harsh environment in Chile, installation and maintenance can only be performed by an Anchor Handling Tug (AHT) or an Offshore Construction Vessel (OCV). From the five ports analysed, the port of San Vicente is chosen as the most suitable option.

At the chosen location, different species are found, and therefore, an environmental impact analysis needs to be performed. In addition, a single air bubble curtain can be used to minimise noise impact on the environment during installation.

A forecast model was developed to predict the expected wave energy output in Concepción. The model uses numerical forecasts of wave parameters provided by the University of Valparaíso, such as significant wave height and wave period. By combining these inputs with the power performance characteristics of the CorPower buoys, the model estimates the energy production for the next seven days. Surplus outputs can be predicted, allowing for efficient green hydrogen production.

To clarify the steps required for the effective installation of a wave energy farm, a roadmap is proposed. This roadmap visualises the entire process from site selection and permitting to construction, grid connection, and long-term operation. It serves as a proposed guideline that outlines the sequence of actions, key stakeholders involved, and potential challenges at each stage. By structuring the process in this way, the roadmap helps identify critical dependencies, streamline decision-making, and support efficient project planning for future wave energy developments in Chile.

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Nomenclature

Abbreviations

Abbreviation	Definition
AAA	Áreas Apropriadas para el ejercicio de la Acuicultura
AEY	Annual Energy Yield
AFD	Agence Française de Développement
AHT	Anchor Handling Tug
AMERB	Áreas de Manejo y Explotación de Recursos Bentónicos
BBC	Big Bubble Curtain
BCN	La Biblioteca del Congreso Nacional de Chile
CAPEX	Capital Expenditures
CEN	Coordinador Eléctrico Nacional
CNE	Comisión Nacional de Energía
CORFO	Corporación de Fomento de la Producción
CPT	Cone Penetration Testing
DBBC	Double Big Bubble Curtain
DR	Democracia Cristiana
DIRECTEMAR	Dirección General del Territorio Marítimo y de Marina Mercante
dB	Decibel
DOP	Dirección de Obras Portuarias
EPV	Empresa Portuaria Valparaíso
ERA5	ECMWF Reanalysis v5
EUR	Euro
FLS	Fatigue Limit State
GHG	Green House Gas
HSD	Hydro Sound Dampers
IEA	International Energy Agency
IHC-NMS	Royal IHC - Noise Mitigation Screen
ILO	International Labour Organisation
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LCA	Life Cycle Analysis
LCOE	Levelised Cost Of Energy
LMCC	Ley Marco de Cambio Climático
LOA	Length Overall
MCA	Multi-Criteria Analysis
MERIC	Marine Energy Research and Innovation Center
MMA	Ministerio de Obras Públicas
MPA	Marine Protected Areas
MOP	Ministerio de Obras Públicas
NDC	National Determined Contributions
NGO	Non-Governmental Organisation
OBIS	Ocean Biodiversity Information System
OCV	Offshore Construction Vessel
OES	Ocean Energy Systems
OPEX	Operational expenditures
OWC	Oscillating Water Column
PACCC	Plan de Acción Comunal de Cambio Climático
PARCC	Plan de Acción Regional de Cambio Climático
PR	Partido Republicano
PSC	Partido Social Cristiano

Abbreviation	Definition
PLAXIS	Plane Strain Axial Symmetry
P90%	90% chance that the outcome is equal to or greater than
PTO	Power Take off
ROV	Remotely operated Vehicle
SDG	Sustainable Development Goals
SEA	Servicio de Evaluación Ambiental
SEC	Superintendencia de Electricidad y Combustibles
SECOS	Instituto Milenio en Socio-Ecología Costera
SLS	Serviceability Limit State
SMA	Superintendencia Del Medio Ambiente
SUBPESCA	Subsecretaría de Pesca y Acuicultura
TLS	Tension Leg System
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
TRL	Technology Readyness Level
TSEJ	Transición Socioecológica Justa
UACH	Universidad Austral de Chile
ULS	Ultimate Limit State
USD	United States Dollar
UMACK	Universal Mooring, Anchor & Connectivity Kit Demonstration
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WACC	Weighted Average Cost of Capital
WEC	Wave Energy Converter

Symbols

Symbol	Definition	Unit
c_{rf}	Capital Recovery Factor	[-]
E_{wave}	Wave energy flux per unit crest length	[W/m]
$E_{kinetic}$	Kinetic energy component of wave energy	[J/m ²]
$E_{potential}$	Potential energy component of wave energy	[J/m ²]
D	Depth	[m]
d	Distance	[m]
F_d	Cost factor for distance	[€/kW/km]
g	Gravitational acceleration	[m/s ²]
h	height	[m]
H_m	Mean wave height	[m]
H_{m0}	Significant wave height	[m]
N	Lifespan	[y]
T_e	Energy period	[s]
T_p	Peak Wave Period	[s]
ρ	density	[kg/m ³]
λ	wavelength	[m]
η	efficiency	[-]
π	pi	[-]

1 Introduction

Around the world, societies are facing the accelerating consequences of climate change. Continued dependence on fossil fuels for electricity production has contributed to rising greenhouse gas (GHG) emissions (IPCC, 2023) (United Nations, 2025). Global warming has altered the atmosphere, oceans, cryosphere, and biosphere, leading to widespread adverse impacts. These range from an increase in climate extremes, like droughts, to impacts on human health, such as air pollution and broader societal impacts, including forced migration due to inhabitability. (OECD, 2025) (WHO, 2022) (IPCC, 2023).

The challenges posed by climate change make the shift from fossil to renewable energy inevitable (United Nations, 2025). Chile has set ambitious targets for the integration of renewable energy into its national grid, aiming for a net-zero emission energy supply by 2050 (COP25, 2021). On top of that, Chile aims to be the largest exporter of green hydrogen in the world by 2040 (Green Hydrogen Organisation, 2025), stressing the need for renewable energy even more. In recent years, Chile has made significant strides in developing renewable energy projects. The country is home to several large-scale green energy projects, including solar farms, wind farms, and hydroelectric power plants, which contribute to the growing share of renewables in its energy mix (Generadoras de Chile, 2025). For instance:

- In the Atacama desert, a solar plant is under construction, called Oasis de Atacama, with an estimated total power of two gigawatts (Greenergy, 2025)
- Horizonte Wind Farm, situated in the Atacama Desert, has a capacity of 816 MW (Gobierno de Chile, 2025).

Solar and wind power, while renewable, are intermittent sources of energy that depend on weather and time of day. Wave energy, on the other hand, is nearly continuous due to the constant motion of ocean waves along the coastline of Chile. However, it also ultimately depends on weather patterns, as wave intensity and frequency are influenced by wind strength and storm activity. By complementing solar and wind, wave energy has the potential to stabilise the renewable energy supply during periods of low output, ensuring a more constant and reliable green energy supply.

Chile's long coastline creates a unique opportunity for the production of wave energy, a renewable source that could play a key role in the country's energy transition. Unfortunately, momentum in wave energy research has faded, and Chile's leading wave energy research centre will end its research activities later this year (Interviewee 14, Personal Communication, October 21, 2025). However, the potential remains substantial. This report, therefore, aims to revive the interest in wave energy in Chile by

finding a preferred combination of a location and a suitable wave energy converter (WEC). In addition, it seeks to develop a roadmap for the integration of wave energy in the already existing energy mix. Thereby, this report offers both a technical as well as a strategic perspective on wave energy, and is aimed at restarting the public debate.

The research question is formulated as presented below:

What is a preferred combination of a location and wave energy converter, and how could this be integrated into the energy system of Chile?

This report is structured as follows. First, a thorough background is offered. Next, the method for determining a preferred location and device is presented. After that, suitable sites and WECs are identified and investigated. In the following section, a multi-criteria analysis is conducted to select a preferred location and WEC, after which this location is worked out in more detail, and a possible way of integration in Chile is proposed. The report concludes by presenting a forecast model and a roadmap that can serve as a framework for the integration of wave energy in Chile and to restart the discussion around wave energy in Chile.

2 Background

This chapter provides the contextual foundation for assessing wave energy in Chile. It addresses five key dimensions that together frame the opportunities and constraints for wave energy development. First, the social and stakeholder context is considered, highlighting the importance of societal acceptance, stakeholder alignment, and community benefits. The environmental perspective then outlines the ecological setting and potential impacts of offshore energy projects. The technological dimension reviews the state of the art, looking at wave energy converters and supporting infrastructure, while the economic analysis evaluates cost structures and financial feasibility. Finally, the political and regulatory context examines the policies, institutions, and governance arrangements that influence project development.

By combining these perspectives, the chapter builds an integrated understanding of the environment in which wave energy projects would operate, providing the basis for the multi-criteria analysis, evaluations, and strategic outlook developed in later sections.

2.1 Social & Stakeholder Analysis

The development of wave energy in Chile depends strongly on the social dimension, where public acceptance and stakeholder alignment determine whether projects can move beyond the pilot stage. Projects which neglect these dynamics often encounter delays or face outright rejection, as communities and organisations play a decisive role in legitimising energy transitions (Oliva et al., 2024). This section examines the social context in which wave energy projects would operate, focusing on determinants of social acceptance as well as the stakeholder landscape that shapes opportunities for collaboration or conflict.

2.1.1 Social Context

Chile's coastline is central to cultural identity and economic livelihoods, with fisheries, shipping activities, industry, aquaculture, tourism, and conservation overlapping in coastal zones (Davies et al., 2014; Tampier et al., 2021). Nationally, support for renewable energy is high, particularly among younger and more educated groups (Bronfman et al., 2012; Véliz et al., 2023). However, among some groups, awareness of wave energy remains limited, creating uncertainty and perceived risks (Oliva et al., 2024). Social acceptance is thus an important factor to consider and is shaped by three main determinants: socio-political, community, and market acceptance (Wüstenhagen et al., 2007). Experience from past megaprojects, such as the HidroAysén hydropower project, shows that when these conditions are not carefully considered, projects risk being perceived as imposed rather than collaborative, and may ultimately be rejected by the community despite initial governmental approval (Grey & De Bene, 2015). In

addition to consideration of social acceptance, mapping out the stakeholder landscape and identifying possible socioeconomic opportunities is essential in considering the viability of a wave energy project.

2.1.2 Key Stakeholders

The successful development of wave energy requires coordination across a wide range of actors, from ministries and regulators to local communities, Non-Governmental Organisations (NGOs), and industry. To map this landscape, the most relevant stakeholders are identified based on their potential influence, interests, and proximity to wave energy projects. Table 2.1 presents these groups, outlining their roles and relevance to offshore development.

The table highlights that governmental actors such as the Ministry of Energy and the Ministry of Environment are central in shaping policy, regulation, and permitting, while regional governments play an intermediary role between national strategies and local communities. Interviewee 8 from Ocean Energy Systems (IEA-OES) (Personal Communication, September 26, 2025) and Interviewee 10 from Austral University of Chile (Personal Communication, October 3, 2025) confirm that government backing is one of the most decisive factors for wave energy development. In particular, the promotion of dedicated test sites is seen as essential for enabling research, attracting investment, and moving projects from the experimental stage toward implementation. Industry actors, including energy companies, Wave Energy Converter (WEC) producers, and port operators, are crucial for investment, technology development, and integration into existing infrastructure. Academia and research institutes contribute knowledge and testing capacity, whereas civil society organisations, indigenous communities, and fisheries unions influence legitimacy through local acceptance. Finally, funding institutions and international bodies provide essential financial support and knowledge exchange.

Table 2.1: Overview of identified stakeholder groups relevant for wave energy in Chile

Type	Stakeholder	Description
Government	Ministry of Energy: CNE, SEC	Responsible for national energy policy, regulation, and oversight (Ministry of Energy, Government of Chile, 2025). CNE develops policy, while SEC supervises compliance and safety (Comisión Nacional de Energía (CNE), 2025).
	Ministry of Public Works: DOP	Oversees planning and construction of public infrastructure (Ministerio de Obras Públicas (MOP), 2025). The Port Works Directorate (DOP) plays a key role in offshore construction.
	Ministry of Environment: SEA, SERNAPESCA, SMA	Formulates environmental policies (Ministerio del Medio Ambiente (MMA), 2025). SEA conducts assessments, SERNAPESCA regulates fisheries, SMA enforces compliance.
	Chilean Navy: DIRECTEMAR	Chilean Navy's maritime authority; regulates navigation, safety, and maritime space (DIRECTEMAR, 2025). Their approval is required for offshore projects.
	Regional Governments	Regional and municipal authorities mediate between national policy and local communities, influencing acceptance locally.
Industry	Energy companies	Domestic utilities (e.g., Enel Green Power Chile, Colbún) and international actors invest in renewables; essential for financing and deployment (Davies et al., 2014).
	WEC developers	International technology developers such as CorPower, Ocean Energy and Carnegie provide the devices needed.
	Port & grid operators	Integration requires coordination with local ports and the national grid (SEN), managed by the National Electric Coordinator (CEN).
	Marine construction & engineering	Provide expertise for offshore installation, anchoring, and maintenance.
Academia / Knowledge Institutes	MERIC	Chile's Marine Energy Research and Innovation Center; backed by Enel Green Power and Naval Group.
	Local & international universities	Local universities research coastal systems and energy; international partners contribute knowledge transfer.
Civil Society	NGOs & environmental groups	Oceana Chile and local NGOs such as SECOS act as watchdogs for marine conservation, influencing public opinion and permitting. SECOS also advances socio-ecological research. (Greyl & De Bene, 2015).
	Community & indigenous groups	Artisanal fisheries unions and indigenous communities directly affected by coastal projects; historically opposed imposed projects, stressing inclusion (Palma-Behnke et al., 2021; Selman-Caro et al., 2024).
	General public	Broader opinion shapes political legitimacy; acceptance depends on awareness, trust, and visible benefits.
Funding & International Institutions	CORFO & Invest Chile	National development agencies supporting renewable innovation and investment (Corporación de Fomento de la Producción (CORFO), 2025).
	International funding	Institutions such as the World Bank and Green Climate Fund provide funding and assistance for Chile's energy transition.
	International bodies	IEA-OES facilitate collaboration and knowledge exchange on ocean energy (Ocean Energy Systems (OES), 2025).

2.1.3 Stakeholder Analysis

To further analyse these relationships, a stakeholder network was constructed, mapping connections and information flows between the identified actors (see Appendix B). This is complemented by a stakeholder power–interest matrix, illustrating the degree to which power and interest align with wave energy development (Figure 2.1).

The mapping shows that influence over decision-making is concentrated within national authorities such as the Ministry of Energy, while the actors with the strongest technical capability and motivation to advance wave energy are universities, research institutes, and WEC developers, which hold very low institutional power. This power–interest gap helps explain the limited progress of wave energy in Chile to date: although high-interest stakeholders are driving innovation, they depend on ministries, regulators and funding whose priorities remain focused on established renewables. In addition, on the social side members of civil society such as indigenous communities hold great power over the possible implementation of offshore projects, as noted by Interviewee 10 (Personal Communication, October 3, 2025).

2.1.4 Social Challenges & Opportunities

Experience shows that the social dimension can determine whether marine energy projects succeed or fail. The main challenges and opportunities can be summarised as follows:

- Public support is critical. Early engagement is essential to avoid opposition. Past megaprojects in Chile have shown that a lack of participation fuels resistance, while transparent communication and co-benefits can build legitimacy. The Open Sea Lab in Las Cruces demonstrated how sharing data with local communities and supporting fisheries and tourism transformed potential opposition into collaboration (Cortés et al., 2022).
- Government support enables progress. Beyond shaping policy and regulation, government backing of pilot and test sites is decisive for advancing marine energy. As noted by Interviewee 8 (Personal Communication, September 26, 2025), such support creates the conditions for research and attracts the investment needed to move projects toward implementation.
- Socio-economic benefits create opportunities. International experience from Scotland shows how renewables can create jobs, stimulate supply chains, diversify economies, and help retain young talent: “Population in Orkney has increased by 10% over 10 years, in part due to renewables jobs” (Davies et al., 2014). In Chile, similar benefits could arise through job creation, industry diversification, eco-tourism, and local capacity building.

These insights underline three critical social factors that

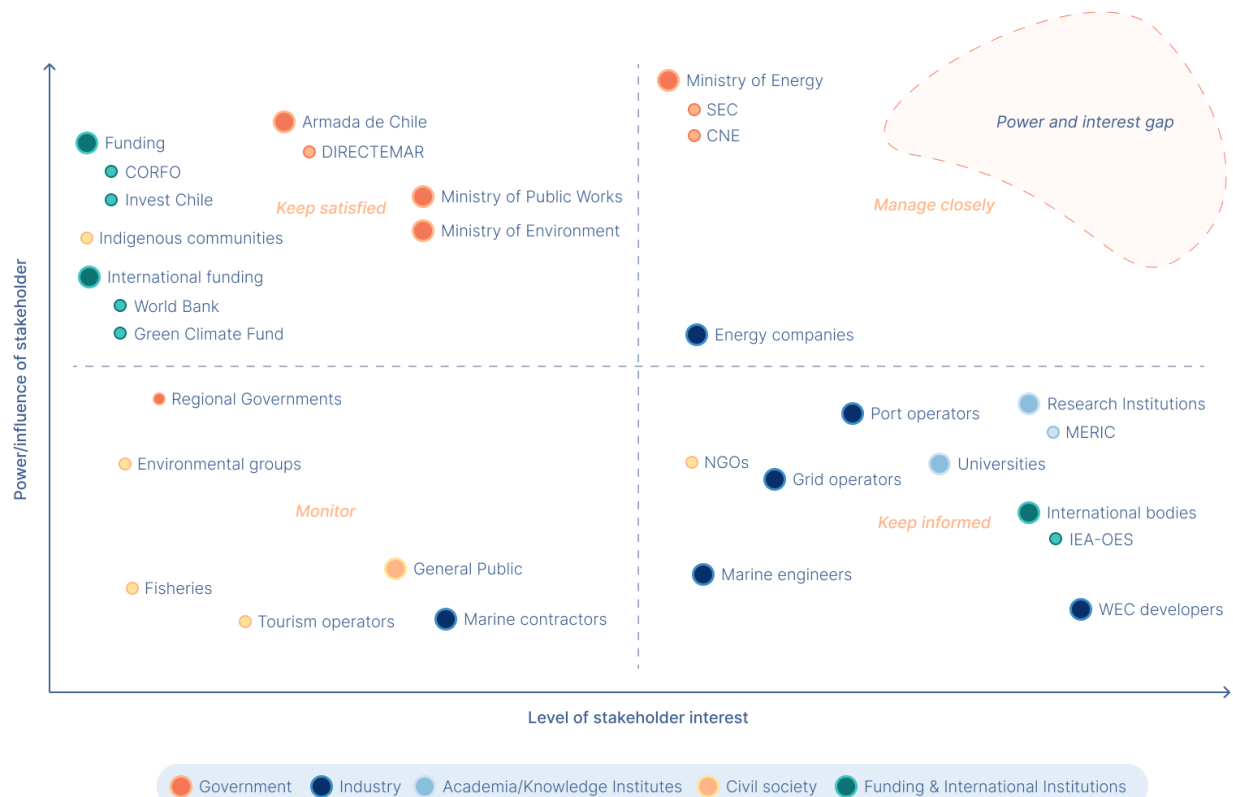


Figure 2.1: Stakeholder power-interest grid

will guide the evaluation of potential sites and technologies: social acceptance, stakeholder alignment, and socioeconomic community benefits.

2.2 Environmental Analysis

Several projects in Chile have been denied in the past due to their environmental impact on marine ecology. The Dominga port and mining project, which threatened one of the world's largest biodiversity hotspots, the Humboldt Current, was rejected multiple times for this reason. (Oceana, 2023) (Sphenisco e.V., 2025). After almost 12 years of environmental and legal disputes, the Supreme Court of Chile has granted final approval to the project, rejecting appeals to deny the project from the government, the Committee of Ministers, and several environmental groups (Orellana, 2025) (de Vicente, 2025).

This example, highlights the importance of taking the environmental effects and potential conflicts with marine life into account when designing offshore wave energy systems close to the Chilean coast.

This section presents an analysis of biodiversity concentrations along the Chilean coast and explains the environmental impact of WECs and respective anchoring systems. Finally, different marine zones and areas are mapped to create an overview of possible conflicts that can occur when building WECs.

2.2.1 Impact on Marine Ecology

Chile's extensive Pacific coastline, stretching for more than four thousand kilometres, encompasses a wide range of marine environments shaped by its geography and oceanography. The influence of the Humboldt Current system, the presence of nutrient-rich upwelling zones, and the complex fjord and channel systems of southern Patagonia create ecosystems that support high levels of biodiversity (Miloslavich et al., 2011) (Tecklin et al., 2024). According to the Ocean Biodiversity Information System (OBIS), Chile's waters host over five thousand documented marine species, with biodiversity concentrations found in particular along continental shelves and oceanic islands such as the Juan Fernández and Desventuradas Archipelagos (Friedlander et al., 2016) (Ocean Biodiversity Information System (OBIS), 2025).

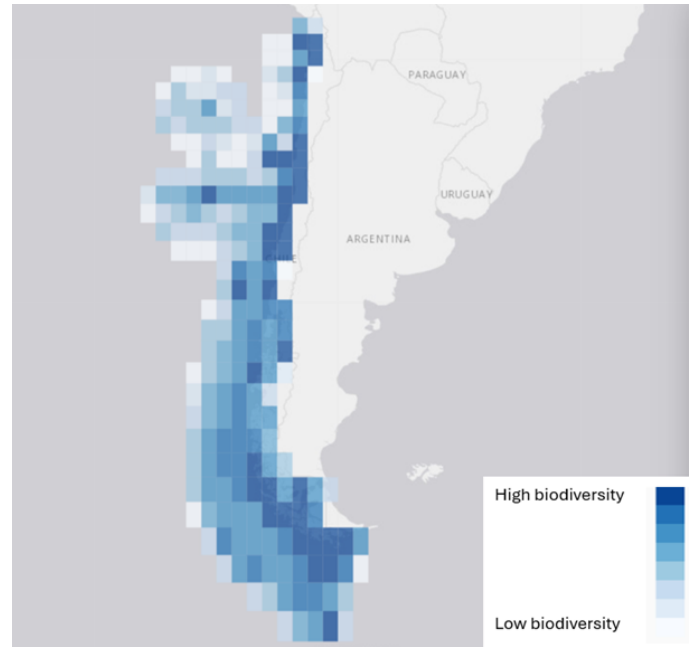


Figure 2.2: Marine Biodiversity Concentration in Chile, (Ocean Biodiversity Information System (OBIS), 2025)

The extent of the environmental impact of a WEC strongly depends on the type of WEC and respective anchoring method. Bottom-fixed systems that require pile driving can generate significant underwater noise and vibrations, potentially disturbing marine mammals and fish. On the other hand, floating WECs with drag anchors may cause localized seabed disturbance. (Interviewee 5, Personal Communication, September 22, 2025). Thus, both installation and structural design should be assessed correctly when developing a WEC. The technical aspects of WECs and mooring systems are explained in more detail in Section 2.3.

2.2.2 Marine Areas & Zones

Besides the impacts on marine biodiversity explained in the previous paragraph, the implementation of wave energy farms can also interfere with existing human uses, such as fishing and other aquaculture. Chile has multiple regulatory and zoning instruments to regulate diverse uses of its coastal and ocean spaces, such as aquaculture, artisanal fishing, and biodiversity conservation. These zones provide the legal and spatial basis for sustainable resource management. The different zones will be explained in this paragraph.

Concessions

Marine concessions in Chile are legal authorisations that grant organisations or individuals the right to use defined portions of coastal or marine public goods, such as beaches, seabed, or water columns, while ownership remains with the state. Administered by the Subsecretaría de Marina under the Ministry of Defense, they are required for infrastructure developments (e.g., ports, aquaculture, energy production), and are subject to a rigorous regulatory pro-

cess including environmental assessment and fees (DIREC-TEMAR, 2018).

Destinations

In Chile, marine destinations were introduced by Law No. 21.027 to give artisanal fishing organizations long-term rights (up to 30 years) to use and manage areas traditionally linked to fishing coves. Unlike marine concessions, which are available to a wide range of actors, destinations are reserved for legally recognized artisanal groups and cover marine space and fiscal lands. They enable communities not only to maintain fishing and resource extraction but also to diversify into complementary activities such as tourism, cultural initiatives, or small-scale commerce. Management requires an approved administration plan and a formal use agreement with Sernapesca, the National Fisheries and Aquaculture Service of Chile, ensuring local participation while safeguarding compliance with conservation and regulatory standards (SUBPESCA, 2025c).

Areas Suitable for Aquaculture (AAA)

These geographical zones, defined by the Ministry of Defence, indicate where aquaculture may legally take place. They cover stretches of seabed, bays, and water columns suitable for farming species such as fish, molluscs, or algae. Their designation does not automatically give them usage rights, so applying for concessions and environmental approvals is still a must. Besides, AAAs are not exclusive and may overlap with other authorised activities, like AMERBs (SUBPESCA, 2025b).

Benthic Resource Management and Exploitation Areas (AMERBs)

Benthic Resource Management and Exploitation Areas are granted to artisanal fishers' organisations to manage and exploit benthic species, organisms living on or in the seabed, like shellfish and sea urchins. These zones aim to stimulate sustainable, locally managed exploitation of benthic species by artisan fishers, giving them more secure access while controlling overexploitation (SUBPESCA, 2025b).

Marine Protected Areas (MPAs)

MPAs are zones with special conservation status that are intended to protect marine ecosystems. MPAs include marine reserves and multiple-use coastal protected areas that protect the life of these ecosystems. They may permit certain regulated activities, but prohibit destructive practices to maintain ecological integrity. 41.5 percent of Chile's marine and coastal areas consist of marine protected areas (AFD, 2025) (ProtectedPlanet, 2025), serving as the backbone of Chile's marine conservation strategy and helping to align national commitments with international biodiversity goals (SUBPESCA, 2025a).

Vulnerable Marine Ecosystems

Vulnerable Marine Ecosystems, entail fragile ecosystems particularly sensitive to disturbance, such as coral or

sponge habitats. Regulatory measures aim to minimise harmful activities like bottom trawling or seabed alteration (SUBPESCA, 2025b).

Access Free Zones

Access free zones are open to the general public or users without pre-assigned exclusive rights. They may allow certain uses like fishing, recreation and navigation (SUBPESCA, 2025b).

2.3 Technological Analysis

In the following section, the technological background of wave energy is presented. First, the principles of wave energy are explained. Then, various technologies are introduced, along with the methods used to secure them to the seabed.

2.3.1 Wave Energy

Wave energy is a form of renewable energy that harnesses the kinetic and potential gravitational energy of ocean waves (ScienceDirect, 2025). Waves are oscillations of the ocean surface that are primarily vertical in nature. They can be generated by different mechanisms such as wind, gravity, and tectonic movements. Most commonly, waves are formed by the interaction between wind and gravity, with typical wave periods ranging between 0.1 and 30 seconds. In addition, tides also contribute to variations in the wave field.

The propagation of waves is influenced by the seabed. Depending on the water depth, the wave motion can be classified, as expressed in Equation 2.1:

$$\text{Deep water: } \frac{h}{\lambda} > \frac{1}{2}, \quad \text{Shallow water: } \frac{h}{\lambda} < \frac{1}{20} \quad (2.1)$$

Here, h is the water depth and λ the wavelength. In between these limits lies the intermediate water depth regime. The average wave energy per unit horizontal area can be expressed as the sum of potential and kinetic energy, which are equal in magnitude. This leads to Equation 2.2:

$$E_{\text{wave}} = E_{\text{kinetic}} + E_{\text{potential}} = \frac{1}{8} \rho g H_{m0}^2 \quad (2.2)$$

where ρ is the water density, g is the gravitational acceleration, and H_{m0} is the significant wave height.

The wave power per unit crest length (in W/m) is obtained by combining the wave energy with the group velocity. In deep water, this simplifies to Equation 2.3:

$$P_{\text{wave}} = \frac{\rho g^2 H_{m0}^2 T_e}{64\pi} \quad (2.3)$$

where T_e is the energy period of the irregular sea state.

2.3.2 Wave Energy Converters

WECs turn the motion of the waves into mechanical energy, which is then used to generate electricity. Wave energy is considered highly reliable because it is consistent, unlike other renewable sources such as wind or solar (Global

Bioenergy, 2025). It offers the potential to supply power continuously, especially in coastal regions with strong wave activity. As a clean energy source, wave energy produces no greenhouse gas emissions and has minimal environmental impact.

In Table 2.2 and 2.3 the different WECs are listed; a more detailed explanation is given in C. These are not all the technologies available on the market, but the main con-

cepts.

2.3.3 Mooring System

The mooring system is a critical component of any WEC deployed offshore. It consists of anchoring and mooring lines and its primary function is to maintain the device in position while allowing a controlled degree of freedom that enables efficient energy capture. WECs are often deployed

Table 2.2: Floating Wave Energy Converter (WEC) concepts (Doyle & Aggidis, 2019; (EMEC), 2025; Tampier et al., 2021)

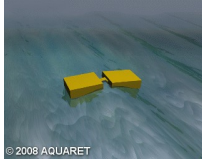
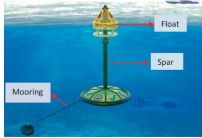
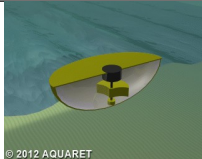
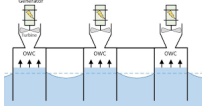
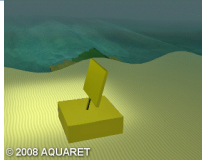
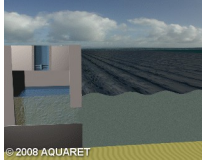
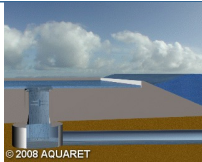
Concept Image	Description
1. Floating, with Conventional Moorings	
	Attenuator: Long floating structures aligned with wave direction. Wave motion at hinged joints or inside flexible tubes drives a PTO.
	Moored Point Absorber: Floating buoy oscillates with waves, converting vertical motion into electricity via PTO.
	Rotating Mass: Internal rotating mass driven by wave-induced body motion powers a generator.
	Oscillating Water Column (OWC): Wave-driven oscillations of air inside a chamber drive a turbine.
2. Floating, with Bottom-Fixed Element (e.g. PTO)	
	Point absorber with bottom-fixed: Buoy oscillates with waves, converting vertical motion into electricity via PTO.
	Pressure Differential: Submerged buoy system operating below the surface, converting pressure differences into power.

Table 2.3: Bottom-Fixed and Coastal Wave Energy Converter (WEC) concepts (Doyle & Aggidis, 2019; (EMEC), 2025; Star, 2025; Tampier et al., 2021)

Concept Image	Description
3. Bottom-Fixed	
	Surge Converter: Hinged flaps move back and forth with waves, converting the moment into electricity.
4. Coastal	
	Oscillating Water Column: Integrated into breakwaters or coastal structures, using wave-driven airflow to power a turbine.
	Point Absorber on Structure: Buoy attached to fixed infrastructure; relative motion generates electricity.
	Overtopping Device: Waves fill a raised basin; stored water flows back through turbines to generate power.

in relatively shallow to intermediate water depths (40–100 m) (Vicente, Falcao and Justino, 2011) and in highly dynamic wave environments. According to a marine renewable energy expert at TU Delft, WECs can be deployed in deeper waters at higher costs (Interviewee 5, Personal Communication, September 22, 2025). This places unique demands on the design of the mooring system, which must withstand cyclic loading from waves, currents, and wind, while also minimising installation and maintenance costs. Furthermore, the choice of mooring lines and anchoring configuration is not universal: for each WEC type-waterdepth-soilprofile combination, a different combination of mooring lines and anchoring is favourable.

2.3.4 Anchors

Anchoring solutions for WECs strongly depend on the local seabed conditions. Different anchor types have been developed to provide reliable holding capacity while adapting to site-specific geology:

- Gravity anchors: Massive concrete or steel blocks that rely on self-weight and seabed friction. Gravity anchors simply rest on the seabed without embedment. They are not preferred on sloping seabeds (Pacific Northwest National Laboratory, 2024)

- Drag anchors: Anchors that embed themselves into the soil as the mooring line is tensioned.
- UMACK anchors: achieve high holding capacity through soil remolding and plug-effect mechanisms. UMACK anchors have currently been installed at waterdepths of around 40m (Group, 2022) (World, 2023).
- Drilled anchors: Rock anchors installed by drilling 5–20 m into competent bedrock and fixing with grout or bolts. Drilled anchors provide high holding capacity but require specialised subsea drilling equipment.
- Driven piles: Steel piles that are hammered or vibrated into the seabed, typically 20–50 m depending on soil and loading conditions. They provide very high axial and lateral resistance and are widely used in offshore wind foundations.
- Suction anchors: Large hollow steel cylinders that are embedded into the seabed by pumping out the internal water, creating a pressure differential that drives the skirt into the soil. Suction anchors typically achieve embedment depths of 10–30 m.

In Table 2.4 the different anchors are compared (Trust, 2015), (CoE, 2024) and (CoE, 2024).

Anchor Type	Clay	Sand	Coarse Sediment	Rock	Any waterdepth?	Sloped	Cost
Gravity anchor	✓	✓	✓	✓	✓	×	Cheap
Drag anchor	✓	✓	×	✓	✓	?	Cheap
UMACK	✓	✓	-	×	Expected to work	✓	No data
Driven pile	✓	✓	✓	×	✓	✓	Medium
Drilled anchor	×	×	✓	✓	?	✓	Expensive
Suction anchor	✓	✓	×	×	✓	×	Expensive

Table 2.4: Suitability of anchors to seabedtype, slope and water depth + relative cost of anchors

2.3.5 Mooring Lines

Below, a list of types of mooring lines is presented:

- Catenary moorings: Long lines resting partly on the seabed; simple and cost-effective but need large footprint.
- Taut-leg moorings: Lines kept in tension (often synthetic ropes).
- Semi-taut moorings: Hybrid of catenary and taut; balance between cost, footprint, and control; often used in pilot WECs.
- Tension leg systems (TLS): Vertical tendons fix device with minimal motion; highly stable but costly, less common for WECs.
- Spread moorings: Multiple lines in different directions; provide redundancy, used in arrays or multi-directional wave climates.

as well as the anchors are shown in Figure 2.3.

It is important to note that for certain WEC concepts, the energy output directly depends on the tension in the mooring lines. In such cases, conventional mooring arrangements may not be sufficient. Some of the moorings

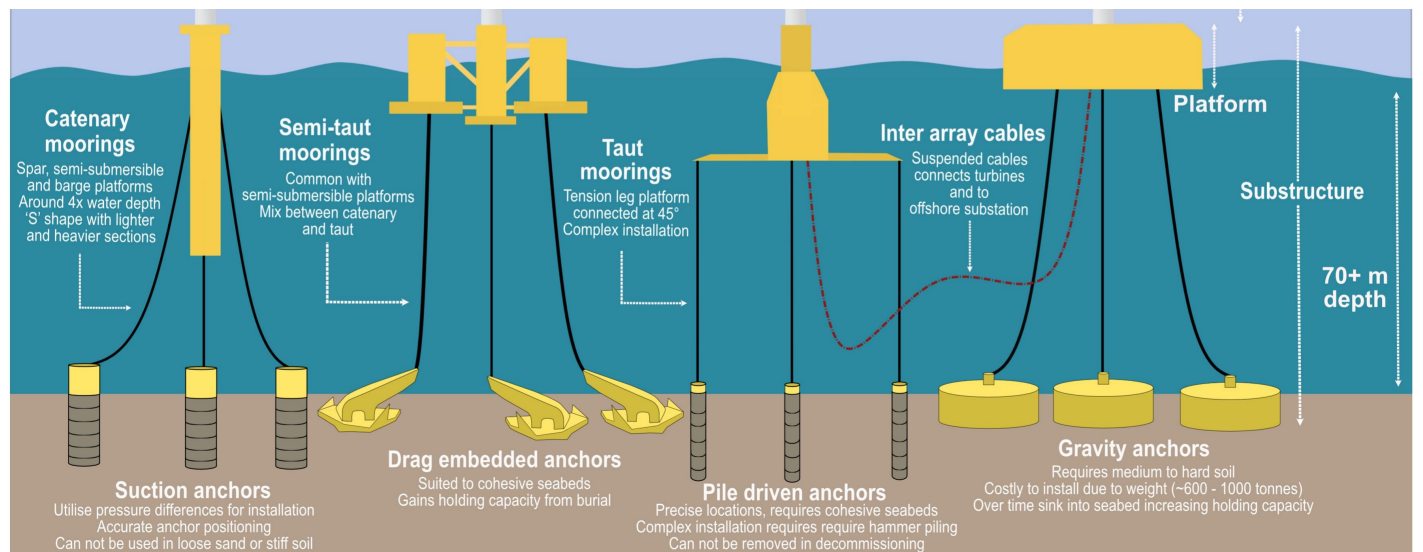


Figure 2.3: Anchors and mooringlines (Harris et al., 2025)

2.3.6 Energy mix in Chile

The energy mix in Chile for energy in general and electric energy is provided in Figures 2.4 and 2.5.

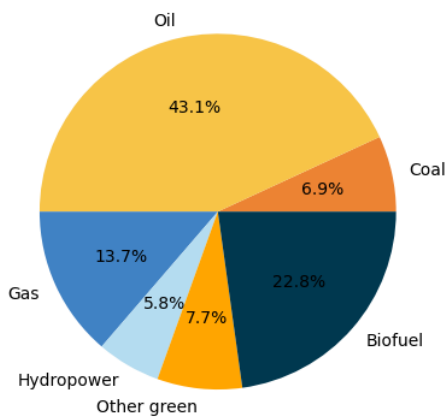


Figure 2.4: Energy sources in Chile (International Energy Agency, 2025)

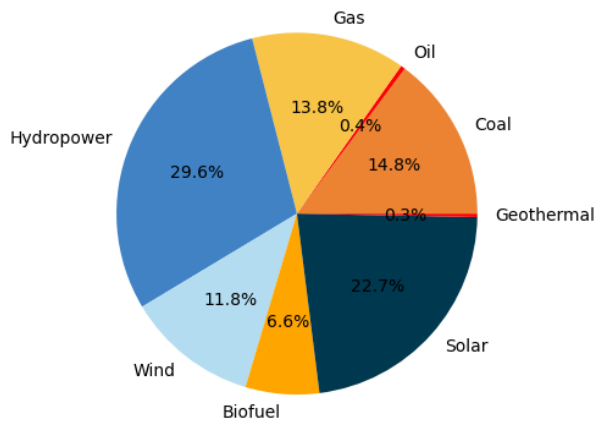


Figure 2.5: Electricity sources in Chile (International Energy Agency, 2025)

2.4 Economic Analysis

An important aspect for every emerging technology is the economic feasibility. A context on energy economics in Chile is given in this section.

2.4.1 Economic Context

The Chilean energy market is transforming rapidly from a fossil towards a renewable energy system and is ranked as the most attractive for renewable energy investments (Invest Chile, 2021). The market is split up into three distinct segments by regulation: generation, transmission and distribution, which are all fully privatised. The generation market is expected to grow from 39 GW in 2025 to 193 GW by 2050 (de Energía, 2025), and the emissions are expected to drop from 12 *MT CO₂* to 1,99 *MT CO₂* (de Energía,

2025).

According to Invest Chile, 2021, the Chilean grid operators typically choose the cheapest possible generation mix, this was also indicated in an interview with an Electrical Engineer from CEN (Interviewee 7, Personal Communication, September 24, 2025). Therefore, wave energy should have a competitive price to be a viable option.

2.4.2 Levelised Cost of Energy

The Levelised Cost Of Energy (LCOE) is a metric that combines all cost elements directly associated with the energy production of a technology (IEA, 2023). For example, it contains construction, maintenance and financing costs, but excludes networking costs. Using this metric, the energy price of different energy sources can be compared, allowing for viability assessment of wave energy.

Prediction of Alternatives' LCOE

The prediction of the LCOE ranges of available energy sources in Chile differs per alternative. The best alternative is likely photovoltaic solar energy. This energy source has enough potential (1180 GW) to power the whole Chilean grid (Ministry of Energy, Government of Chile, 2020), and has the lowest LCOE at 19-22 \$/MWh in 2025 and 16-21 \$/MWh in 2030 (Ministry of Energy, Government of Chile, 2020). The LCOE for wave energy is calculated with the method in Chapter 3.

2.5 Political & Regulatory Context

In this section, the first two levels of a policy mix analysis will be explained. The reasoning behind the performance of a policy mix analysis will be further enlightened in Chapter 3.

2.5.1 Global Policy Frameworks

Global policy frameworks are overarching policies and shared ambitions that create a broad context in which parties are free to operate. In this section, the most important global policies in which Chile is represented are highlighted.

Paris Agreement

The Paris Agreement's main objectives are: to hold the increase in global average temperature, to increase the ability to adapt to the adverse effects of climate change, foster low Green House Gas (GHG) emissions development, and to make finance flows consistent with a pathway to low GHG emissions and climate resilience (UNFCCC, 2015).

To achieve these objectives, all participating countries agreed to reduce their GHG emissions as quickly as possible (UNFCCC, 2015). Developing countries, of which Chile is one, will be provided with extra support to allow higher ambitions. These ambitions are set by countries themselves, in their Nationally Determined Contributions, which are written every five years (UNFCCC, 2015).

In the agreement no direct consequences are stated if parties do not act according to the agreement. However, the International Court of Justice has ruled that countries can be held responsible for climate inaction and that penalties in the form of restitutions or compensations could be imposed (Zia Weise, 2025).

UN Sustainable Development Goals

All UN member states have adopted the 2030 Agenda for Sustainable Development in 2015. This agenda provides all states with a blueprint for peace and prosperity for both the planet and people. Putting an end to all dimensions and forms of poverty is the greatest challenge that this agreement tries to achieve (United Nations General Assembly, 2015).

To overcome global poverty, 17 Sustainable Development Goals (SDGs) are set, which aren't binding in contrast to the Paris Agreement. Of these SDGs, SDG 7 and SDG 13 are the most interesting for this research. SDG 7 states that all member states should: "Ensure access to affordable, reliable, sustainable and modern energy for all". In SDG 13 is said that all states should: "Take urgent action to combat climate change and its impacts", with the note that climate action is mainly regulated through the UNFCCC (United Nations General Assembly, 2015).

Washington Convention

The Washington Convention's main goal is to protect flora, fauna and natural scenic beauty in all Americas (Government of Chile, 1967). As a result of this convention, national parks and reserves are set up and laws to conserve and protect the nature within are established.

Indigenous & Tribal Convention

The ILO Convention on Indigenous and Tribal populations aims at overcoming discriminatory practices affecting these populations and enabling them to participate in decision-making that affects their lives (International Labour Organization, 2013), and it requires the state of Chile to develop action to protect and respect them. The convention contextualises fundamental human rights for these special populations.

2.5.2 National Coordination Policies

In this section, the policies and regulations in the second level of the policy mix analysis are elaborated upon.

National Determined Contributions

Chile's National Determined Contributions (NDC) is aimed at maximising the synergies between their climate goals and SDGs (Ministerio del Medio Ambiente de Chile, 2022). To accomplish this, they have set up an interministerial committee for a just socio-ecological transition called Transición Socioecológica Justa (TSEJ). They also aim to transition cost-effectively, with plans including a focus on equality and equity.

Furthermore, a framework of the laws on climate change has been presented, the Ley Marco de Cambio Climático

(LMCC). This framework will guide Chile to comply with the Paris agreement as outlined in 2.5.1. It obliges ministries to develop sectoral, regional and municipal action plans before 2024. Also, it includes some government budgets on GHGs and sectors, which have to be specified in these plans. In the NDC, multiple goals are specified for Chile, which are depicted in the Table 2.5.

Table 2.5: NDC Goals (Government of Chile, 2020) (Ministerio de Energía de Chile, 2025)

Year	Goal
2025	• GHG Emissions Peak • Regional Climate Change Action Plans in 10 regions • Protect at least 20 coastal wetlands as new protected areas
2030	• GHG Emissions 95 MtCO_{2eq} • Regional Climate Change Action Plans in all regions • Forest recovery accounting for 0.9–1.2 MtCO_{2eq} captured annually • Afforesting accounting for 3.0–3.4 MtCO_{2eq} captured annually • Protect at least 10% of underrepresented marine eco-regions • Protect at least 10 additional coastal wetlands as protected areas
2050	• GHG Neutrality • > 96% renewables in energy mix • Capturing 65 MtCO_{2eq} annually

National Energy Policy 2050

The National Energy Policy 2050 provides a long term strategy that is updated once every five years (Ministerio de Energía de Chile, 2017). This strategy includes national demand projections, energy scenarios and the identification of development poles. Regional strategic energy plans with

development guidelines, management areas and zones with potential energy are provided as well. In the plan, a strong incentive to conserve biodiversity and ecosystem functions is present (Ministerio del Medio Ambiente de Chile, 2022).

Decarbonisation of the Energy Mix

Chile plans to shut down or reconvert all coal-powered electricity generators by 2040 (Ministerio de Energía de Chile, 2022).

tem (Orellana, 2025). In response, the government and political candidates ahead of the upcoming elections are prioritising new legislation aimed at streamlining these kinds of approval processes a reform that, once enacted, is expected to reduce permitting times by around 30% to 70% (Reuters, 2025).

2.5.3 Subnational Implementation Policies

In this section, the policies and regulations that support the national ambitions and goals as implementation policies are explained.

Medium Systems Operation and Management

This decree establishes a framework for medium-sized energy installations to operate within. It makes sure that the generation stays efficient and coordinated with multiple independent installations. To do so, it includes multiple committees, communication rules and pricing and revenue distribution guidelines (Ministry of Energy of Chile, 2015).

Atmosphere Contaminating Emissions Tax

Chile currently taxes GHGs and three local pollutants: PM , NO_x and SO_2 , to reduce harmful emissions. The tax is applicable for installations emitting more than one hundred tonnes annually of Particulate Matter (PM), or more than 25 thousand tonnes of CO_2 annually (Ministry of the Environment of Chile, n.d.). The tax will increase gradually, and by 2030, the tax rate should have a price of $35 \frac{\$}{tCO_2}$ (International Energy Agency, 2024).

Regional & Municipal Action Plans

The municipal & regional action plans should be finished by 2025, which means that at the moment of this research, not all plans are presented. In Chapter 5, the available regional, Plan de Acción Comunal de Cambio Climático (PARCC), and municipal action plans, plan de Acción Regional de Cambio Climático (PACCC), are presented.

Energy Education

The Ministry of Energy, the Ministry of Education and the Energy Sustainability Agency together set up an education system on the subject of energy. From kindergarten until the 4th year of secondary school, Chileans will be educated on this subject (Ministerio de Energía de Chile, 2022). This program could also harness education on wave energy.

Current regulatory hazards

Large renewable energy projects in Chile often experience long timelines due to complex permitting and approval processes, which stakeholders regard as a major bottleneck (Reuters, 2024). The earlier mentioned Dominga project is such an example, that after almost 12 years of environmental and legal procedures has been granted approval by the Supreme Court of Chile, marking the urgency for a more transparent and technical environmental review sys-

3 Method

This chapter provides an overview of the methods used to solve the main research objective in this report. These methods include strategic frameworks as well as technical evaluations on the extracted data and research.

3.1 Stakeholder Engagement

To complement quantitative analysis and literature research, semi-structured interviews were conducted with stakeholders across policy and regulation, grid operations, ports and logistics, and the wave energy research and industry sectors. The interviews were selected by nonprobability sampling methods, as knowledge of the research area is concentrated and the research is limited by time (Sekaran & Bougie, 2020). The specific method is a mix of convenience- and judgement sampling (Sekaran & Bougie, 2020). The first interviews were set up by interviewing easily accessible people. Furthermore, people with certain expertise or roles were contacted or contacted by earlier interviewees. The list of interesting expertises or roles was created through the judgment of the research team and recommendations of interviewees.

These interviews were used to triangulate statements and evidence from different sources. The semi-structured format allowed us to address comparable themes while adapting follow-up questions to each expert's context. Interviews typically lasted 30–60 minutes and were conducted either in person or online. To protect participants' identities, all interviewees were assigned anonymous identifiers (e.g., Interviewee 1, Focus Group 2). Details about each stakeholder type are provided in Appendix A.

3.2 Multi-Criteria Analysis

In this research, a decision encompassing a broad variety of factors on a preferred combination of a location and WEC was made. To do so, the real-world situation was simplified to a list of criteria. A multi-criteria analysis (MCA) is performed to make the most preferred decision. This section explains what an MCA is and describes the method applied.

A multi-criteria analysis is an analysis where more than one criterion is considered (Taherdoost & Madanchian, 2023). To do so, there are multiple tools and frameworks, which are widely used in a broad variety of fields, ranging from finance to engineering. Almost always, such an analysis is a complex procedure that should be context-specific and is influenced by several factors, such as social, psychological, and cultural (Taherdoost & Madanchian, 2023). An MCA aims to determine the most preferred option from a list of possible alternatives. An MCA can be split up into three main steps: Identifying and selecting the criteria; determining the weights of resources; ranking

the resources (Taherdoost & Madanchian, 2023). In the first step, alternatives and criteria have to be identified and organised. In the second step, normalised weightings are given to all criteria. Scoring all alternatives and calculating the most preferred combination is part of the last step, leading to a final result (Chaubé et al., 2024).

As MCAs are context-specific, establishing the correct criteria and weights is very important. To determine these as correctly as possible during this research, various local experts and students were consulted for both the criteria and weights. After a preliminary and literature-based criteria selection, as explained in Section 3.2.1, these were reviewed and iterated with local experts on marine engineering, civil and oceanic engineering, electrical engineering, and the Chilean national electricity grid.

Thereafter, local students and experts, originating from multiple regions in Chile, assigned weights individually. The average of these given weights was assumed to be a close representation of the actual context. However, both the criteria and weights are subjective. To see if this subjectivity had a high impact, multiple scenarios were derived from the base weights, essentially performing a sensitivity analysis. Each scenario added ten percent to the one category's base weight, while the remaining category's weights were proportionally reduced so that their relative ratios stayed the same, skewing the results to one category per scenario.

With these criteria and weights, a TOPSIS method (Chaubé et al., 2024) was used to select the most preferable combination of a location and WEC device. TOPSIS is the most commonly used method (Taherdoost & Madanchian, 2023), which ranks alternatives based on how close they are to the optimal solution and how far away from the negative ideal. This method is less sensitive to outliers than other methods, such as the weighted sum method, adding rigour to the MCA result.

The base scenario was used to point out the most preferred combination. The results from the skewed scenarios were used to indicate whether the subjectivity of the weights had a significant influence, which is likely to be the case if other combinations score higher in these scenarios. If the skewed scenarios result in the same combination as the base scenario, the influence of the subjective weightings is small.

3.2.1 Criteria Development

This section elaborates on the different criteria used in the multi-criteria analysis.

Social Analysis

To evaluate the social dimension of potential wave energy sites, three indicators are considered: Social Acceptance, Stakeholder Alignment, and Socio-economic Community Benefits (Wüstenhagen et al., 2007) (Oliva et al., 2024).

- Social Acceptance was evaluated through demographic and contextual data, including population size, age structure, and presence of indigenous communities. In addition, literature and interviews on local sentiment toward renewable energy, analysis of indigenous community presence, and fishing activity were reviewed to capture the likelihood of support or opposition at the local level.
- Stakeholder alignment was assessed by mapping the number, diversity, and interaction of stakeholders in each region. This includes government bodies, industry, port operators, fisheries, NGOs, and community groups. The analysis identified areas of convergence and conflict between stakeholder interests.
- Socio-economic Community Benefits was examined by analysing employment potential, opportunities for economic diversification, infrastructure synergies, the availability of relevant skills, and the distribution of benefits within the local population.

For each indicator, demographic statistics and regional economic data were combined with insights from academic and grey literature as well as interviews. Scores were assigned during the MCA workshop through assessment of the outcomes and group discussion.

Environmental Analysis

To evaluate the environmental impact of implementing wave energy throughout the different sites, two aspects were analysed: biodiversity concentrations and existing marine areas and zones.

- Biodiversity Concentrations were retrieved from the Ocean Biodiversity Information System (OBIS), the world's largest open-access repository for marine biodiversity data (Ocean Biodiversity Information System (OBIS), 2025). Species counts were compared across the five sites using equivalent surface areas. In this section, higher biodiversity concentrations were assumed to correspond to greater impacts on marine ecosystems.
- Marine Areas and Zones were mapped through the online portal of Subpesca (Subsecretaría de Pesca y Acuicultura), where all the marine zones and areas are shown; both the permanent zones and the applications for new zones are visible (Subpesca, 2025). In this section, the sites were scored based on the amount, the type, and the stage of all the marine areas and zones, to assess possible conflicts.

Technical Analysis

This section first describes the methods used for wave data extraction, and the calculations performed to estimate the power output for each device and location are presented. Then, the criteria used in the MCA are explained.

Data extraction

Wave data: To extract wave data for the installation of a WEC at the chosen locations, offshore wave data was used. ERA5 data is not calibrated for the Chilean coast, and therefore, offshore data points were used from the University of Valparaíso. To obtain reliable data that could be processed, the dataset contained 3-hourly data from 1979 to 2015. For the final calculations in Concepción, a more detailed hourly data set from 1979 to 2024 was used. The extracted wave data contained the significant wave height, the peak period, and the mean wave direction.

WEC data: All the power matrices of the WECs were extracted from the following paper (Majidi et al., 2025) except CorPower is obtained from (de Santiago et al., 2021). A power matrix contains the amount of energy produced by a WEC for a certain sea state (period and wave height combinations).

The locations along the Chilean coastline were selected based on their distance from the grid, proximity to demand centres, and accessibility to a port. The different locations with their bathymetry and ports are visualised in QGIS.

Offshore Chilean Geotechnical Data: Preferably, extensive geotechnical data is collected to ensure reliable anchor design, since strength, stiffness, and stratification are key to predicting performance and long-term stability. In practice, however, offshore data is almost non-existent because deep-water sampling is prohibitively expensive, and past projects provide no usable records. Nearshore, only a few harbour studies are available, but these are distorted by river sediments and not representative of offshore conditions. In southern Chile, floating salmon farms are anchored to buoys, yet information on anchoring methods and seabed profiles is lacking. To reduce uncertainty, local experts will therefore be consulted to provide practical insights into seabed conditions and anchoring challenges.

Data Processing

Wave data: The mean and maximum wave height and period were determined. Furthermore, the wave direction was plotted in a wave rose, which indicates the mean wave directions, with an accuracy of three degrees, and the occurrence per wave height for each direction. The mean and maximum wave heights were used for a simplified assumption to determine the survivability of the structure.

System performance: First, the data was arranged into an

occurrence matrix per location, representing the frequency of the combinations of (H_{m0}) and peak wave period (T_p). Normalising this matrix yields the bi-variate distribution, with bin width $T_p = 1$ (e.g. $0.5 \leq T_p < 1.5$ for $T_p = 1$).

This occurrence matrix was matched in size with the WEC power matrix, and their element-wise product gave the mean power per sea state. Multiplying by the number of hours in a year gave the annual energy per sea state, and summing all entries provided the annual energy yield (AEY) for each location–WEC combination. Calculations were performed using Python. Finally, the capacity factor was calculated as

$$C_f = \frac{AEY}{\text{Rated power} \times 8766} \quad (3.1)$$

where 8,766 is the number of hours in a year with leap years accounted for.

Geotechnical viewpoint: Retrieved data guided the choice and design of the anchoring system, which primarily depends on seabed conditions (Table 2.4).

Initial anchor dimensional estimates were made through simplified analytical calculations, assuming basic bearing capacity formulas per soil type. These calculations considered maximum anchor forces from the buoy, arising from combined hydrodynamic and mooring line effects, which depend on site-specific wave conditions. A full coupled hydrodynamic–mooring analysis is beyond the scope of this study; instead, tension values from literature and public sources were used with a safety factor to obtain conservative anchor load estimates.

In the detailed design phase, PLAXIS was used to assess anchor stability and soil–structure interaction (Bentley Systems, 2025). Combining analytical calculations with advanced numerical modelling ensured both practicality and accuracy in the design process.

Criteria

To analyse the performance of the wave energy converters (WECs), the capacity factor and the annual energy yield were evaluated. The capacity factor represents the fraction of time per year that the buoy operates at full power, whereas the annual energy yield quantifies the total amount of energy produced in one year.

Installation complexity was used to assess the level of difficulty associated with installing the buoys at a specific location. This criterion was evaluated based on the following sub-criteria, which were firstly established based on academic research and then iterated in consultation with a local ocean engineering expert (Interviewee 2, Personal Communication, September 23, 2025):

- Anchoring assessed the difficulty of installing the specific anchoring system of the buoy at a given location. The higher the installation difficulty, the lower the score.

- Distance to ports described the distance from the buoy to the nearest port. Greater distances resulted in lower scores.
- Distance to grid connection indicated the distance to the nearest high-voltage grid connection. Greater distances resulted in lower scores.
- Port facilities evaluated whether nearby ports are equipped to accommodate the vessels required for installation, operation, and maintenance. The factors draft, berth availability, and crane capacity were considered. Ports with better facilities received higher scores.
- Workability represented the fraction of time a vessel can operate at a location under a defined significant wave height threshold. A lower workability corresponds to a lower score.

Survivability refers to the ability of the buoy to withstand the environmental forces it will encounter over its lifetime. In this study, it was simplified to the following two sub-criteria, where increasing wave heights corresponded to decreasing scores.

- Extreme wave height is the maximum wave height observed in the dataset.
- Mean wave height is the average wave height over the dataset.

Economic Analysis

In this section, the Levelised cost of energy (LCOE) calculations are explained. The LCOE of a wave energy plant of point absorbers is mainly determined by the Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) costs and was calculated with the following formulas as discussed in a meeting with a renewable energy expert at TU Delft (Satymov et al., 2024) (Interviewee 5, Personal Communication, September 22, 2025):

$$LCOE = \frac{CAPEX \cdot crf + OPEX}{FLH_{farm} \cdot AvF_{unit}} \quad (3.2)$$

$$FLH_{farm} = FLH_{unit} \cdot \eta_{farm} \quad (3.3)$$

$$crf = \frac{WACC \cdot (1 + WACC)^N}{(1 + WACC)^N - 1} \quad (3.4)$$

The full load hours of a unit (FLH_{unit}) were determined with the capacity factor following from the capacity factor analysis in Section 2.3, by multiplying them with the total annual number of hours (8,766).

The CAPEX is primarily dependent on the CAPEX of the floating device, which remains constant for every location. However, depth and distance from shore do influence the total CAPEX costs if the location is deeper than 50 meters and/or further than 10 kilometres from shore. This influence is given by Equation 3.5, in which $F_D F_d$ are distance and depth factors.

$$CAPEX = CAPEX_{base} + F_D \cdot D + F_d \cdot d \quad (3.5)$$

The OPEX costs are a fraction of the CAPEX costs in wave energy farms (Satymov et al., 2024). Therefore, the OPEX was presented as a percentage of the CAPEX costs, calculated with Equation 3.6.

$$OPEX = 5,8\% \cdot CAPEX \quad (3.6)$$

In these calculations, the constants as seen in Table 3.1 were used (Satymov et al., 2024) (McKinsey & Company, 2020) (Steffen et al., 2025) (Engelfried et al., 2025) (ECB, 2025). As the efficiency of a wave farm couldn't be accurately predicted, a lower bound and an upper bound were estimated (Interviewee 5, Personal Communication, September 22, 2025).

As the data from the WECs and the report on which the LCOE calculations were based date back to the years from 2023 to 2025, these LCOE numbers were the numbers for approximately 2024, which is a six-year difference from the alternatives' LCOE predictions.

The first offshore wind farm was launched in 1991 (Tethys, 2025); the first wave energy farm in 2008 (Bray, 2014), which is a 17-year difference. Assuming that the LCOE of wave energy will develop similarly to the worldwide LCOE of offshore wind farms around 15 years ago, as suggested by Interviewee 8 (Personal Communication, September 26, 2025) and Interviewee 5 (Personal Communication, September 22, 2025), the LCOEs of wave energy in 2030 were estimated to be able to compare them to the 2030 estimations of alternatives. From 2010-2016, the LCOE of wind energy dropped by 36,8% (International Renewable Energy Agency, IRENA, 2024), and shows comparable developments to that of onshore wind (Roland Berger, 2024). A similar drop in the LCOE of wave energy was used to predict the 2030 values.

Interviewee 8 (Personal Communication, September 26, 2025) and Interviewee 10 (Personal Communication, October 2, 2025) have pointed out that the environment in Chile is very harsh, and that lifetimes and expected maintenance costs and windows in Chile would be worse than in other regions of the world. Therefore, the LCOE prices as calculated with the presented method are probably all low estimations.

Policy & Regulatory Analysis

Market supply is widely regarded as a primary driver of innovation, but it is insufficient to ensure the continuous development of innovations. Therefore, the involvement of non-market factors, such as the implementation of policy interventions, is crucial to support and catalyse innovation (Wang, X. et al., 2019). Additionally, climate and environmental policies can influence market participants' perceptions and behaviours, shaping the energy sector

(Xiaoyan Zhou and Gireesh Shrimali, 2023). However, the effectiveness of such policies is greatly shaped by the composition of the policy mix (Marcello Nieddu et al., 2024). Therefore, the policy mix in Chile is a crucial factor in the innovation and implementation of wave energy farms in Chile.

To create a clear picture of this policy mix, policies at three levels were analysed. The first level is the global level, in which broad ambitions and overarching global policies were examined. National objectives, goals, and strategies that support the global level were examined in the second level. At last, policies that support implementation and adoption at (sub)national level were evaluated (Karki, 2024).

In the background in Chapter 2, all information on the policies and regulations that were equivalent for all regions is provided. The policies and regulations that differ per region are elaborated upon in Chapter 5.

3.3 Design & Implementation

The preferred location, as determined by the TOPSIS method MCA, was taken as the central combination for further research. The main goal in this part of the study was to determine how to implement the wave energy converter in the energy system. This includes specifying the design of the wave farm, choosing an application for the produced energy, and establishing a roadmap to work towards this future vision.

3.3.1 Installation Complexity and O&M

The installation complexity was assessed based on the working wave heights and periods for each vessel. From this data, graphs showing the monthly working intervals per vessel were created. Based on this, it could be concluded which vessels are suitable for installation operations. Additionally, a conceptual stepwise installation plan is provided.

3.3.2 Environmental Impact

To mitigate the environmental impact, various noise reduction measures were described. In addition, the most abundant species in the area were identified to support the development of a targeted mitigation plan that minimises potential ecological disturbance. The species in Concepción are visualised in QGIS.

3.3.3 Ports

Port facilities were evaluated on the maximum length of the berths, the number of berths, and the maximum draft. In addition, an overview is made of the different construction phases.

3.3.4 Construction Phases

States and steps during the three construction phases, installation, operation, and decommissioning, were listed using information from an existing wave energy project in Ireland (Giorgi et al., 2022).

Table 3.1: Overview constants LCOE calculation

Constant	Abbreviation	Value	Unit
Weighted Average Cost of Capital	WACC	6	%
High farm efficiency	$\eta_{\text{farm-high}}$	100	%
Low farm efficiency	$\eta_{\text{farm-low}}$	60	%
Cost factor depth	F_D	0.66	€/kW/m
Chosen anchoring depth	D	150	m
Cost factor distance	F_d	2.97	€/kW/km
Chosen maximum distance to shore	d	<10	km
Base CAPEX	$CAPEX_{\text{base}}$	6,326	€/kW
EUR to USD exchange rate	–	1.18	\$/€
Lifespan Point Absorber	N_{PA}	20	years
Lifespan Oscillating Water Column	N_{OWC}	50	years
Lifespan Surge	N_{surge}	25.8	years

3.3.5 Energy Mix

To assess the potential role of wave energy in Chile’s electricity system, a wave energy production profile was made using a 45-year data set. The energy profiles of the existing energy sources and electricity consumption were extracted from Generadoras Chile Monthly Report (Generadoras de Chile, 2025).

Using this information, the production and consumption of electricity in Concepción were compared. To support the integration of wave energy into the overall energy mix, the short-term energy supply of a wave farm was also estimated. For this purpose, wave forecast data provided by the University of Valparaíso was used as input to the wave farm model. Based on these forecasts, the predicted energy supply over seven days was determined.

Finally, the different uses of electricity were identified and analysed to understand potential applications of the surplus energy within the regional grid.

Local Outlook & Perspective

Up until the MCA, the social perspective was mainly based on demographic data and academic literature. To get a clearer view of the actual values dominating society, the regional and municipal electoral results from 2024 were reviewed. The main values of the most important political parties were researched, and taken as the best representation of the local values at the preferred location.

Furthermore, locals and experts were interviewed. By performing these interviews, the local attitude and hurdles were assessed. As the number of people that were reached out to was limited due to the time constraint of this research, this attitude assessment may be biased and subjective. However, it did result in an extra data point that could be combined to form a more complete view on the preferred location.

Roadmap

To construct a roadmap of steps that could be taken to accomplish the established future vision of wave energy at the preferred location, the following method was used. Firstly, pain points and hurdles were determined through a role-play exercise. Role-playing can be an effective research method, as it can help researchers to explore different points of view and explore the way in which people perceive real-world cases (O’Sullivan, 2017). Thereafter, the research team has formulated a multi-step strategy to overcome these pain points best, based on all gathered information during a joint discussion.

To create a setting that mimics the real world, the intention was to invite local experts to take on the roles of different stakeholders. Unfortunately, as the intended Focus Group 1 (Personal Communication, September - October, 2025) was not available in the short time in which the role-play had to be performed, the research team itself was used. Five people were assigned the roles of different stakeholders, whilst one individual was assigned the role of moderator. For all stakeholders, a short but specific description, as described in Appendix Q, was written to ensure that all role-players could embody their role best. The moderator assigned each member a role that was outside of their comfort zone, one that they would be relatively unfamiliar with and had not extensively researched. This enabled biases to be minimised. The moderator was neutral during the discussion, but did guide the group to the goal of identifying pain points and hurdles.

3.4 Limitations

This section highlights the limitations of the chosen methods in this research.

3.4.1 Social Analysis

The social analysis is subject to several limitations. First, the availability and scope of academic literature on social factors such as acceptance was limited to and varies across locations. Second, interview insights were limited to a small number of stakeholders and may not have captured the full diversity of local perspectives. Finally, the scoring of indicators during the MCA workshop involved a degree of subjectivity, as it relied on group interpretation and discussion rather than purely quantitative measures.

3.4.2 Environmental Analysis

Several limitations must be acknowledged in the environmental analysis. The first concerns the availability and distribution of data in the OBIS. Although OBIS is the world's largest open-access repository for marine biodiversity, its spatial coverage along the Chilean coast is highly uneven. In Concepción, for example, 48,409 measurements are available, while in Valdivia there are only 2,228, almost twenty times fewer. This imbalance resulted in uncertainty into the MCA, as regions with fewer data were less likely to reflect existing biodiversity patterns. Given the absence of alternative datasets, this limitation should be acknowledged in this research.

The second limitation relates to the simplified representation of ecological impacts. In this analysis, biodiversity concentration was used to determine impact on marine ecology. The study did not differentiate between the types of species, WECs or their associated mooring systems, even though different technologies and configurations can produce distinct ecological effects depending on species behaviour and habitat. Similarly, factors such as species distribution, dominant or keystone species, and the presence of critically endangered species were not incorporated fully due to time and data constraints. However, Marine Protected Areas (MPAs) were included in the marine zones and areas part of the MCA and assigned greater weight to partially account for the higher ecological value and impact of these regions.

Finally, the study did not account for the migration routes of megafauna such as marine mammals and sea turtles. This comment was raised by an expert from the Austral University of Chile (Interviewee 10, personal communication, October 2-3, 2025) after the mid-term presentation, when the MCA framework had already been finalised.

3.4.3 Technical Analysis

In the technical analysis, there are some limitations regarding the calculation of the system performance. The availability of the buoys were not taken into account. This is because there is not enough information of the buoys. This means that the capacity factors are a lot higher than they should be. The availability of a CorPower buoy with a good operations and maintenance plan is around 85% (Giorgi et al., 2022). Of the other buoys, there is little to

no information found, so this is why an availability of 100% is assumed.

Furthermore, the power matrices used for the different buoys were the most up-to-date publicly available versions. Developers themselves might have more recent power matrices. As a result, the comparison between them may not be entirely consistent or fair. In addition, none of the power matrices have been officially verified by the respective companies; they were instead obtained from literature sources.

Lastly, the fatigue life and Ultimate Limit State (ULS) of the buoys have not been explicitly calculated. Instead, a design life of 20 years was assumed, along with the assumption that the ULS is never exceeded. The performance scores were therefore based on the mean and maximum wave heights.

3.4.4 Economic Analysis

In the economic analysis, some assumptions have been made, leading to limitations. Firstly, the formulas with which the LCOEs were calculated are only used in one source. In this source, these formulas were derived for one type of wave energy converter, the point absorber. Although the formulas were determined by an expert with access to company information, the LCOE calculations could be slightly off. Furthermore, as the formulas were derived for point absorbers, the comparison of the LCOE of point absorbers to that of non-point absorbers probably isn't entirely correct, but was the best available estimation.

Secondly, in the economic analysis, constants were used to determine the LCOE. Some of these weren't certain as they estimate future conditions or are unknown for the specific conditions in Chile. One of these is the WACC, which has a very large impact on the LCOE results compared to other variables, especially because the lifespan of projects is long. An increase of the WACC of 1% would increase the LCOE by almost 5%. The WACC represents the rate a company pays to finance its activities, and is dependent on the capital structure, and risk assessment of operations, among others (Berk & DeMarzo, 2020). The capital structure is a business decision, which was assumed to be chosen optimally, so it has little effect on the difference between firms. However, the assessed risk of wave energy might be different across the renewable energy sector. Smaller firms working with unproven technologies, such as wave energy companies, are often assessed as more risky, resulting in a higher WACC. During pilot phases, when companies and wave technology aren't proven, this could have a big impact on costs. Assuming that by 2030 the technology is at TRL 9, the assessed risk effect on Weighted Average Cost of Capital (WACC) is relatively low, but remained a focus point in the further research.

4 Site & Wave Energy Converter Selection

This chapter shows the selection process of five locations and three WECs. The locations are chosen by analysing the energy demand, the energygrid and the wave energy potential along the Chilean coastline.

4.1 Wave Energy Distribution & Demand

According to Monárdez et al., 2008, the wave power probability P90% never decreases below 5 kW/m. In most locations, it never descends below 10 kW/m. This would make the Chilean coastline suitable for the development of wave energy. Figures 4.1 and 4.2 show that the wave power is large in the south and decreases towards to north.

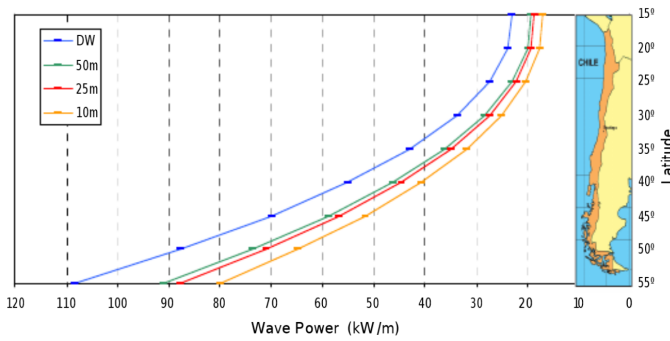


Figure 4.1: Wave power distribution along the Chilean coastline as a function of water depth (Monárdez et al., 2008)

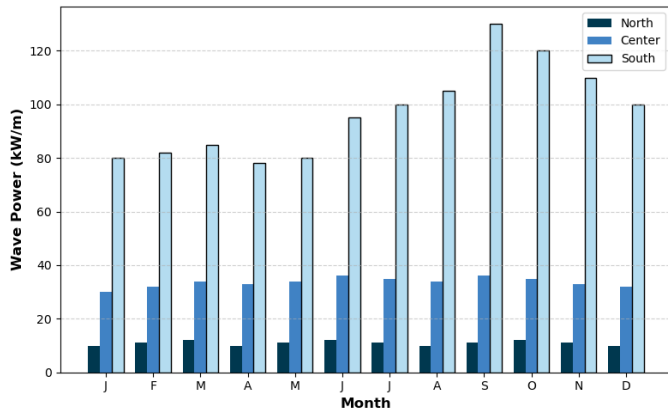


Figure 4.2: Monthly wave power distribution North, Central, and South of Chile at 25 meters depth (Monárdez et al., 2008)

The variability of the wave power along the coast is depicted in Figure 4.3. This shows high variability both annually and seasonally, but low daily variability ($<5\%$), which is favorable compared to the daily variability of wind power, which ranges from 4 to 12 percent (Potisomporn & Vogel, 2022). The total energy flux can be determined by combining the wave energy with the variability.

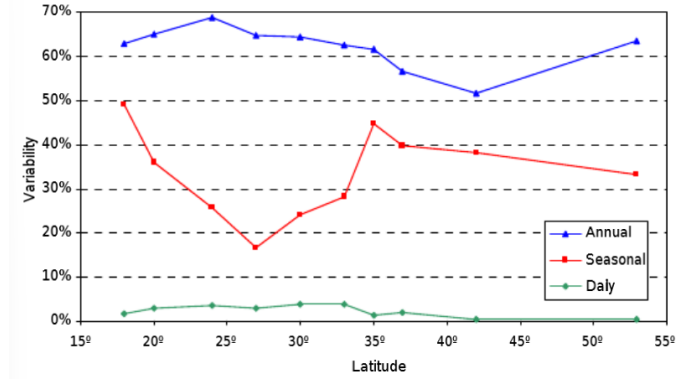


Figure 4.3: Variability of wave energy along the Chilean coastline at 25 metre depth with North left and South to the right from 15°degrees to 55°degrees latitude (Monárdez et al., 2008)

For Chile specifically, energy consumption is shown per district in Figure 4.4. Clearly, most energy is consumed in central Chile, around Santiago. This centralisation reflects the high population density in the area as well as the presence of energy-intensive sectors such as manufacturing, services, and transportation. In contrast, the northern and southern regions of Chile, while important for mining and natural resource extraction, show comparatively lower levels of overall consumption due to their smaller population centres and less diversified economic activity.

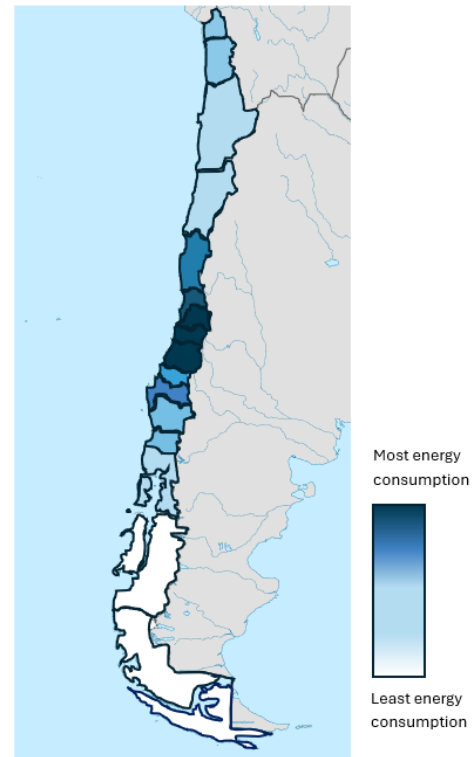


Figure 4.4: Energy consumption in Chile, (Comisión Nacional de Energía (CNE), Chili, 2018)

4.2 Site selection

To assess the wave energy potential along the Chilean coastline, several suitable locations must be identified. The selection of the sites is guided by two main criteria:

- **Feasible grid connectivity:** The presence of high- or medium-voltage transmission lines is critical because generated electricity must be efficiently transmitted to areas of high demand, for example, ports or urban areas. By placing Wave Energy Converters (WECs) close to existing high- or medium-voltage infrastructure, transmission losses are minimised and the need for extensive new cabling or substations is avoided. In addition, high- or medium-voltage grid points provide the stability and capacity required to integrate fluctuating renewable power into the Chilean energy mix without jeopardising reliability. See Appendix D for the existing energygrid.
- **Distance to ports:** Proximity to ports is vital for wave farm projects, as it reduces transport time, lowers installation costs, and ensures efficient maintenance operations.

Accordingly, the following five locations have been selected:

- Mejillones
- La Serena
- Valparaíso
- Concepción
- Valdivia

The distribution of the locations along the coast is shown in Figure 4.5. Their location relative to the grid is indicated in Appendix D.

It is important to note that the far south of Chile, despite offering the country's highest wave energy potential, is not included in this selection. This decision is supported by Figure 4.4 and Figure D.1. The absence of a high-voltage grid and ports in that region makes connecting wave farms to the national network technically and economically undesirable. A relatively small amount of energy is needed in the south, see 4.4. Installing WECs in this region would therefore not be cost-effective, as significant investments in grid development would first be required before the generated electricity could be transmitted to the areas with actual demand.

During the preliminary phase of this research, all five selected locations will be assessed. Subsequently, a more detailed investigation will be carried out in Section 5 for the location identified as most promising based on the outcomes of the preliminary phase.



Figure 4.5: Potential locations for wave farms

4.3 Wave Energy Converters

To assess the potential of wave energy, a wide range of different WECs are selected, as summarised in Table ??.

To make the evaluation of the wave potential feasible within the time constraints of this project, three WECs have been selected for more detailed analysis:

- CorPower
- Ocean Energy Buoy
- CETO

These devices combine relatively high Technology Readiness Levels (TRL 7-8) with competitive capacity factors across the studied locations, making them the best options according to the available data (see E). Other concepts for WECs will not be considered in this study for several reasons, which are given in F.



Figure 4.6: Selected buoys

5 Site Analysis

As stated in the previous chapter, five different locations are selected. In this chapter, the different locations are evaluated along different criteria to determine a preferred location and device for wave energy deployment in Chile. The criteria are:

1. Social - Demography - Social Acceptance - Community Benefits - Stakeholder Alignment
2. Geography - Ports - Bathymetries
3. Environmental Impact
4. Technical Feasibility - Survivability - Installation complexity - System Performance
5. Economic Feasibility
6. Political & Regulatory Context

Note: Geography is not a criteria in the MCA, it serves as information for the other criteria.

5.1 Social

This section evaluates the five locations across three social indicators: social acceptance, stakeholder alignment, and socio-economic community benefits.

5.1.1 Demographic & Social Profile

Each location presents distinct demographic profiles and social characteristics that shape how wave energy projects may be perceived and what benefits they could deliver. To provide a concise overview, key demographic indicators for the five shortlisted sites are summarised in Table 5.1 and further elaborated in the text below. Significant figures have been marked in shades of red. Demographic information is obtained from the Chilean Library of Congress (BCN) municipal reports (del Congreso Nacional de Chile, 2025).

- Mejillones is the most northern site located in the Antofagasta region. It is a small commune dominated by Chile’s 4th largest port, heavy industry, ther-

moelectric plants and mines, having made it grow a reputation as a “sacrifice zone” (Correa et al., 2025).

- La Serena is the capital of the Coquimbo region, the fourth most populated area in Chile undergoing rapid metropolisation (Castillo, 2022). It is one of the country’s main sun-and-beach tourist destinations (Araya-Pizarro & Cortés, 2024), while also hosting astronomy facilities and mining activities. Despite its touristic profile, electricity generation in the region still relies predominantly on fossil fuels (Selman-Caro et al., 2024)
- Valparaíso is the largest commune and region of the five sites. It hosts the country’s second largest port and its historic quarter is recognised as a UNESCO World Heritage Site (Cáceres-Seguel, 2023). The city combines port and logistics activities with a strong tourism sector and several universities, making it both a hub for maritime trade and cultural heritage.
- Concepción is the capital of Biobío, the second largest metropolitan area and the country’s central energy-producing region (Broto & Calvet, 2020). It has a diverse economy based on industry, forestry, and services, supported by several universities that provide a skilled workforce. Its role as an industrial and educational hub makes it an important centre for innovation and regional development.
- Valdivia is a mid-sized city in southern Chile, serving as the capital of Los Ríos Region. The city has a large movement of sustainable cooperatives and strong university presence (Sarabia & Peris, 2024). The local economy is rooted in forestry, wood pulp, and processing industries, alongside tourism, conservation, and cultural heritage. Surrounded by rivers, temperate rainforest, wetlands, and tribal presence, Valdivia also hosts a unique environmental landscape.

Overall, these profiles highlight a spectrum from highly industrialised areas (Mejillones, Concepción, Valparaíso) to

Table 5.1: Key demographic and socio-economic indicators for selected locations

Indicator	Mejillones	La Serena	Valparaíso	Concepción	Valdivia
Inhabitants commune	14,084	250,141	284,938	230,375	170,043
Inhabitants region	635,416	832,864	1,896,053	1,613,059	398,230
Age 0–29 (%)	47.5	40.7	37.6	37.9	39.1
Indigenous people (%)	3.8	5.2	2.6	4.5	15.9
Foreigners (%)	23.4	4.3	3.0	5.3	23.0
Total companies commune	882	18,314	18,127	28,771	13,915
Total companies region	42,344	58,282	146,138	110,774	32,603

tourism- and conservation-oriented regions (La Serena, Valdivia). This diversity shapes how local communities may perceive wave energy projects and the extent to which they could deliver meaningful socio-economic benefits.

5.1.2 Social Acceptance

To evaluate the social acceptance of potential wave energy sites, a number of sub-criteria are considered. These capture both perceptual and socio-economic dimensions influencing community support for marine energy development.

Local Sentiment

Community sentiment toward wave energy was assessed through a review of academic literature, policy reports, and stakeholder insights, including an interview with a focus group from Valdivia (Interviewee 10, Personal Communication, October 2-3 2025). A detailed overview is presented in Appendix G.

Table 5.2: Summary of community sentiment across study sites

Site	Description	Sentiment
Mejillones	Legacy of industrial pollution, distrust in institutions.	Very negative
La Serena	Concern for tourism, culture, and beaches; value sustainability.	Indifferent
Valparaíso	UNESCO site, strong activism, positive experience with Open Sea Lab.	Very positive
Concepción	Industrial and innovation potential, cautious public.	Positive
Valdivia	Strong environmental awareness and activism.	Positive

Overall, attitudes vary strongly across regions: Mejillones shows low trust due to its industrial legacy, while Valparaíso and Valdivia demonstrate greater openness when projects are transparent and community-oriented. In Concepción, (Oliva et al., 2024) found that marine energy is

generally viewed more favourably than other renewables when local ownership is included. In Valdivia, students emphasised that “transparency is the most important thing,” (Focus Group 2, October 2 2025) linking acceptance to environmental protection and participation.

Indigenous Community Presence

The presence of indigenous communities was examined across all sites and is presented in Table 5.1. Valdivia has the highest number of indigenous population at 15.9%, with two groups represented: the Wadalafken and the Leufu Mapu communities (Subpesca, 2025). Indigenous communities form an important part of the local social fabric. However, they may also express greater resistance to new developments in the region, making Valdivia the least preferred location.

5.1.3 Stakeholder Alignment

Stakeholder alignment is assessed by mapping the number, diversity and interaction of key actors. This is based on literature review, semi-structured interviews with a researcher at Universidad Austral, an Aquatera employee and a MERIC employee and on data obtained from Chilean Library of Congress (BCN) municipal reports (del Congreso Nacional de Chile, 2025), combined with interviews conducted (Interviewee 10, Personal Communication, October 2-3, 2025)(Interviewee 13, Personal Communication, October 21, 2025)(Interviewee 14, Personal Communication, October 21, 2025).

Overall, stakeholder alignment varies considerably across regions (Table 5.3). Valparaíso and Concepción show the most complex networks, where universities, NGOs, and local governments interact with port and industry actors, yet coordination remains challenging. Nonetheless, initiatives such as the Valparaíso Dialogue have helped advance port development discussions (Interviewee 12, 18 October, 2025). La Serena demonstrates strong alignment through collaboration between tourism, fisheries, and municipal organisations (Araya-Pizarro & Cortés, 2024), whereas Mejillones remains dominated by industrial stakeholders and marked by low institutional trust (Flechas, 2024). In Valdivia, alignment is moderate, driven by cooperation

Table 5.3: Stakeholder alignment across study sites

Site	Number	Diversity	Interaction	Key actors	Alignment
Mejillones	Low	Low	Weak	Mining industry, energy firms, port	Low
La Serena	Medium	Medium	Moderate	Tourism, fisheries, municipality, NGOs	High
Valparaíso	Very high	Very high	High	Port, cultural NGOs, universities, municipality	Moderate/High
Concepción	High	High	Moderate	Universities, municipality, environmental NGOs	Moderate
Valdivia	Low	Medium	Moderate	NGOs, UACH, forestry, indigenous communities	Moderate

between universities, NGOs, and indigenous communities, but constrained due to the role that indigenous communities can play in rejecting marine projects, as experienced with the attempt to host MERIC’s Open Sea lab there (Interviewee 10, Personal Communication, October 2-3, 2025).

5.1.4 Socio-economic Community Benefits

Through an analysis of the availability of local skills, potential opportunities for economic diversification, and existing infrastructure synergies, socio-economic and community benefits are assessed. This evaluation is based on a literature review and stakeholder interviews. Overall, the potential benefits of wave energy development differ across regions (Table 5.4). Concepción and Valparaíso show the greatest potential due to their diversified economies, strong connections between universities and industry, and established port infrastructure, which together facilitate job creation and innovation (Interviewee 12, Personal Communication, October 18, 2025) (Cortés et al., 2022; Oliva et al., 2024). Valdivia presents potential through research and maintenance related employment, supported by its university base. In contrast, Mejillones and La Serena show lower benefits: Mejillones due to its industrial dependency and limited diversification (Correa et al., 2025), and La Serena due to its reliance on seasonal tourism and limited industrial capacity (Selman-Caro et al., 2024).

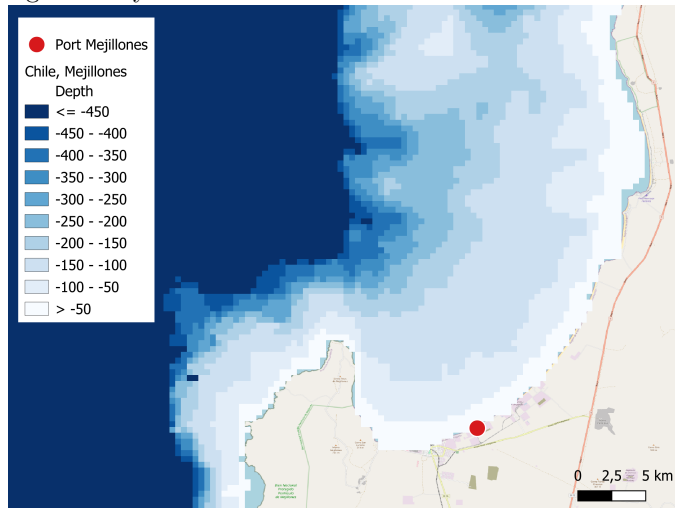
Table 5.4: Socio-economic & Community Benefits across study sites

Site	Description	Benefits
Mejillones	Highly industrial economy with limited diversification; few employment opportunities beyond energy and mining.	Low/Moderate
La Serena	Tourism-driven economy; potential benefits restricted by seasonality and low industrial capacity.	Low
Valparaíso	Strong innovation and education base; potential for job creation through port integration and university collaboration.	High
Concepción	Diversified industrial hub with strong academic-industry links, offering potential for employment and innovation.	Moderate/High
Valdivia	Academic and eco-tourism economy; moderate job creation potential in research and conservation sectors.	Moderate

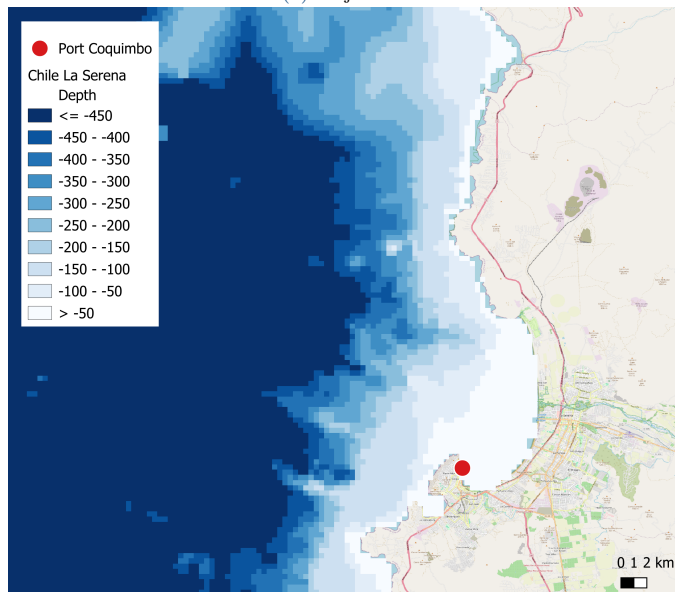
5.2 Geography

Figure 5.1 presents depth bands and marks the ports (red dots) in the areas of the selected locations. Values are given in metres, with 0 representing sea level. Increasingly negative values indicate greater water depth. Concepcion and Valdivia have the largest shallow water area.

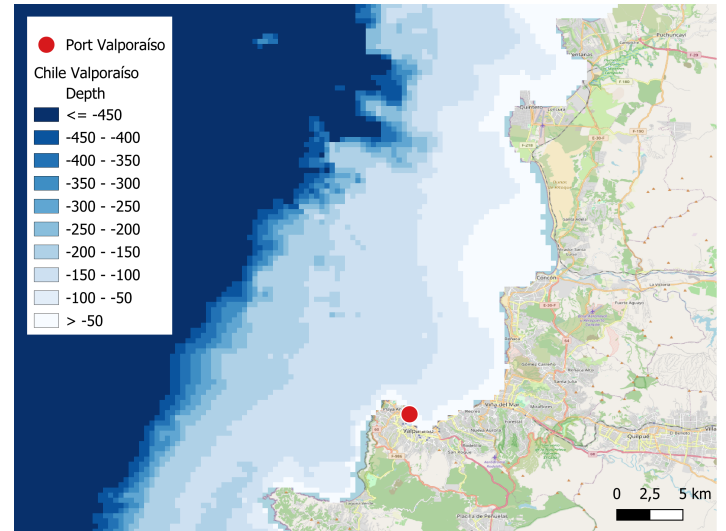
In the bay of Mejillones, there is high industrial presence where energy could be utilized, in mining for example. In the bay of La Serena, the Coquimbo port is located, which is big enough to house installation equipment. Concepcion is the only location with more than one port, the Talcahuano port (east and west), and the San Vicente Port. The availability of ports and port facilities makes Concepción an attractive location to develop wave energy. Valdivia has only one small port, Corral Port, which is not suitable for large installation equipment. Therefore, the installation equipment and the WECs need to be transported from Concepcion, which increases the costs significantly.



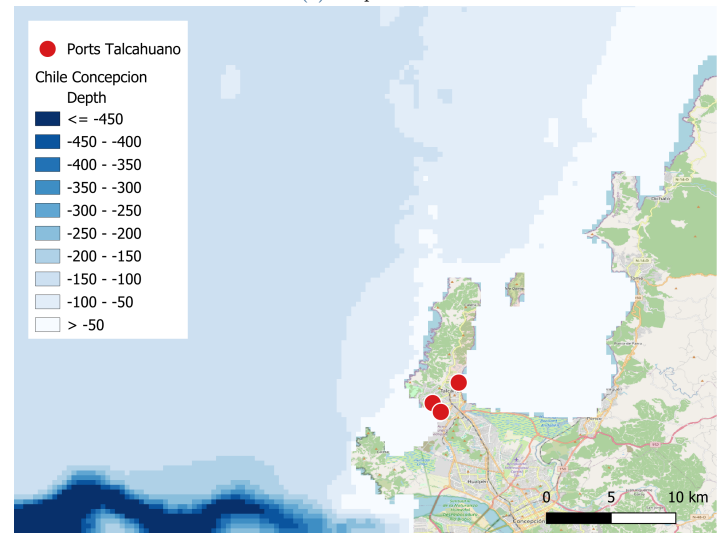
(a) Mejillones



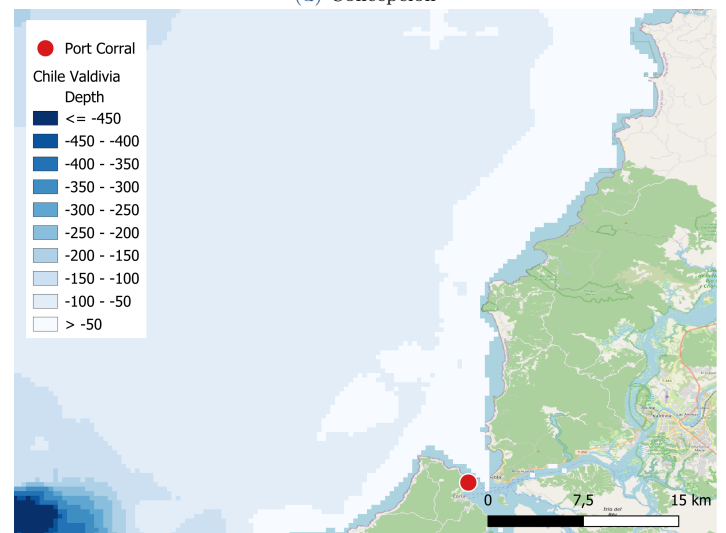
(b) La Serena



(c) Valparaíso



(d) Concepción



(e) Valdivia

Figure 5.1: Bathymetry and port locations along the Chilean coast: Mejillones, La Serena, Valparaíso, Concepción, and Valdivia (GEBCO Compilation Group, 2025)

5.3 Environmental

This section assesses the environmental impact of implementing wave energy converters and examines potential conflicts with existing marine zones across the five studied sites. It begins by comparing biodiversity concentrations at each site, using equivalent surface areas. Next, the analysis maps the surrounding marine areas and zones to identify and evaluate any potential zoning conflicts.

5.3.1 Impact on Marine Ecology

For all sites, the biodiversity concentrations are retrieved from the Ocean Biodiversity System (OBIS). The results are indicated in Table 5.5, showing the highest concentration in Valparaíso and the lowest concentration in Valdivia. As Valparaíso has the highest biodiversity concentration, the impact on marine ecology will be of greatest magnitude there, thus making it the least preferred location.

It is important to note that the number of records varies significantly among the five locations, which reduces the reliability of the results. This limitation will be addressed in detail in the discussion chapter.

Table 5.5: Marine biodiversity records and species across the five chosen sites (Ocean Biodiversity Information System (OBIS), 2025)

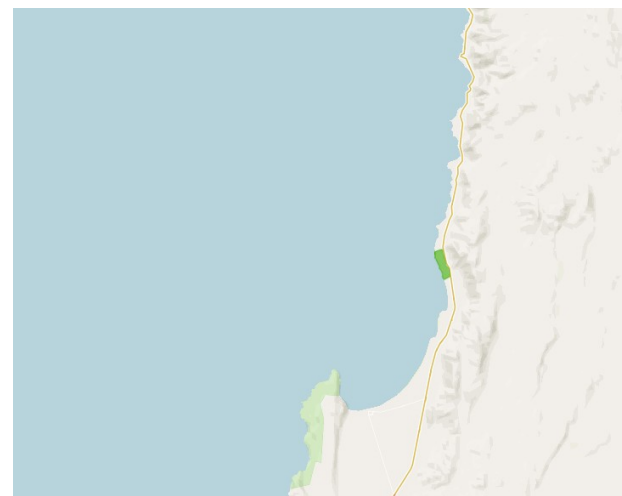
Site	Records	Species
Mejillones	21,777	616
La Serena	4,185	407
Valparaíso	10,259	877
Concepción	48,409	625
Valdivia	2,228	375

5.3.2 Marine Zoning Conflicts

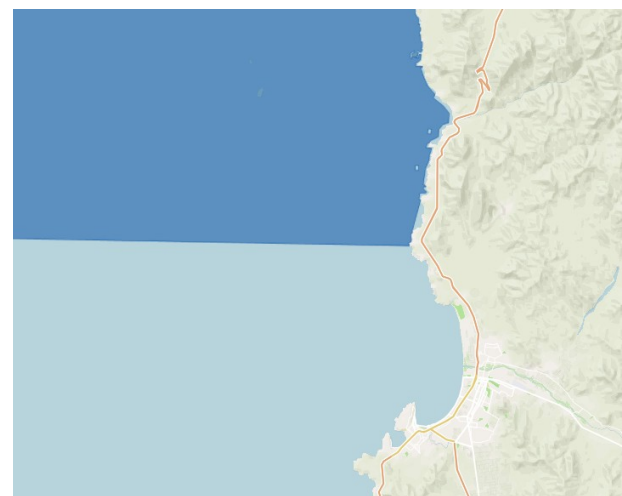
To assess if marine zoning conflicts will arise when implementing a wave energy farm in one of the studied sites, maps are retrieved from Subpesca (Subpesca, 2025), showing the different designated areas and zones (Appendix H). When comparing the five sites, differences are shown in the presence and the type of marine areas and zones across the sites. Marine Protected Areas (MPAs) have the highest protection level, resulting in higher constraints and higher weight in the scoring of the sites within the MCA. Therefore, these areas will be assessed individually, and then the remaining areas and zones will be compared, to conclude where the potential of zoning conflicts is the highest.

The Marine Protected Areas (MPAs) are mapped and shown in dark blue in Figure 5.3. Firstly, the Archipiélago de Humboldt MPA, shown in lies just north of the selected grid of La Serena. This area is one of the most biodiverse marine ecosystems of the Humboldt Current, home to Humboldt penguins, fin whales, bottlenose dolphins, and many fish and benthic species (Oceana, n.d.). As described

in the environmental background chapter, offshore energy systems can create noise and vibration disturbance that may affect marine ecosystems. Although the project site does not overlap directly with the MPA, its close distance means that ecological disturbance is very likely. In Mejillones no MPAs are present, so no conflict is expected. In Valparaíso the Acatilados Federico Santa María MPA protects unique plant communities and supports research and education activities (Ossa Barrientos & Maldonado Escobar, 2021). While located onshore, it may still be indirectly affected. In Concepción the MPA is near the river delta and well separated from the offshore WEC site, so no major impact is expected. In Valdivia MPAs are limited to inland waters, where the coastline acts as a barrier to offshore disturbances. Overall, considering MPAs alone, La Serena is the most vulnerable and therefore the least preferred location for wave energy development, and Concepción the most preferred.

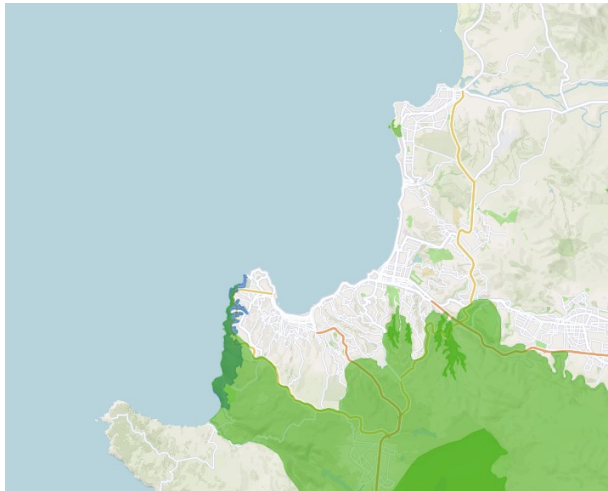


(a) Mejillones

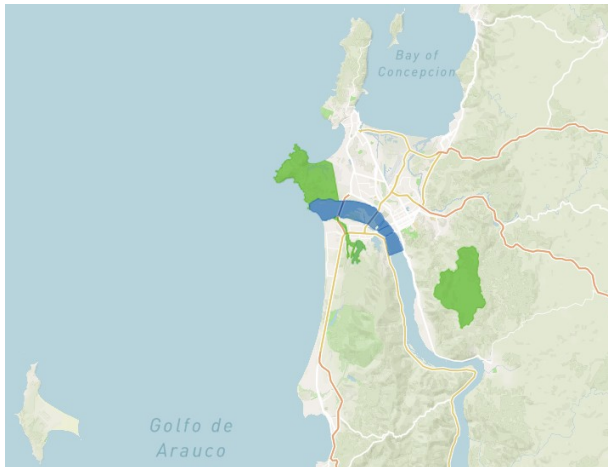


(b) La Serena

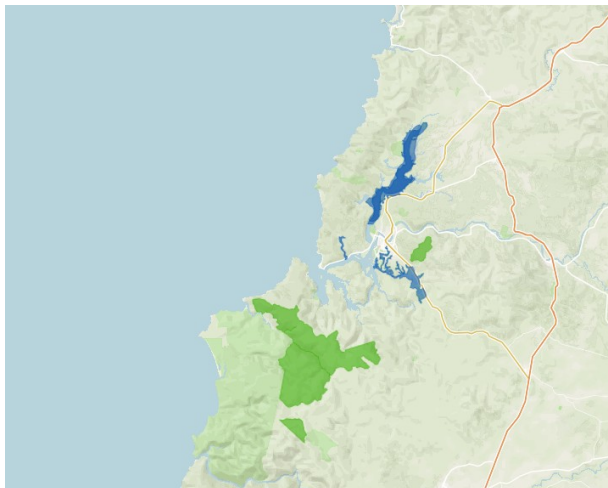
Figure 5.2: Protected Areas along the Chilean coast: Mejillones, La Serena (ProtectedPlanet, 2025)



(a) Valparaíso



(b) Concepción



(c) Valdivia

Figure 5.3: Protected Areas along the Chilean coast: Valparaíso, Concepción, and Valdivia (ProtectedPlanet, 2025)

When comparing the different types of marine areas and zones presented in Appendix H, several observations can

be made. Valparaíso has the fewest designated areas and zones, whereas La Serena shows the highest concentration. In all locations except Valparaíso, concessions are present, including both permanent and requested ones. Regarding Benthic Resource Management and Exploitation Areas (AMERBs), two categories can be distinguished: management areas and planning areas. All studied sites contain AMERBs, but La Serena, Concepción, and Valdivia have a higher number of permanent ones. Similarly, Áreas Apropriadas para el ejercicio de la Acuicultura (AAAs) are found at all sites, except Valparaíso. In Valdivia, they extend along almost the entire coastline; in Mejillones, the coast is also densely covered except for a small part near the city; while in La Serena and Concepción, AAAs appear along specific coastal sections.

Considering the overall distribution of areas and zones across all sites, it can be concluded that potential spatial conflicts are most likely to arise in La Serena and least likely in Valparaíso.

5.4 Technical Feasibility of Wave Energy

This section evaluates all technical criteria needed in the MCA to choose a wave energy converter and location. For this research, some assumptions are made:

- Depth of WEC installation is 150 metres;
- Lifetime of the wave buoys is 20 years;
- Location of WEC installation is maximum 10 km from the coast;
- Installation vessels can only operate when the significant wave height is below 2.5 metres;
- Geotechnical analysis is not taken into account for the MCA;
- Survivability is simplified as the mean and max wave height of a location;
- For every location, there is a nearby Port;
- For every location, a good connection to the grid is possible.

5.4.1 Survivability of the Buoy

Table 5.6 presents the mean and maximum wave heights and periods along the Chilean coast. A clear trend is observed: the mean wave height increases towards the southern locations. In contrast, the mean wave period decreases slightly in the same direction. For the maximum values, the wave height also shows an increase towards the south, while the maximum wave period is almost the same for every site.

Table 5.6: Mean and maximum of significant waveheight and period along Chilean coast (Focus Group 1, Personal Communication, September, 2025)

Location	Parameter	Mean	Max
Mejillones	Height (m)	2.03	5.18
	Period (s)	13.6	23.95
La Serena	Height (m)	2.30	6.31
	Period (s)	13.2	23.95
Valparaíso	Height (m)	2.30	6.51
	Period (s)	13.2	23.95
Concepción	Height (m)	2.42	7.90
	Period (s)	13.0	23.95
Valdivia	Height (m)	2.53	8.61
	Period (s)	12.9	24.0

The survivability of a buoy can be estimated using the Fatigue Limit State (FLS) and the Serviceability Limit State (SLS) to test the buoy on fatigue and on the maximum exerted force. For this section, these criteria are simplified into the mean wave height (FLS), and max wave height (SLS) seen in Table 5.6. This Table shows that Valdivia has the highest mean and maximum wave height. Therefore, it scores low on survivability.

5.4.2 Installation Complexity

For the MCA, it is assumed that the installation complexity depends on the number of wave heights below a certain wave height and the port facilities. For every location, the amount of time below the assumed 2.5 metres is computed.

Interviewee 1 (Personal Communication, September-October, 2025), highlighted that the ports of Mejillones, La Serena, Valparaíso, and Concepción are sufficiently large to support the deployment and installation of wave energy converters (WECs). In contrast, the port of Valdivia lacks the depth and facilities required to accommodate larger vessels, meaning that deployment operations for this location would need to be carried out through the port of Concepción. An overview of the results is visible in Table 5.7. The percentages are calculated using the data from Focus Group 1 (Personal Communication, September, 2025).

Table 5.7: Percentage of time with wave height < 2.5 metres at different locations and availability of port facilities

Location	Percentage of time < 2.5 m (%)	Port facilities
Mejillones	83.21	Major industrial port (mining exports)
La Serena	63.79	Medium port facilities (fishing, tourism)
Valparaíso	63.82	Major commercial port
Concepción	57.10	Large port facilities (Talcahuano, San Vicente)
Valdivia	53.50	Small river port (limited capacity)

5.4.3 System Performance

Using Appendices I and J the system performance is assessed. The results for the capacity factor and the Annual Energy Yield (AEY) at the five study locations are presented in Table 5.8. A clear geographical trend can be observed: both the capacity factors and the AEYs generally increase towards the southern sites. Among the devices, the CorPower system consistently demonstrates the highest capacity factor, reaching its peak performance in Valdivia. In contrast, the OE buoy delivers the largest annual energy yield, which can be attributed to its larger size relative to the other wave energy converters (WECs). Notably, the maximum AEY is not found in Valdivia but rather in Concepción. The lowest performance is recorded for the CETO buoy in Mejillones, highlighted in red in the table. A detailed assesment of the capacity factors and annual yield can be found in Appendix E.

Table 5.8: System performance along Chilean coast

Location	Technology	Capacity Factor (%)	AEY (MWh)
Mejillones	Corpower	70	2,447
	CETO	31	714
	OE Buoy	35	8,912
La Serena	Corpower	77	2,697
	CETO	43	995
	OE Buoy	40	10,017
Valparaíso	Corpower	77	2,708
	CETO	45	1,029
	OE Buoy	39	10,063
Concepción	Corpower	79	2,786
	CETO	48	1,094
	OE Buoy	41	10,330
Valdivia	Corpower	80	2,817
	CETO	47	1,072
	OE Buoy	41	10,233

5.5 Economic Feasibility of Wave Energy

The results for the LCOE analysis are presented in Table 5.9 for all locations and devices.

Table 5.9: LCOE results per location and technology

Location	Technology	2020 (\$/MWh)	2030 (\$/MWh)
Mejillones	Corpower	214-356	135-225
	CETO	460-766	291-484
	OE Buoy	357-595	226-376
La Serena	Corpower	194-324	123-204
	CETO	331-552	209-349
	OE Buoy	313-521	198-329
Valparaíso	Corpower	194-324	123-204
	CETO	317-528	200-334
	OE Buoy	321-534	203-338
Concepción	Corpower	189-315	120-199
	CETO	297-495	188-313
	OE Buoy	305-508	193-321
Valdivia	Corpower	187-311	118-197
	CETO	303-505	192-319
	OE Buoy	305-508	193-321

What stand out first is that the CorPower device consistently outperforms the other two technologies with respect to LCOE. Mejillones ranks lowest in terms of economic feasibility compared to the other locations. La Serena shows a more favourable outlook than Mejillones, although its financial performance remains weak relative to the other regions. Valparaíso performs at a level similar to La Serena. Concepción and Valdivia emerge as the most attractive locations from a financial perspective, with CorPower achieving the strongest results in both cases. In fact, Valdivia records the lowest LCOE overall for the CorPower device. Note: a low LCOE is positive.

5.6 Political & Regulatory Context

In this section, the PARCC (regional action plans) and PACCC (municipal action plans) are discussed. These plans are the main differentiators between sites in terms of the political & regulatory context.

For both Mejillones and Valparaíso, the PARCC as well as the PACCC aren't finished. Therefore, there is no comparable local information on the political and regulatory framework. This is assessed as low proactiveness in these areas, signalling the least-preferred context at these two sites.

The region Los Ríos, in which Valdivia is located, has released its PARCC. In this plan, multiple different lines of action are present, of which bringing GHG emissions down is one (Gobierno Regional de Los Lagos, 2025). Although there is a focus on GHG emissions, a focus on new renewable energies isn't stated. The plans mainly seem to focus on limiting current energy usage or other emitting activities.

The PACCC of Valdivia isn't available. Therefore, only the PARCC provides information that can be compared to other sites.

The draft version of the PARCC for the Coquimbo region, the region of La Serena, is available. The region of Coquimbo aims to reduce GHG emissions by 20% compared to the current balance, which is 545,5 kt CO_{2eq} . This reduction should mainly result from changes in the energy, transport, waste, and agriculture sectors (Gobierno Regional de Coquimbo, 2024). It furthermore emphasises multiple areas of improvement in the resilience of people and ecosystems. The main goal on energy generation is to transition toward natural gas backup plants and promote renewable energy generation (Gobierno Regional de Coquimbo, 2024).

In the PACCC for La Serena, there is a strong focus on community participation and a multisectoral approach (Christian Pérez Trujillo, 2025). The plan includes workshops and participation of public, private & academic sectors, making sure to bring together multiple perspectives.

The PARCC of the Biobío region, the region of Concepción, specifies a lot of action points (Gobierno Regional de Biobío, 2025). For the reduction of emissions, these plans range from afforesting 1000 hectares to promoting and disseminating alternative renewable energies. In this plan, the industrial use of natural gas is highlighted as well.

According to (Unda, 2025), the PACCC of Concepción is also finished, and contains more than 30 concrete goals and measures on a wide scale of improvements.

Following the same reasoning as for the pro-activeness of Mejillones and Valparaíso, Valdivia is seen as a less preferred site than La Serena and Concepción.

Out of the last two, Concepción has the clearest trajectory set out for alternative fuels and renewable energies. Thus, the political and regulatory context is the best at this site. The context in La Serena is only slightly less preferable.

6 Multi-criteria Analysis

As stated in the method, the TOPSIS method MCA is used to find the most preferred combination of a location and WEC device. In this chapter, the weights and results are shown.

6.1 Factors & Weights

In general, five overarching MCA factors were identified. These can be subdivided into smaller categories. The smaller categories can be found in Appendix K and can also be seen in the complete MCA tables as in Appendix L, Figures L.3 & L.4. The major factors and their final weights are stated in Table 6.1.

Table 6.1: Overarching MCA factors

Factor	Weight
Technical feasibility of wave energy	0.20
Economic feasibility of wave energy	0.24
Environmental impact and zoning conflicts	0.30
Social aspects when building wave energy farms near shore	0.18
Political considerations and legal requirements	0.09

6.2 Results

The results that follow from the complete tables as shown in Appendix L, Figures L.3 & L.4 of the MCA TOPSIS method are depicted in Figure 6.1.

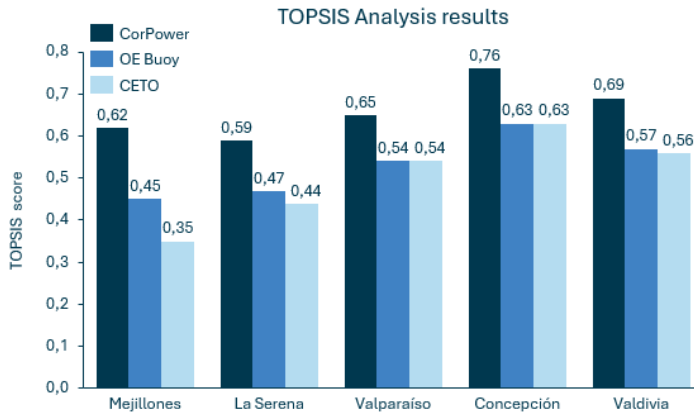


Figure 6.1: Multi-criteria Analysis Scores

The barplot in Figure 6.1 presents the total MCA scores

for the evaluated locations and WECs. The CorPower buoy scores best in every location. Furthermore, the results show that Concepción is the most suitable location for a wave farm regardless of the choice of WEC. The CorPower & Concepción combination scores the highest overall; therefore, this is the preferred location.

6.2.1 Results Sensitivity Analysis

The full skewed results can be seen in Figure L.2 in Appendix L. These results show that the CorPower & Concepción combination scores best in all but one skewed perspective. Only in the social perspective, the CorPower & Valparaíso combination scores higher than in Concepción, by 0.03 points. As only one of these skewed results indicates that another combination is preferable, together they further support the result that the CorPower & Concepción combination is the most preferred, and indicate that the subjectivity of the weightings has limited influence on the results.

7 Design & Integration Concepción

In the multi-criteria analysis in Chapter 6, Concepción is chosen to be the preferred location for the extraction of wave energy in Chile. This chapter will include the final conceptual design of the location of the wave energy farm. In this choice, the direction of waves, water depth, existing project concessions, installation complexity, operation and maintenance and energy use are considered. In the previous chapters, assumptions were made for the multi-criteria analysis. In this chapter, new assumptions will be defined:

- Installation in CorPacks
- The soil consists of sand and clay (hypothetical profile)
- UMACK anchor installation is possible
- Tow-to-shore one in every 5 years

7.1 Local Strategic Outlook & Perspective

The recent municipal elections of 2024 give a more detailed picture of the local values and concerns in Concepción.

In Concepción, Hector Muñoz Uribe of the Partido Social Cristiano (PSC) is elected as mayor with 21,96% of the votes. In the results, he was closely followed by someone from the Democracia Cristiana (DC) party and an independent person, who was supported by the Partido Republicano (PR) (TVU Noticias, 2024) (Servicio Electoral de Chile, 2025a).

The council in Concepción consists of ten people. There are only two parties that have more than one of these places, namely the PSC and the PR, both with two elected candidates (Servicio Electoral de Chile, 2025b).

As in both the mayor and council elections, PSC and PR have won, and their main values and concerns are assumed to most closely reflect those of Concepción. Both parties are right-wing, socially conservative parties with a strong focus on order, security, sovereignty, and traditional Christian values on family and life (abortion and end of life). Although both adhere to Christian values, freedom of religion, expression, and objection are important for both (Partido Social Cristiano, n.d.) (Partido Republicano, 2025). The PR furthermore advocates free-market economics. None of the pillars is specific on renewable energies.

The attitude towards wave energy in Concepción will correspond to the above values. It is expected that the attitude towards renewables in Concepción is positive, if and only if it could benefit energy security & sovereignty, community welfare, and/or could enhance the private market.

7.2 Wave Energy Integration in Existing Concession Floating Wind Farm

To enhance the feasibility and stability of offshore renewable energy generation, the wave energy system is

integrated with a floating offshore wind farm (Interviewee 10, Personal Communication, October 2, 2025). Different concessions for wind parks in the area are evaluated. The wind park Vento Azul BioBio is chosen as the optimal wind energy park due to its proximity to ports, depth, and the absence of fishery and environmental conflict zones. This concession spans 354 km^2 , with 64 wind turbines of 15 MW, making up to 960 MW of installed capacity. In Figure 7.1, the location of this farm can be seen in combination with the area chosen for a possible wave farm.

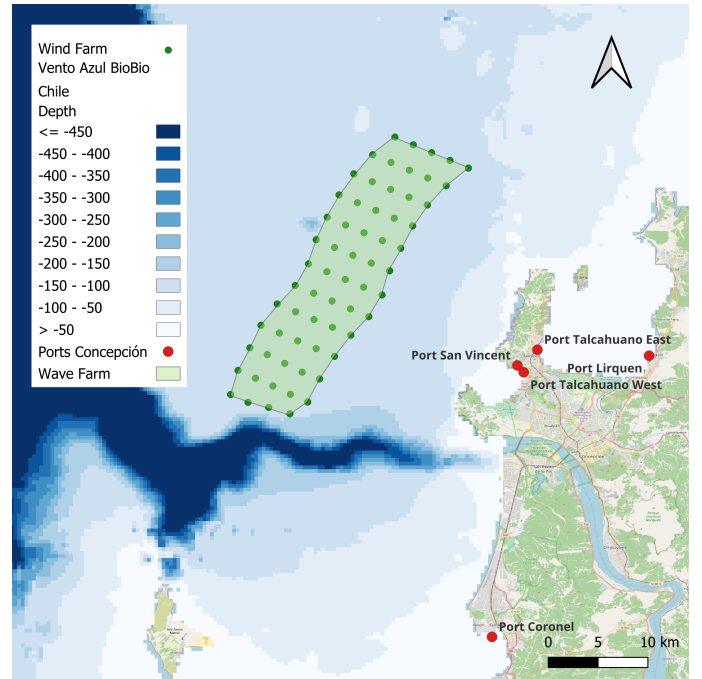


Figure 7.1: Bathymetry and ports in Concepción with floating wind farm Vento Azul BioBio

It is assumed that one CorPack unit (see Figure 7.2) can be installed between each pair of wind turbines. This layout allows for the placement of 51 CorPower packs within the wind farm area as seen in Figure 7.1, corresponding to a total installed capacity of approximately 510 MW.

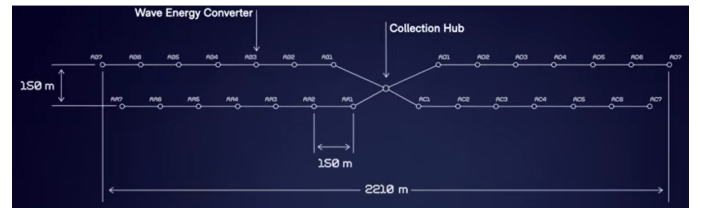


Figure 7.2: Layout for CorPower pack of 10 MW (CorPower Ocean AB, 2025)

The direction of the waves can be used to align the wave energy farm in a position for the optimal energy output without wake effects. Figure 7.3 presents the wave rose with a bin width of three degrees, indicating a dominant wave direction between 228° and 231°. The CorPacks are therefore positioned between the wind turbines following this orientation. This combined system forms the basis for assessing the contribution of wave energy to the overall energy mix and its influence on energy utilization.

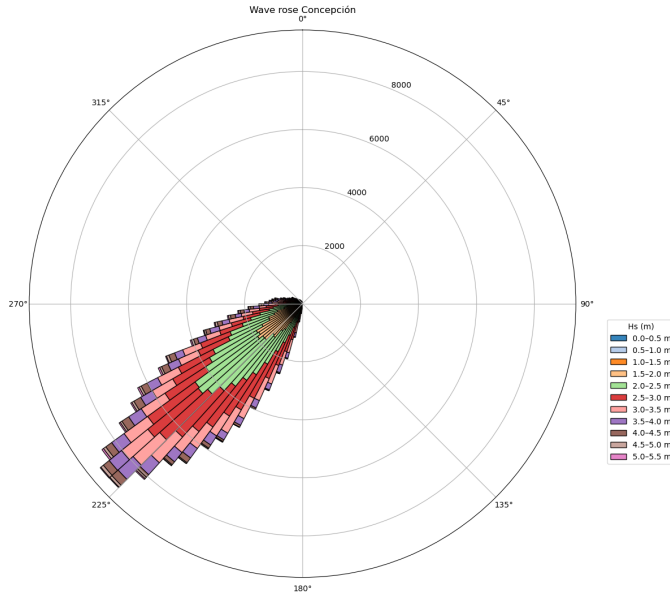


Figure 7.3: Wave rose Concepción

7.3 Installation Complexity

The complexity of installing a wave farm depends on the soil conditions, wave conditions, port facilities, and distance to the port. The preferred location Concepción contains 5 ports: the port of San Vicente, the west port of Talcahuano, the east port of Talcahuano, the port of Coronel, and the port of Lirquen. In this section, the installation complexity of a wave farm in Concepción is being evaluated.

The installation complexities that arise from wave parameters depend on the height of the waves, the period, and the time the waves are below a certain value. This value differs per installation vessel as seen in Figure 7.4 (O'Connor et al., 2012). This Figure is used to determine the time vessels can operate.

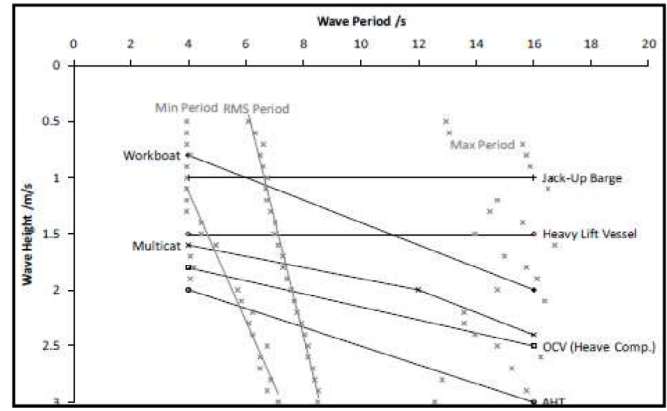


Figure 7.4: Workability of vessels with different significant wave height and peak period (O'Connor et al., 2012)

Using data from the University of Valparaíso, the wave parameters for Concepción over 45 years from 1979-2025 can be determined. An analysis is made assuming the different possible installation vessels. In Figure 7.5, the working windows for the specific vessels in Concepción are visible.

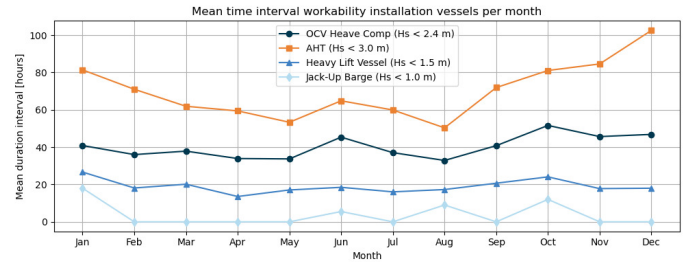


Figure 7.5: Workability interval in hours per installation vessel with data from Concepción

Using Figure 7.5, a simplified proposal for the steps of a CorPower buoy installation consists of:

1. June: Site investigation (which can be combined with the offshore wind park): Remotely Operated Vessel or Sonar checks the site conditions. This task is performed with an offshore construction vessel (OCV) as the site conditions in Chile are very rough.
2. October: Umack Anchor is placed with an OCV
3. December: Anchor Handling Tug (AHT) drags the CorPower buoy to the site
4. December: The AHT connects the CorPower buoy to the Umack anchor
5. Januari: The OCV performs cable installation

7.3.1 Environmental Impact

When designing offshore wind and wave energy farms, it is essential to look at the possibilities for nature inclusive design, state several experts in the field of marine engineering (Interviewee 8, Personal Communication, September

26, 2025) (Interviewee 10, Personal Communication, October 3, 2025) (Interviewee 14, October 21, 2025). To assess the impact on this region's marine life when implementing a wave and wind farm and seek possible nature based solutions, existing species in the region of Concepción are mapped in Figure 7.6. This map shows lower occurrence of marine life located at the chosen site compared to the rest of the grid. Besides, the species with the highest occurrence are shown in Appendix N. In reality, when designing an offshore wind and wave farm, all species in the region should be assessed carefully, but due to time restrictions, this report has focused on the 30 most common species. Appendix N, shows the 30 species with the highest occurrence within the chosen site. These are mostly bacteria and two types of albatross: the Black-browed Albatross and the Northern Royal Albatross. The installation of wave and wind energy farms can have adverse impacts on bird populations, such as increased collision risks, disturbance, and changes to movement patterns during construction, operation, and decommissioning. However, when appropriate mitigation measures are applied, these projects can also help improve habitats (Grecian et al., 2010). To get a better understanding of the possible effects and benefits, an in-depth analysis should be performed.

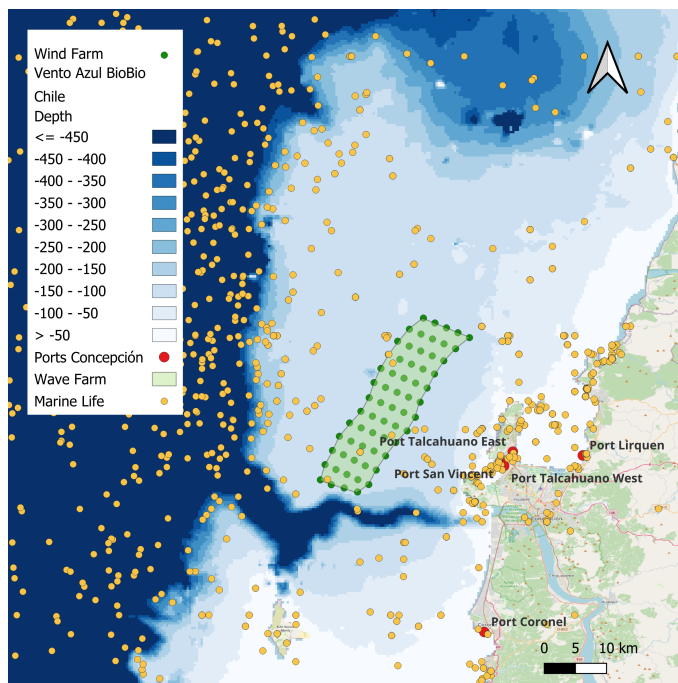


Figure 7.6: Occurrence of marine life at the chosen location in Concepción (GEBCO Compilation Group, 2025); (Ocean Biodiversity Information System (OBIS), 2025)

Noise mitigation

During an installation process, different kinds of noise can be produced, which were listed during an interview (Interviewee 5, Personal Communication, May 5, 2025).

- Hammer impacts

- Acoustic waves from pile wall expansion
- Sound radiation from the vibration of the Umack anchor into the seawater(primary noise path)
- Sound that reflects into the water from the soil or propagates along the seabed-water interface(secondary noise path)
- Noise of installation vessel itself

Different noise mitigation measures can reduce the impact of the noise produced. A list of possible mitigation measures is provided:

1. Gentle driving of piles
2. Double or single Air Bubble Curtain (Hose at the seabed with air escaping from the holes to create an air-bubble screen in a single (BBC, 10-12 dB noise reduction) or double configuration (DBBC, 16-17 dB noise reduction)
3. Hydro-sound dampers consist of fishing nets with gas-filled balloons (HSD, $8 < 10 < 13$ dB noise reduction)
4. Noise mitigation screen, space between inner and outer tube, additional BBC inside(IHC-NMS, $10 < 12 < 14$ noise reduction)
5. AdBM system (Helmholtz resonators)

Currently, there is no specific law in Chile regulating the underwater noise emissions. Therefore, every project that may generate noise emissions that could affect marine life must present an environmental impact study in reference to international standards (PROSAC, 2023). The UMACK anchor of the wave buoys is vibrated into the soil, instead of hammering, which produces less noise. To further decrease the noise levels, it is recommended to use a single air bubble curtain during installation.

7.3.2 Anchoring

Due to the absence of site-specific geotechnical data, a hypothetical soil profile consisting of sand and clay layers is adopted. The analytical design calculations were carried out based on representative soil parameters and compared with numerical results from the PLAXIS 2D model, showing a good level of agreement. The required monopile/UMACK dimensions to withstand the applied mooring forces, including an appropriate safety factor (buoy force is multiplied with 1.5), are a length of 10.25 metres and a diameter of 1.6 (UMACK diameter (CorPower Ocean, 2022)). This is the result of the analytical calculation. The UMACK pile has a length of 24 metres and does thus easily withstand the exerted forces. The complete calculations are presented in Appendix M.

7.4 Ports

As shown in 7.1, five ports are suitable for the installation of the wave farm. All these ports contain cranes for lifting the wave energy buoy parts onto a vessel. Only the break bulk or multi-purpose terminals can be used for the installation of the wave farm (Sea of Gravity, 2025). In Table

7.1, the maximum draft and length of berth of the ports are listed. The optimal port for the installation of the wave farm at the chosen site is the Port of San Vicente. This port has enough facilities to lift wave energy converter components onto ships and to house large offshore construction vessels(OCV) and anchor handling tugs(AHT). In addition, Port San Vicente is the closest port near the chosen site in Figure 7.1.

Table 7.1: Port details Concepción (D. W. Chile, 2025), (A. Chile, 2025), (DIRECTEMAR, 2022),(Puerto Coronel, 2025), (San Vicente Terminal Internacional, 2025)

Port	Max berth length [m]	Max Draft [m]
Lirquén Port	220	12.80
Port of Talcahuano (East & West)	190	8.2
Port Coronel	366	15.0
Port San Vicente	210	14.02

7.5 Operation & Maintenance

After the installation phase, the buoys are in the operational phase. It is crucial in this phase to perform scheduled control to limit the downtime of the buoys. Routine maintenance must be performed. CorPower itself takes full responsibility for operations and maintenance, which decreases the risk of ownership (CorPower Ocean AB, 2025). This section describes the operation and maintenance procedures.

7.5.1 Operations

The day-to-day operation of a CorPower buoy involves continuous monitoring, adaptive control, reliable power delivery, and strict safety protocols. Monitoring systems track energy production, buoy loading, anchor forces, and cable tensions in real time. Control systems actively adjust the WEC settings to changing wave conditions, ensuring resonance tuning and maximum energy capture. All operational data, including output, loads, and failure events, is logged for performance analysis and predictive maintenance.

Grid connection and power delivery require reliable transmission of generated energy to shore. Protection measures safeguard the system from grid failures and surge voltage, while power optimisation is performed according to the prevailing wave climate.

Safety considerations are central to operations. Offshore interventions must follow strict safety protocols, supported by emergency response plans in case of equipment failure,

cable damage, or extreme storms.

During operation, generated power should be distributed efficiently. The available energy can be used for direct consumption by the grid, while any surplus can be allocated to secondary applications such as green hydrogen production, battery storage, or other flexible demand systems. A forecasting model enables reliable prediction of power output, and when combined with historical consumption data, it supports optimal decision-making on when to activate these supplementary systems.

The forecast model, which is elaborated in Section 7.7.2, can be used to find maintenance windows. In these windows, the significant wave height and wave period should be between the operating windows of the vessels.

7.5.2 Maintenance of a CorPower Buoy

At large water depths, diver-based maintenance is impractical, so a CorPower wave farm in Concepción relies on remote monitoring, ROVs, and periodic tow-to-shore servicing (CorPower Ocean, 2023). In large quantities, wave farms have not yet been deployed. Therefore, it is unknown what the optimal tow-to-shore frequency is. According to Chapter 7.6, the wave buoys are towed to shore three times in their lifetime, two for scheduled maintenance and once for unscheduled maintenance. Assuming there is one extra unscheduled maintenance needed, and the lifetime of the wave buoys is 20 years, the tow-to-shore frequency occurs once every five years.

Section 7.3 defines different offshore vessels that can be used for installation and maintenance. An Anchor Handling Tug (AHT) can be used in the wave conditions in Chile for small repairs on site or to tow the buoy back to shore for the replacement of essential parts.

CorPower buoys have a storm condition to decrease the risk of damage and failures during storms. This survival mode reduces loads and extends service intervals, while condition-based monitoring minimizes offshore interventions (marineenergy2021; Parwal, 2018).

7.5.3 Maintenance Strategy Wave Farm Concepción

The operational availability of the buoy array strongly depends on the operation and maintenance (O&M) strategy. For this study, the O&M approach is benchmarked against the 100 MW wave farm off the west coast of Ireland described by (Giorgi et al., 2022). In that reference case, the O&M logistics were optimised for a wave farm located 35 km from the service port, resulting in an availability of approximately 85%.

In the current concept, the wave farm near Concepción is located only 20 km from the port. Consequently, the mobilisation time of vessels, which accounts for roughly 40% of the total operational time per installation, will be significantly reduced. Assuming a proportional reduction

based on distance, the mobilisation time is scaled by

$$0.4 \cdot \frac{20}{35} = 0.23,$$

A key difference between the two cases is determined by the scale of the installation: the Concepción wave farm is expected to produce roughly five times more power and to include approximately six times as many buoys as the Irish reference farm. Following a linear scaling approach, the O&M resources are adjusted proportionally to the number of buoys and the reduced mobilisation effort.

Based on these assumptions, the resulting operational resources for the Concepción project are:

- Connection/disconnection time: 1 hour
- Number of vessels: 10
- Number of onshore maintenance teams: 10
- Number of WEC assembly teams: 14

It should be noted that this assessment represents a simplified estimation. The linear scaling of resources neglects non-linear effects such as dependencies between weather windows, fleet coordination, and delays. Therefore, these results should not be considered as a definitive O&M plan, but rather as a case study.

7.6 Construction Phases

There are three main construction phases of this wave farm: installation, operation, and decommissioning. In Figure 7.7, the construction phases are outlined in a block diagram. The States and transitions are explained in Table 7.2 (Giorgi et al., 2022).

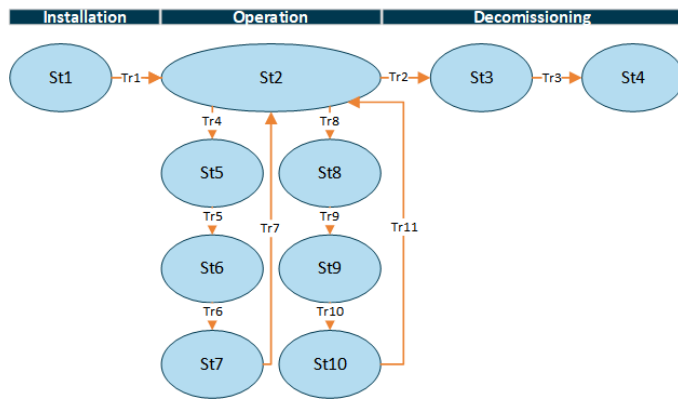


Figure 7.7: Construction phases wave farm (Giorgi et al., 2022)

Table 7.2: Overview of WEC states (Giorgi et al., 2022)

State	Description
St1	Ready for assembling & installation of Umack anchors and buoys (OCV)
St2	Operating
St3	Ready for decommissioning
St4	Decommissioning of Umack anchor and WEC (OCV)
St5	Ready for scheduled maintenance (no energy production)
St6	Device onshore (Port San Vicente) for scheduled maintenance
St7	Ready for reinstallation after scheduled maintenance
St8	Device failed (no energy production)
St9	Device onshore (Port San Vicente) for unscheduled maintenance
St10	Ready for reinstallation after unscheduled maintenance
Tr1	WEC assembly and towing from the Port of Vicente to the farm, followed by connection to mooring and electrical cables (OCV)
Tr2	WEC passes from operating state to ready for decommissioning
Tr3	WEC towed to Port of Vicente and dismissed (OCV)
Tr4	WEC passes from operating state to ready for scheduled maintenance
Tr5	WEC disconnected from mooring and electrical cables and towed to the port (AHT)
Tr6	WEC undergoes scheduled maintenance by an onshore maintenance team at Port San Vicente
Tr7	After scheduled maintenance, WEC is towed from Port Vicente to the offshore farm and connected to mooring and electrical cables (AHT)
Tr8	WEC passes from operative state to failed state
Tr9	WEC disconnected from the mooring and electrical cables and towed to Port San Vicente (AHT)
Tr10	WEC repaired by an onshore maintenance team at Port San Vicente (unscheduled maintenance)
Tr11	After unscheduled maintenance, WEC is towed from Port San Vicente to the offshore farm and connected to the mooring and electrical cables (AHT)

7.7 Use & Distribution of Electric Energy

During the operation phase, the wind and wave farm together have a capacity of 1470 MW. This energy can be consumed in part by the net. In addition, the surplus of energy from the farms can be stored in hydrogen. This section explains the use and distribution of the produced energy.

7.7.1 Energy Mix

This section evaluates the energy mix of Concepción by considering both existing generation sources and local demand profiles. The analysis consists of three parts:

1. Overview of national renewable generation characteristics
2. Assessment of the load profiles
3. Investigation of the potential integration of wave energy into the current system.

Current Energy Production Chile

Figure 7.8 presents the average daily renewable energy production for 2024, which accounts for approximately 71% of total electricity generation in Chile (see Figure 2.5). Solar power is one of the dominant sources, though its main limitation is the inability to produce electricity at night. Other renewable and non-renewable sources compensate for this deficit during the dark hours.

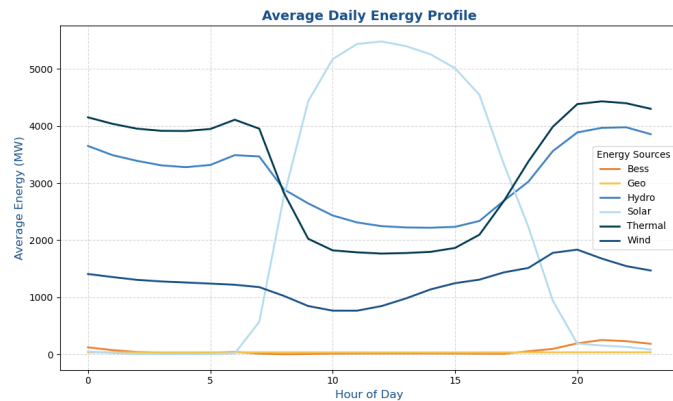


Figure 7.8: Average daily renewable energy production 2024, data from (Nacional, 2025)

Renewables in Concepción

To assess the integration of wave energy in the Concepción region, the production of existing renewable sources is evaluated. The three main renewable contributors are biomass (20 MW), solar (250 MW), and wind (480 MW) (Catapult, 2021). Figure 7.9 shows the daily variation in power generation from these sources. These profiles are obtained by scaling national production data according to the installed capacities within the Concepción region. For monthly average renewable energy production in Concepción, see Appendix O.

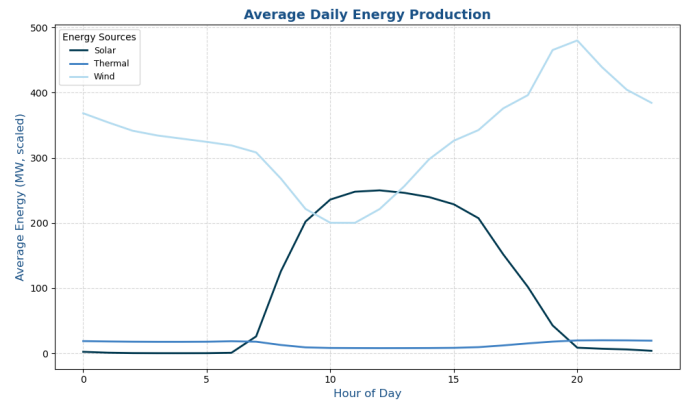


Figure 7.9: Average daily renewable energy production Concepción, data from (Nacional, 2025) scaled to Concepcion size

Load Profile Concepción

The regional load profile is estimated by scaling the energy consumption of the Biobío region to the population of Concepción. The resulting consumption curve, shown in Figure 7.10, provides the basis for assessing the balance between local production and demand.

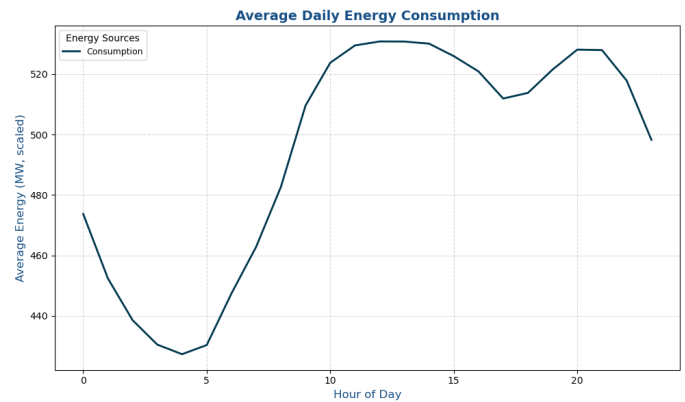


Figure 7.10: Average daily energy consumption Concepción 2024, data from (Nacional, 2025) scaled to Concepcion size

Wave Energy Integration

One of the main advantages of wave energy is its smooth and predictable power output, which allows for easy integration into the energy mix. Figure 7.11 compares total renewable energy generation (including the offshore floating wind farm) with and without the addition of wave energy. As shown, wave energy helps reduce relative fluctuations in total renewable generation. This effect is further supported by the monthly energy profiles in Appendix O, which show the consistently low variability of wave energy compared to other sources.

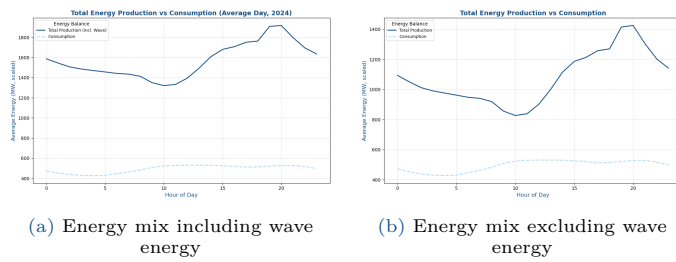


Figure 7.11: Comparison between total renewable energy production and consumption with and without wave energy inclusion.

7.7.2 Forecast Model

Efficient integration of wave energy requires accurate short-term power forecasting. A forecasting model was developed to predict wave energy production up to seven days in advance. The model automatically retrieves updated wave data daily, processes the relevant time series, and computes the corresponding power and energy yield.

The forecast results are visualized using data from the University of Valparaíso enabling continuous monitoring of energy output and early detection of anomalies or periods of reduced performance. See Appendix P for the forecast October 28 + 7 days. This provides valuable insights for both operational planning and maintenance scheduling. In particular, it allows operators to identify short weather windows suitable for installation or maintenance activities.

Hydrogen production, which requires a stable and continuous energy input, benefits strongly from accurate forecasting. The surplus energy from wave generation can be directed toward green hydrogen production whenever conditions are favorable. This predictive capability enables optimized activation of hydrogen electrolyzers, ensuring efficient use of renewable energy while maintaining grid stability and minimizing curtailment losses.

7.7.3 Energy Use

With the large and continuous energy surplus generated by the offshore wind-wave farm near Concepción, effective utilisation of this energy becomes essential. The potential applications can be divided into several categories:

- Local use
 - Ports and industrial zones
 - Desalination plants
 - Remote communities
 - Aquaculture or offshore data centres
- Energy storage and conversion
 - Hydrogen production (electrolysis)
 - Battery storage
 - Pumped hydro storage
 - Compressed air energy storage (CAES)
 - Thermal energy storage
- Grid connection
- Industrial applications

- Synthetic fuel production (methanol, ammonia)
- Carbon capture and utilisation (CCU)

At present, however, the constant energy surplus poses operational challenges. Storage systems such as batteries or pumped hydro rely on fluctuating (loading and consumption) supply and demand cycles due to limited transportation options, which are incompatible with the continuous nature of offshore energy generation. Exporting the energy onto the national grid is difficult due to congestion.

Industrial applications such as synthetic fuel production or carbon capture represent promising long-term options, but currently lack sufficient industrial capacity in the region to absorb the full energy output.

Given these constraints, hydrogen production emerges as the most effective and scalable utilisation pathway. Electrolysis offers a direct conversion route from renewable electricity to a storable and exportable energy carrier. Moreover, this aligns with Chile's national ambition to become a leading global exporter of green hydrogen, ensuring both political support and strategic relevance for such developments.

In total, approximately 25824 MWh of renewable energy could be channelled into hydrogen production per day, amounting to 453 tons of hydrogen per day (Hubert et al., 2024).

8 Challenges

At this moment, there is little interest in wave energy as outlined earlier in this report. This suggests that there are challenges that need to be overcome before wave energy can be a viable green energy source in Chile. Through a role-playing exercise as described in Chapter 3, these challenges were identified. In this chapter, these are explained, providing a clear base for the roadmap as presented in Chapter 9.

8.1 Social

The majority of challenges are social. A lot of different entities are hesitant, as little information on wave energy is known. This is signalled by the fact that Interviewee 15 (Personal Communication, October 22, 2025) said: "I would always start my projects by speaking to the local people".

8.1.1 Fisheries

Fishermen often perceive wave farms and offshore projects as a threat to their livelihoods. They are uncertain about the potential ecological impacts, anticipate restrictions within their fishing areas, and do not recognize direct benefits for their communities.

8.1.2 Indigenous Communities

Indigenous Communities are concerned with their heritage. An important factor in this heritage is its connection with nature. The communities are not familiar with wave farms, and have natural resistance to projects that possibly disturb nature or their activities.

8.1.3 Environmentalists

The impact of wave energy on marine ecology has not yet been accurately investigated, and knowledge of specific local ecosystems is limited. The main objection of environmentalists is that the impact should be known before damage is done.

8.2 Technical

The technical analysis encounters three main challenges. The first is the limited availability of geotechnical data, which is essential for the installation of the buoy anchors. The second challenge is the limited working time windows in Chile, making the installation process difficult to manage. The third challenge lies in the fact that the buoys are still in a pre-commercial stage of development, making it difficult to accurately assess their performance.

8.3 Economic

Multiple stakeholders are concerned with the high costs of wave energy projects, as these are not yet competitive with other green energy sources. Currently, the capital expenditure (CAPEX) costs are very high, as the technology is immature; financing costs are high due to uncer-

tainty; geotechnical research is very expensive, but necessary for design. The current local economic stance, focused on free-market economics, as outlined in Chapter 7, does not provide a perspective on economic support.

8.4 Political & Regulatory

Multiple hurdles are present in the political and regulatory aspects. Many of these are logical consequences of an immature technology.

8.4.1 Lack of Hydrogen & Wave Energy Focus

As seen in Chapter 5, the policy mix of renewable energies in Concepción is quite extensive, and policies on multiple levels support each other. However, this is not the case for Chile's green hydrogen ambitions as stated in Chapter 1. Furthermore, a focus on wave energy is currently completely absent.

8.4.2 Permitting Procedures and Zones

Currently, there is no specific wave energy permitting procedure, which results in long delays and uncertainty (Focus Group 1, Personal Communication, September 23, 2025) (Interviewee 15, Personal Communication, October 22, 2025). Besides, there are no specific zones designated for the deployment of offshore projects, making it more difficult to develop these offshore projects in Chile (Interviewee 13, Personal Communication, October 21, 2025).

8.4.3 Political Agendas

As outlined in Chapter 7, local politicians are elected on promises of security, stability, and control. As these politicians likely want to be re-elected, they cannot afford scandals and thus are hesitant to cooperate with risky projects. As wave energy is not a proven technology, they are reluctant to it.

9 Roadmap

In this chapter, the roadmap, consisting of four stages and 24 steps, will be presented, and important steps in the different stages will be described. These form a proposed guideline to realise the future vision. This future vision, as described in Chapter 7, is a wave farm that complements an offshore wind farm and generates green hydrogen, contributing to the Chilean government's hydrogen ambitions. To achieve this vision, the steps outlined in Figure 9.2 could be taken to overcome the challenges as described in Chapter 8.

The four main stages of the roadmap are: interest alignment, concept pilot development, co-creation, and deployment & integration. This chapter is structured accordingly, explaining specific steps in these stages. Due to this structure, these steps seem to follow each other chronologically, but this is not the case, as the proposed steps can be taken simultaneously as depicted in Figure 9.2. The main challenges that this approach is trying to overcome are: the high cost expectations, the inaccurate performance predictions, the knowledge gap on ecosystem impact and the complex social acceptance in Chile.

The existing power-interest gap, as seen in Chapter 2 should be bridged as a result of the first three stages of the roadmap. The power-interest grid is used to indicate which stakeholder movements are desirable. In the next paragraph, an explanation of these movements is provided.

9.1 Rebalancing Stakeholder Power & Interest

To enable further progress for wave energy development in Chile, shifts in both stakeholder power and interest are desirable. Figure 9.1 illustrates how the influence of high-interest but currently low-power actors such as universities, research institutes, and WEC developers could increase, while mobilising stronger engagement from central authorities like the Ministry of Energy and funding bodies. At the same time, energy companies might be encouraged to take an active role in early pilots rather than waiting for proven concepts. These shifts would bridge the existing power-interest gap, stimulate more balanced collaboration, and accelerate the translation of research into large-scale implementation.

9.2 Interest Alignment

The primary goal of the first stage is to establish a clear framework for designing the wave farm in Concepción. This framework should encompass technical details, but it should also create a clear vision of all stakeholders' interests. This way, impacting- and impacted stakeholders are engaged early on in the process, and their interests are directly incorporated into the process as a set of boundary conditions.

9.2.1 Shaping Green Hydrogen Incentives

As seen in Chapter 8, the hydrogen ambitions aren't sufficiently supported. Creating a clear regulatory context for hydrogen could lead to additional support and clear incentives to invest in green hydrogen.

9.2.2 Monitor Semi-Technical Prerequisites

Before the development of a specific wave farm as a complement to offshore wind in Concepción, global advancements in wave energy technology should be made. Before production, more accurate predictions for WEC performance should be available.

9.2.3 Preliminary Stakeholder Involvement & Explanatory Dialogues

To create a clear framework for designing the wave farm, all stakeholders, including actors like the government and acted upon (positively and negatively), will be invited to dialogue sessions. In these sessions, the future perspective and project process will be explained, and stakeholders are asked to consider the potential benefits a wave farm could bring to themselves or the broader stakeholder environment. Apart from the design framework, this could lead to active involvement and a first sense of co-ownership among stakeholders. Overall, this could result in a wave farm with better overall performance and less social friction.

9.2.4 Setting Up Wave Energy Permitting Procedures

To smooth the process of permits for wave farms, it would help to set up guidelines specific to wave energy. This process takes place simultaneously with the preliminary stakeholder involvement step, so that information from different stakeholders can be used when starting the permitting procedures.

9.3 Concept Pilot Development

In the second of the four stages, a pilot concept will be developed by the project team, and partnerships will be established. The stage is completed when a preliminary design is formed, which includes all findings of the interest alignment stage. This design will serve as the starting point of the co-creation stage.

9.3.1 Concession Procedures for Pilot

After the permitting procedures have been set up in the interest alignment phase, permits for the pilot should be applied for.

9.3.2 Outlining Informative Platform

Before the co-creation stage, an outline of an informative platform should be made, based on the information from the stakeholder dialogues. The platform aims to add value for the local community, fishermen, and all other social stakeholders. The platform will be improved further in the

next stage, so this outline functions as a starting point. An example of information that could be provided through this platform is the oxygen level in the sea, which is useful for fishermen (Interviewee 2, Personal Communication, September 2025).

9.3.3 Concept Pilot Creation

In the same way as the informative platform, a first pilot should be created to serve as a starting point. This design combines the information on the technical prerequisites and the dialogues, and aims to test any knowledge gaps, such as on the impact of wave farms on marine ecosystems. In addition, pilots reduce social challenges in the future implementation of wave farms.

9.3.4 Geotechnical Analysis

Seabed conditions are an important factor for the rest of the roadmap, as they influence the design, costs, and impact of a wave farm. After the choice of an offshore wind project, a geotechnical analysis should be carried out in co-operation with the wind project. This will result in boundary conditions that need to be taken into account in the further design of the farm.

9.3.5 Building Trust & Legitimacy

Bringing down the costs of the project can be done by decreasing the risk perception of financial institutions. To do so, trust and legitimacy should be built. This can be done by partnering up with trustworthy companies that already have a track record; the offshore wind developer could serve as a first partnership. Other ways could be by getting relevant certificates, prices, or quality marks.

9.3.6 Monitoring Ecosystems

As specific information on marine ecosystems in Concepción is lacking, ecosystems at and around the chosen site should be monitored and researched in greater detail. The gathered information should be communicated transparently to the whole stakeholder community, preventing misunderstandings and enlarging the trust of environmentalists and others.

9.3.7 Preliminary Life Cycle Analysis

A life cycle analysis is a way of assessing the impact of the whole lifetime of a product. A start of this analysis can be made as soon as the first idea on the concept draft is present. An LCA is an important part of a new product, and thus is often asked for by investors or regulators. Early efforts into it can prevent later delays.

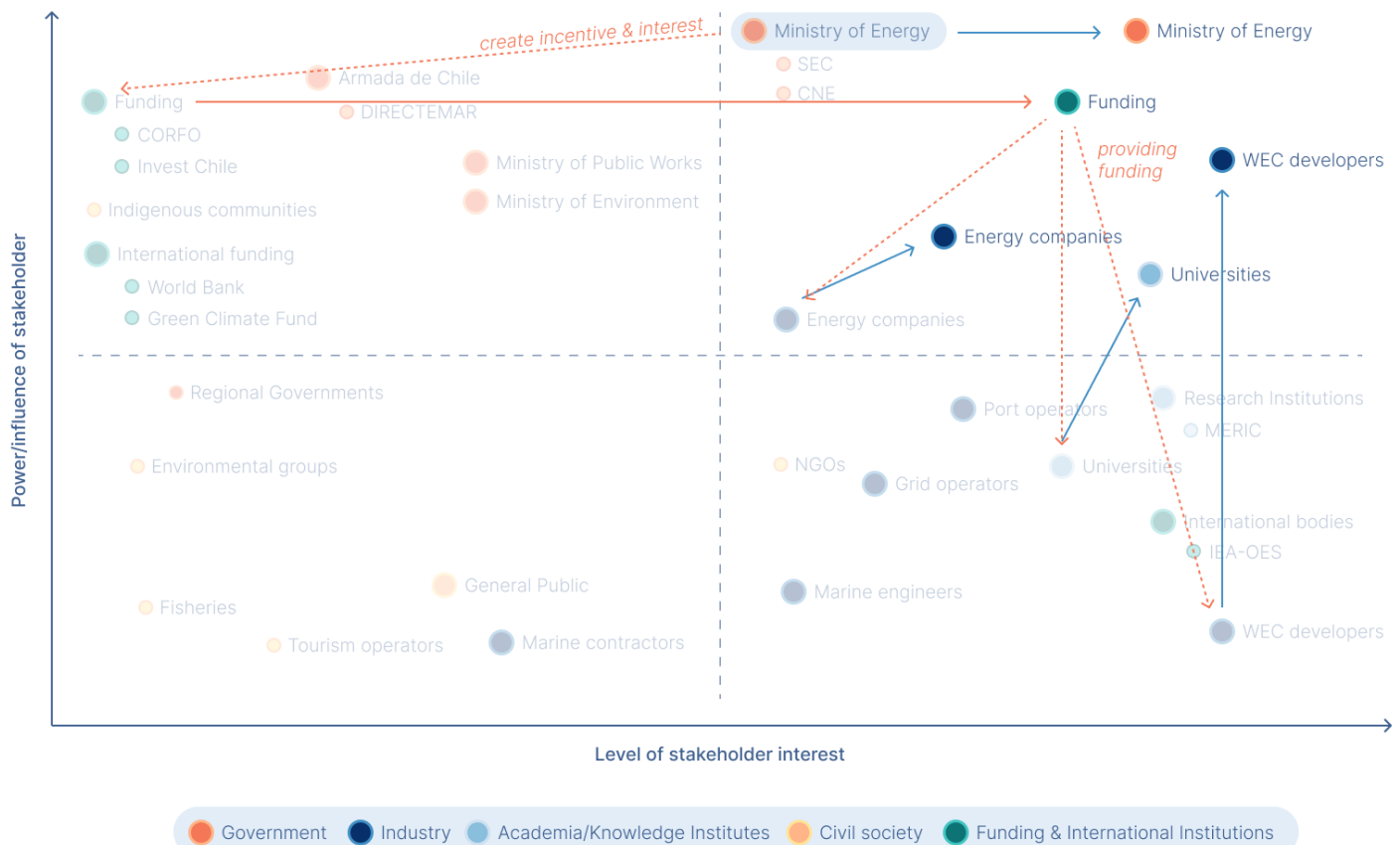


Figure 9.1: Desired shifts in stakeholder power and interest to enable wave energy progress in Chile

9.4 Co-Creation

The co-creation stage is the main stage of the proposed roadmap. In this stage, the wave farm design progresses from a first pilot to the final design, the costs should be cut to a competitive level, and as much stakeholders' demands as reasonably possible should be met. To achieve this, many stakeholders will collaborate in an iterative process. If demands contradict each other, a decision is made based on the power of the stakeholders in conflict, and the size of the impact of the decision on the stakeholders.

9.4.1 Co-creation Workshops

The backbone of the co-creation stage is formed by co-creation workshops. Through workshops with stakeholders, new knowledge can be shared, problems can be addressed, and new pilots should be developed until a final design emerges. This design includes the practical design of the wave farm, but also encompasses the information platform and agreements with stakeholders.

Apart from leading to the final design, it engages stakeholders, and it offers a broad variety of opportunities to gradually take away stakeholders' challenges, by showcasing results and creating co-ownership.

9.4.2 Concession Procedures for Large Scale Wind-Wave Farm

For all new pilots, permits should be renewed or extended. As the pilot is developing to the final design, the permits will be developing along with them. By doing so, the final permits will be applied for by the end of the co-creation phase.

9.4.3 Information Platform Fully Implemented into Society

During the co-creation workshops, the information platform should constantly be developed to better meet the stakeholders' needs. As the stakeholders are actively involved in this process, they will familiarise themselves more and more with the platform during this phase, and it will be auto-implemented in a natural way.

9.4.4 Ecological Impact Assessment

An important pain point for multiple stakeholders is the knowledge gap on the ecological impact, as highlighted in Chapter 8. As a part of the pilots, this impact can and should be assessed and measured, as suggested by Interviewee 8 (Personal Communication, September 26, 2025). The acquired knowledge can immediately be used in the co-creation workshops.

9.4.5 Life Cycle Analysis

During the development of the wave farm design, the LCA should be updated to avoid delays later on in the process.

9.4.6 Concept Proving

The constantly developing pilots provide a clear opportunity to prove the concept of wave energy, and the concept of a wind-wave farm. By actively showcasing advancements and proof, the perceived risk of the project can be brought

down step by step. This can be used to affect the financing costs, but also the attitude of local politicians, which is important to overcome both economic and political challenges as seen in Chapter 8.

9.4.7 Technical Design Iterations

During the pilot phase, technical advancements should be made to lower the CAPEX costs and to overcome technical hurdles. As technical changes could have an influence on the overall design, these changes should be taken into account in the co-creation workshops.

9.4.8 Setting Up Specialised Education Programs

To operate and maintain the wave energy buoys, specialised personnel should be trained. To train these people, specialised education programs should be set up. These programs can be integrated with the current national energy education programs, as described in Chapter 2.

9.5 Deployment & Integration

The last stage of the roadmap is the deployment & integration stage. During this stage, the full-scale wind-wave farm is installed and operated. Concepción is provided with green energy, green hydrogen is produced, and stakeholders are enjoying additional benefits.

9.5.1 Securing Collaboration Networks & Co-creation Frameworks

In Chile, collaboration networks aren't common (Interviewee 10, Personal Communication, October 2-3, 2025) (Interviewee 11, Personal Communication, October 9, 2025) (Interviewee 12, Personal Communication, October 18, 2025). The co-creation workshops do provide such a network, and local experience. This network should be secured, and experiences should be documented as it can be useful for other projects.

9.5.2 Manufacturing & Acquisition

Before the wind-wave farm can be installed, all materials should be gathered through acquisition or manufacturing.

9.5.3 Setting Up the Logistical Plan

Whilst all materials are gathered, a logistical plan for installation should be set up together with a port and contractors.

9.5.4 Installation, Operation & Maintenance

The last steps before reaching the future vision are the installation of the wind-wave farm, and the operation & maintenance.

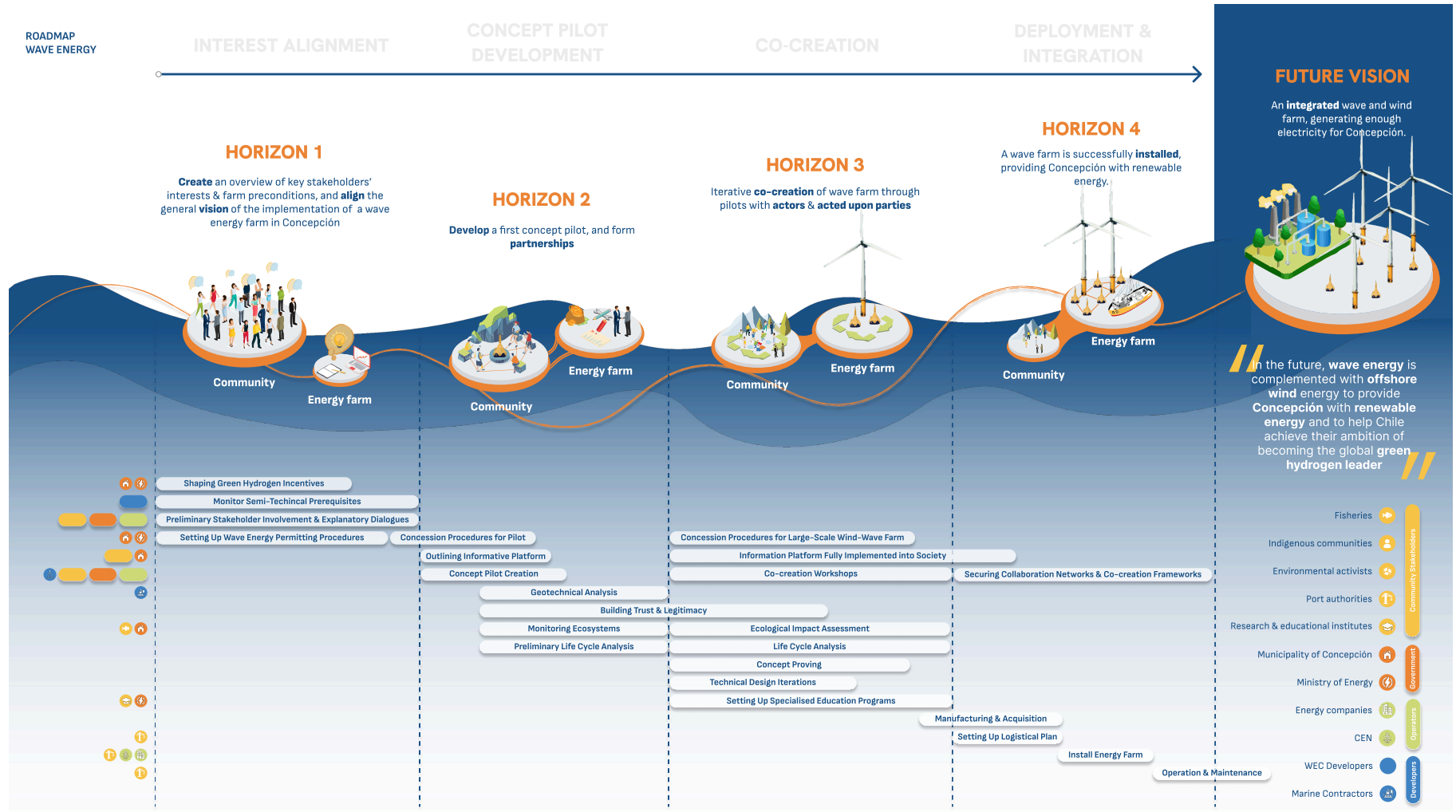


Figure 9.2: Proposed Roadmap Wave Energy Concepción

10 Conclusion

In this research, the potential for implementing wave energy converters (WECs) along the Chilean coast has been assessed from five perspectives: social, environmental, technological, economic, and political. A multi-criteria analysis is then conducted to evaluate these aspects, followed by the selection and conceptual integration of a specific site and wave energy converter into Chile's energy landscape.

From a social perspective, Chile generally shows openness towards new technologies and a strong drive for renewable energy, particularly due to its ambition to export green hydrogen. However, moving from north to south, the level of social acceptance decreases because of lower industrialisation and the stronger presence of indigenous communities, where cultural and environmental sensitivities are higher.

The environmental assessment focused on marine biodiversity and the characterisation of marine areas and zones. The highest concentrations of marine species were identified in the Valparaíso region, while a marine protected area is located just north of La Serena. For the deployment of wave energy in Chile, appropriate mitigation measures must be implemented, along with monitoring of existing ecosystems. This is particularly important given the current limitations in available ecological data for the area.

From a technical perspective, the southern Chilean coastline exhibits high potential for wave energy due to increased capacity factors. Existing port infrastructure can support installation operations, though limited workability presents logistical challenges. The scarcity of geotechnical data further complicates installation planning. While survivability was not quantitatively calculated, comparative analysis of mean and max wave heights and periods indicates that southern locations face harsher environmental conditions, requiring more robust structural designs.

The economic evaluation reveals that wave energy remains a relatively expensive technology, approximately three times more costly than solar photovoltaic systems. Consequently, its viability depends on complementary advantages such as energy diversification, improved grid stability, and synergy with hydrogen production.

The political context in Chile generally supports renewable energy through established national strategies and a growing focus on hydrogen production. However, wave energy has not yet been explicitly incorporated into national policy frameworks, which presents an implementation challenge. The main opportunity for WEC deployment lies in linking wave energy with green hydrogen production, aligning with Chile's long-term decarbonization ambitions.

The multi-criteria analysis, which compared three WEC types (CETO, CorPower, and OE Buoy) across five locations (Mejillones, La Serena, Valparaíso, Concepción, and Valdivia), identified Concepción as the preferred site. This location offers strong energy performance and relatively favourable social acceptance. However, the region's high biodiversity and indigenous community presence require careful stakeholder engagement and environmental management.

In the design and integration stage, an implementation plan was developed for Concepción. Installation and maintenance activities were scheduled considering Chile's limited workability, with October identified as the optimal installation window for wave energy installation. The general timeline includes a site investigation in June, anchor installation in October, buoy deployment in December using tug assistance, and subsequent cable installation. Maintenance should be focussed in December. Integration into the national grid would enhance energy stability by reducing intermittency, while hydrogen production represents the most strategic application for the surplus power.

Finally, the roadmap outlines a possible path from concept to realisation: aligning stakeholder interests, conducting pilot testing, and progressing toward full-scale development. Although immediate large-scale deployment is unlikely due to limited governmental support and unfavourable economics, there is long-term potential. Chile's strong wave climate, renewable energy ambitions, and hydrogen strategy create favourable conditions for future wave energy adoption once costs decline and policy support increases.

Recapitulating, the answer to the question: 'What is a preferred combination of a location and wave energy converter, and how could that be integrated into the energy system of Chile?' is, that the CorPower & Concepción combination is preferred; that it can be best integrated in combination with a wind farm and that the surplus energy is best used for the production of green hydrogen, but that a lot of steps need to be taken to get to that future vision.

11 Discussion

In this chapter, the results, as presented in Chapter 10 will be discussed. Firstly, the results will be interpreted. Secondly, the implication of these results will be explained. Thirdly, limitations of the research will be discussed, after which recommendations for further research are stated.

11.1 Interpretation & Implication of Results

The results of this study suggest that there is potential for wave energy along the Chilean coastline, especially near Concepción, where favourable wave conditions and existing infrastructure could support future developments. Combining wave energy with offshore wind could help reduce fluctuations in energy production and provide a more stable renewable energy mix, and an energy source for green hydrogen. Although large-scale implementation still faces technical, economic, and policy challenges, this research aims to showcase the potential of wave energy and rekindle the faded debate. Highlighting opportunities for further research.

11.2 Limitations of Results

In this section, the limitations of our results are discussed, structured by the main report phases.

11.2.1 Social Analysis

Reflecting on the social analysis, several limitations can be identified. The first concerns the number of stakeholders interviewed and the stage at which these interviews were conducted. Engaging stakeholders early in the project is highly recommended, as establishing contact and arranging interviews typically requires more time than anticipated. In future studies, expanding the number of engaged stakeholders, particularly those located near the site of interest, would provide a more comprehensive understanding of local perspectives and concerns.

A second limitation is in the structure and consistency of the interviews. Since not all interviews followed the same format, it was sometimes challenging to compare the responses. A more standardised interview structure would improve the reliability of the analysis and allow for better interpretation of different viewpoints.

Despite these challenges, the focus group, co-creative session held at the University of Valdivia proved to be particularly valuable. It provided a platform for open dialogue and collective reflection, demonstrating the potential of co-creation as a tool. Implementing similar sessions at the selected project location could greatly enhance stakeholder alignment and create a sense of shared ownership over the development process.

11.2.2 Environmental Analysis

Reflecting on the environmental analysis, one of the main challenges encountered was the limited availability of data for the marine environment of Chile. This lack of information meant that several ecological aspects could not be fully assessed. In this study, potential sites were ranked based on the overall concentration of species rather than the specific species in that region, and the actual impact. As a result, the varying impacts of a wave energy installation on different species groups, such as marine mammals, compared to microfauna, were not explicitly accounted for. Clearly, different mooring systems and buoys impact different species, and this should be incorporated in future assessments.

Another shortcoming relates to the uneven distribution of environmental sampling across the studied areas. For instance, roughly twenty times more measurements were taken near Concepción than in the Valdivia area. Such inconsistencies can bias the comparative analysis and limit the reliability of conclusions about relative environmental suitability between locations.

Finally, particular attention should be given to the migration patterns of marine mammals to ensure that these are not disrupted by the presence of offshore wind or wave energy farms. Long-term ecological monitoring and collaboration with local environmental organisations would be valuable to safeguard biodiversity while advancing offshore renewable energy in Chile.

11.2.3 Political & Regulatory

In the political & regulatory analysis, the assumption that limited progress on regional & municipal green energy regulations corresponds to reduced activity may not be correct and could have influenced the results.

Additionally, the analysis does not account for the way that policies and regulations are enforced, due to time constraints. However, the enforcement or lack of enforcement of regulations can drastically alter the practical situation. For future research, it is recommended to take time to investigate how regulations and policies are applied in practice, as this could substantially influence the outcomes of the political & regulatory assessment.

11.2.4 Technical Analysis

To reflect on the data extraction and processing, some aspects could have been determined more accurately. The multi-criteria analysis (MCA) relied on data from 1979–2015 due to time constraints; future research should include more recent data as applied in the following chapters.

During the MCA, mean and maximum wave heights were

used to estimate buoy fatigue and ultimate strength. A proper fatigue life assessment and ultimate limit state analysis should instead be performed. In this study, buoy survival was assumed, and detailed calculations are expected to be performed by CorPower.

Reflecting on the capacity factors calculated in Section 5, it should be noted, as discussed earlier in Section 3.4, that the availability of the devices was not considered. Furthermore, the capacity factors estimated for CorPower appear unrealistically high compared to values reported in the literature. This discrepancy can be explained by favourable wave conditions for the site, as well as the early development stage of the devices. Most of the technologies are still undergoing validation, and their reported performance metrics have not yet been consistently verified through full-scale field data. Consequently, the presented results should be interpreted with caution.

Another important limitation concerns the data set used to determine the capacity factors. The wave data employed were not obtained from direct measurements at the site, nor from a high-resolution numerical model specifically calibrated for the exact location. Instead, the values are derived from a regional numerical model, providing estimates of wave height and period in offshore conditions. For a better assessment, it is strongly recommended that, in a potential follow-up phase of this project, in situ wave measurements can be conducted for at least one year. This would allow for a comparison between measured and modelled data, thereby improving the reliability of the performance estimates.

Due to a lack of data, the data used to show the workability of offshore installation vessels dates from 2012, which is too old to produce accurate results for the time windows of the workability of the vessels. In reality, the working windows for installation vessels are higher due to technical development.

11.2.5 Multi-Criteria Analysis

Several aspects of the Multi-criteria Analysis (MCA) require critical reflection. The first concerns the selection of criteria. These were initially proposed by a group of students and then refined through expert review. However, they do not capture the complete scope of relevant factors. Certain criteria could be subdivided into more specific sub-criteria to improve accuracy, but due to time constraints, this was not done. Future studies should therefore re-evaluate and possibly expand the current set of criteria to ensure a better assessment.

The second point relates to the way in which scores were assigned. The scoring of criteria was based on the information available at the time of analysis. Since then, new insights have emerged that would influence several scores. For example, it is now known that the wave farm is

located approximately 20 kilometres offshore, meaning the buoys will barely be visible from land. Similarly, distances to ports and grid connections were scored equally due to the lack of precise site coordinates. In future work, these aspects should be re-examined by establishing an exact project location and defining measurable indicators for each criterion, thereby improving the objectivity and reliability of the MCA results.

The skewed MCA analysis indicates that the CorPower & Concepción combination performs best across all but one perspective. Only within the social perspective the CorPower & Valparaíso combination score slightly higher by 0.03 points.

11.2.6 Design & Integration

The proposed design and integration of a wave farm is based on a lot of assumptions. It is important to note the following:

- The proposed installation, operation, and maintenance procedures represent a possible approach, but they are highly dependent on the specific site conditions. The situation in the report represents a simplified estimation; the linear scaling of resources neglects non-linear effects such as dependencies between weather windows, fleet coordination, and potential delays. Therefore, the presented results should not be interpreted as a definitive O&M plan, but rather as an illustrative case study.
- Reduced energy output caused by nearby wind turbines or other buoys within the array has not been considered in the calculation of annual yield.
- A hypothetical soil profile was adopted for the geotechnical assessment; the proposed anchoring design relies on this. For a valid anchoring design, extensive soil investigations should be performed at the proposed location.

11.2.7 Roadmap

The stages and steps of the roadmap are based on challenges that were determined through a role-play exercise with the research team as role-players. As the research team isn't completely familiar with the Chilean culture, values and beliefs, this role-play exercise isn't a perfect representation of the actual situation. Subtle factors influencing the perception or opinion of people may have not come forward, leading to inaccurate estimations of the importance of challenges, or even inaccurate challenges themselves.

11.3 Recommendations for Further Research

Future studies on wave energy development in Chile should focus on validating and extending the findings of this initial exploration through detailed, site-specific analyses. Emphasis should be placed on areas with high wave energy potential to better assess technical, economic, and environmental feasibility.

A more structured stakeholder engagement process is recommended to clarify where challenges arise among government institutions, private developers, and local communities. Systematic interviews and co-creation sessions can help align interests and identify pathways for collaboration.

The environmental assessment should be expanded to include a thorough evaluation of ecological impacts, such as species interactions, megafauna migration routes, and the effects on local fisheries, which form an integral part of Chile's coastal social fabric.

Improved data collection along the Chilean coastline—covering wave climate, seabed characteristics, and nearshore processes is essential to refine resource and feasibility analyses.

Finally, stronger collaboration between universities, industry, and governmental bodies is needed to integrate wave energy into national renewable energy strategies. Such partnerships can support the development of a realistic roadmap for future implementation of wave energy in Chile.

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A Interviews

Table A.1: Overview of Stakeholder Engagement via Interviews and/or Personal Conversations

ID	Stakeholder	Description	Date
Interviewee 1	Professor	Professor and Chief of Career at the Faculty of Ocean Engineering, University of Valparaíso	Sept–Oct 2025
Interviewee 2	Academia / Consultant	Member of the Ocean Engineering Group at the University of Valparaíso. Research focuses on ocean, coastal, port and environmental engineering problems, emphasizing coastal hazards and climate-driven impacts.	Sept–Oct 2025
Focus Group 1	Research Group	Conducting research at the Ocean Engineering Faculty, University of Valparaíso	Sept–Oct 2025
Interviewee 3	Employees at HINCIO	HINCIO is a technical and strategic consulting firm in Chile. Provided access to the optimisation and simulation software AN-DREA.	11 Sept 2025
Interviewee 4	Professor	Professor at TU Delft with expertise in anchoring systems, among others	15 Sept 2025
Interviewee 5	Expert	Expert in marine renewable energy at TU Delft	22 Sept 2025
Interviewee 6	Expert	Expert in offshore geotechnical engineering at TU Delft	23 Sept 2025
Interviewee 7	Electrical Engineer at CEN	CEN coordinates national electricity system operations, ensuring reliability, cost efficiency, and open access to transmission systems.	24 Sept 2025
Interviewee 8	IEA–OES Employee	The International Energy Association – Ocean Energy. Facilitates intergovernmental collaboration and knowledge exchange on ocean energy.	26 Sept 2025
Interviewee 9	Professor	Geotechnical engineering professor at Universidad de Chile	26 Sept & 23 Oct 2025
Interviewee 10	Professor / Researcher	Professor and researcher at Universidad Austral	2–3 Oct 2025
Focus Group 2	Student Group	Group of 15 students at Universidad Austral taking an elective course in ocean engineering	2 Oct 2025
Interviewee 11	Ambassador	Dutch ambassador in Chile focused on renewable energy development	9 Oct 2025
Interviewee 12	Port Authority of Valparaíso	Responsible for administration, operation, and maintenance of the port and terminals of Valparaíso	18 Oct 2025
Interviewee 13	Aquatera Employee	Provides environmental expertise and operational support for offshore, coastal, and land-based activities	21 Oct 2025
Interviewee 14	MERIC Employee	MERIC aims to make Chile a global benchmark for marine energy by promoting its sustainable development	21 Oct 2025
Interviewee 15	Professor at Universidad del Bío-Bío	Leads multidisciplinary research on wave energy conversion, combining modelling, validation, and innovative offshore renewable energy technologies.	22 Oct 2025

二



Figure B.1: Stakeholder Map

C Wave Energy Converters

Numerous wave energy technologies are (conceptually) available. They can be broadly categorised into four main types: (Tampier et al., 2021):

- Floating structures with mooring, which rely on anchors and buoyancy to remain stable in open water
- Floating structures with fixed bottom, where the system combines buoyant structures with fixed anchors at the seabed for stability
- Bottom-fixed structures, which are anchored directly to the seabed, providing stability for wave energy conversion
- Systems fixed to other structures, typically along the coastline, that harness wave energy through their integration with existing infrastructure

Available technologies within each category are briefly explained below.

1. Floating Structures with Mooring

- Attenuator: Attenuators can take different forms. One type uses hinged floats connected by joints that rotate with wave motion, driving a power take-off (PTO) system, typically hydraulic cylinders, to generate electricity or pressurise water for desalination (Zheng, 2022). Another type, known as the “bulge wave” device, consists of a submerged flexible tube filled with water; wave action creates pressure waves inside the tube that drive a turbine or, alternatively, a distributed PTO system along its length, offering advantages in power capture and survivability. These concepts are illustrated in Figure C.1.

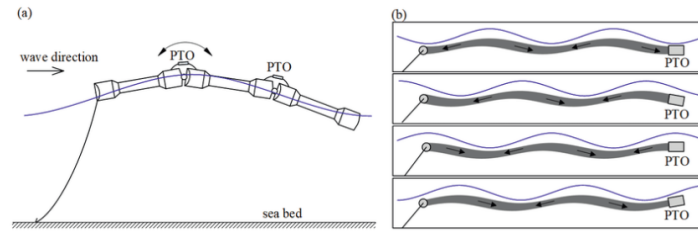


Figure C.1: Working principles of attenuator devices: (a) hinged-float-based and (b) flexible-tube-based.

- Moored point absorber: Consists of a floating buoy connected to a submerged spar via a mooring system, see Figure C.2. As waves pass, the buoy moves vertically, driving a mechanical system that converts the motion into electrical power. The generated electricity is stored in onboard batteries and transmitted to shore via a submerged cable. This technology has been tested in various locations, including Chile, and is designed to provide power for offshore platforms, environmental monitoring, and remote applications (de Chile, 2021).

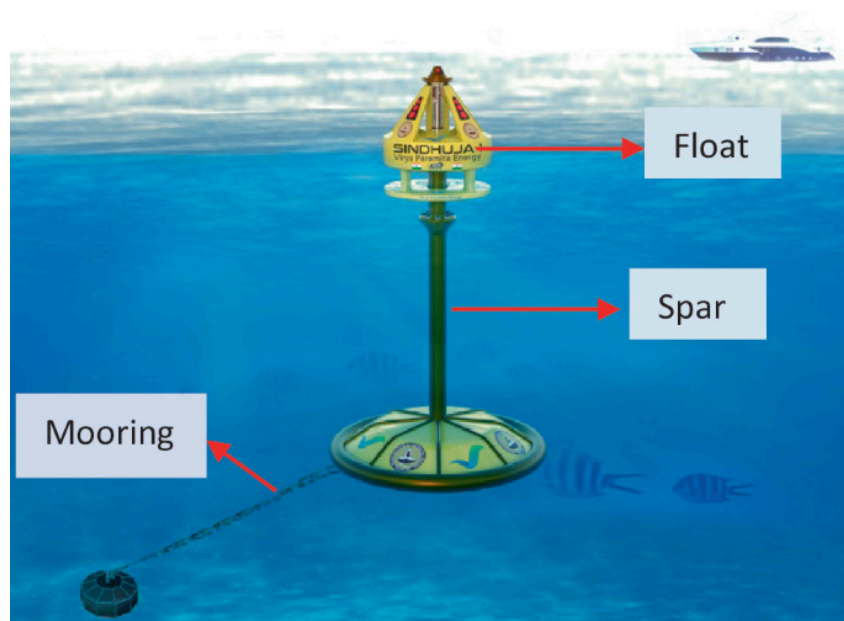


Figure C.2: Moored Point Absorber

- Rotating mass: As the structure moves in response to ocean waves, an internal mass rotates. This rotational motion is then used to drive a generator, converting the mechanical energy from the motion of the waves into electrical power, see Figure C.3.

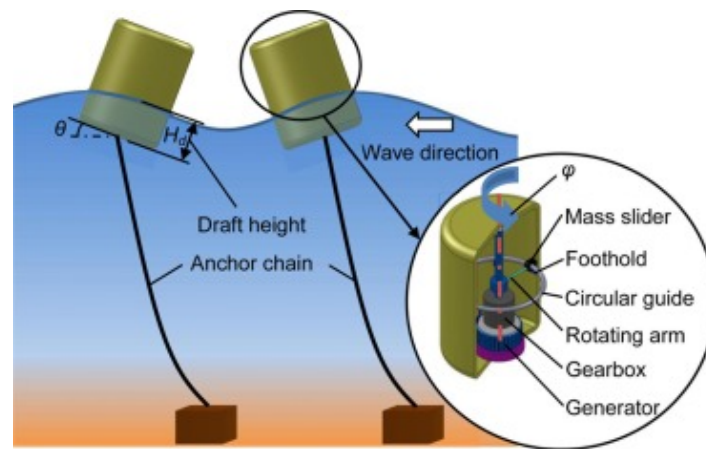


Figure C.3: Rotating mass working principle

- Oscillating water column: The oscillating water column (OWC) works by capturing the oscillation of water within a chamber, where the rise and fall of the water column create fluctuations in air pressure. As the water level rises, it forces air out of the chamber, and as it falls, it forces air in. This movement drives a turbine connected to a generator, producing electricity. This technology has been tested and validated by organisations like DNV, demonstrating its potential as a reliable renewable energy source from wave motion. The working principle is seen in Figure C.4.

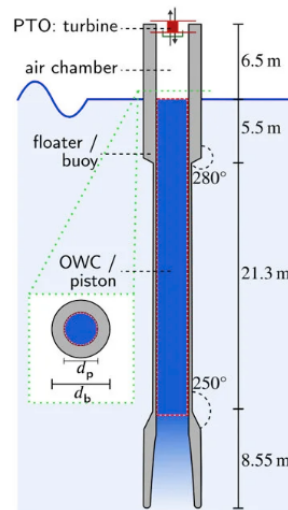
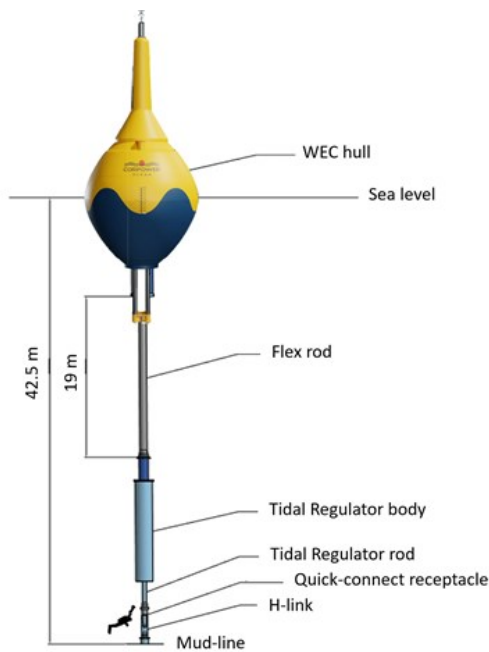


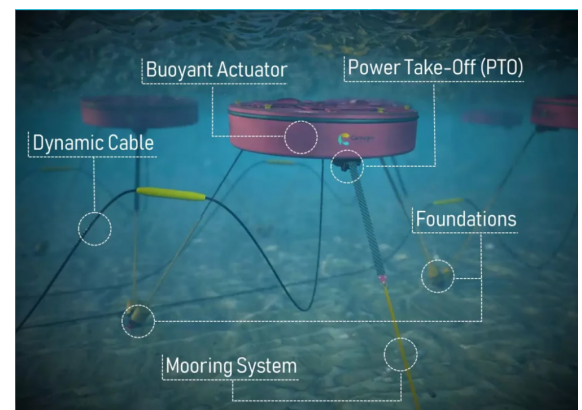
Figure C.4: Oceantec OWC

2. Floating Structures with Fixed Bottom

- CorPower Ocean's WEC: This WEC is based on a resonant system that amplifies wave motion, optimising energy capture by synchronising the device's natural frequency with incoming wave patterns. This approach allows for higher efficiency in converting wave energy into electricity. See Figure C.5.
- Carnegie Clean Energy's CETO system: A WEC that utilises submerged buoys that move with the waves, driving hydraulic pumps to generate electricity, see Figure C.5. The system operates entirely below the water's surface, making it less susceptible to weather conditions and offering a reliable energy source for offshore applications. Both concepts aim to convert wave energy into renewable electricity efficiently.



(a) CorPower wave energy converter



(b) Carnegie clean energy CETO system

Figure C.5: Wave Energy Converter Concepts

3. Bottom-fixed Structures

- **Surge converter:** This WEC captures energy from waves through a rigid vertical body hinged at the bottom. This design allows the structure to move in response to wave motion, with the vertical body rocking back and forth as waves pass. This motion is typically transmitted to hydraulic pumps or other power generation systems, which convert it into electricity. The Wave Roller is designed to operate in relatively shallow waters. This is illustrated in Figure C.6.



Figure C.6: Surge converter

4. Systems Fixed to Other Structures

- **Oscillating Water Column:** As illustrated in C.7, this WEC captures energy from the rise and fall of the water column within a chamber. Unlike traditional offshore installations, this version is typically used in onshore installations, where the system is integrated into a coastal structure.

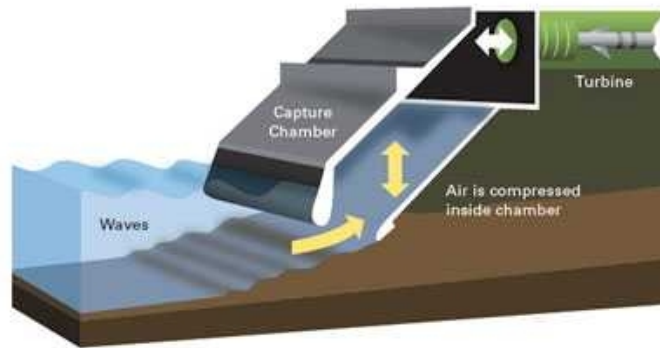


Figure C.7: Oscillating Water Column

- **Point Absorber:** This is a floating device attached to a fixed structure, such as a pier or platform. The buoy moves up and down with the motion of the waves, and this relative motion against the fixed structure is converted into electrical energy, see Figure C.8.

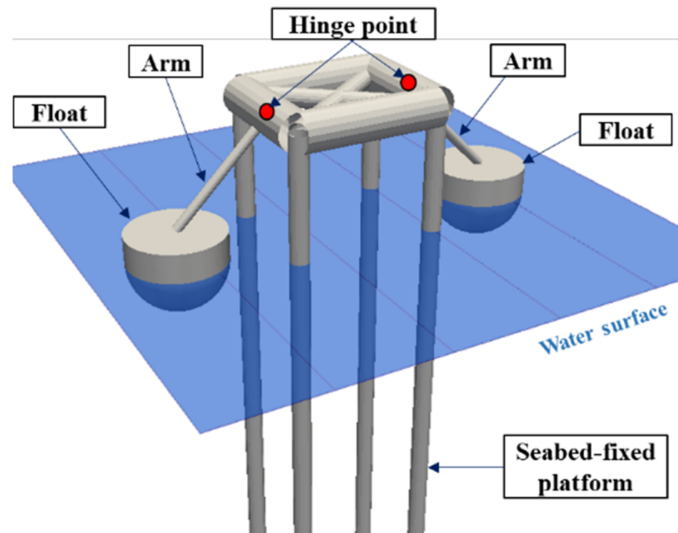


Figure C.8: Wave Star WEC (Point absorber attached to a structure)

- Overtopping Device: The WEC, illustrated in Figure C.9, captures wave energy by using the incoming waves to fill a basin. Once filled, the water is allowed to flow back to a lower point, typically through a turbine, converting the potential energy into electrical energy.

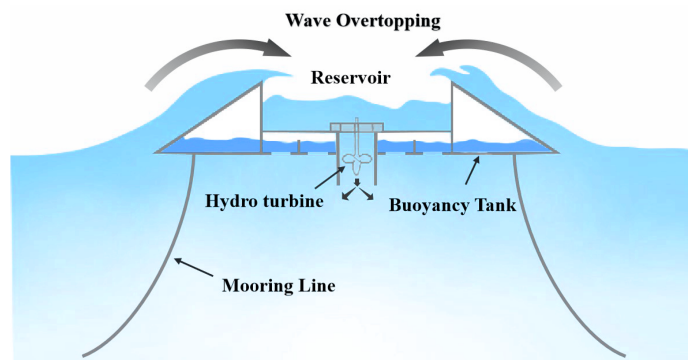


Figure C.9: Overtopping Device

In conclusion, wave energy technologies vary widely, each with distinct strengths and limitations. Later in this report, the most suitable option for Chile and its potential applications will be analysed in detail.

Device	Rated Power [kW]	Category
CorPower	400	Point absorber
AquaBuOY	250	Point absorber
Advanced Archimedes Waveswing (AWS)	2470	Point absorber
Carnegie Clean Energy Techno- logy (CETO)	260	Surge
Ocean Energy Buoy	2880	Oscillating water collom
Langlee	1665	Surge
Oyster 2	3332	Surge
Pelamis	750	Attenuators
Wavebob	1000	Point absorber
Seabasedab	15	Point absorber
SSG	20000	Overtopping
Wavedragon	7000	Overtopping
Wavestar	600	Arms

Table C.1: Overview of selected Wave Energy Converters (WECs).

D Energygrid

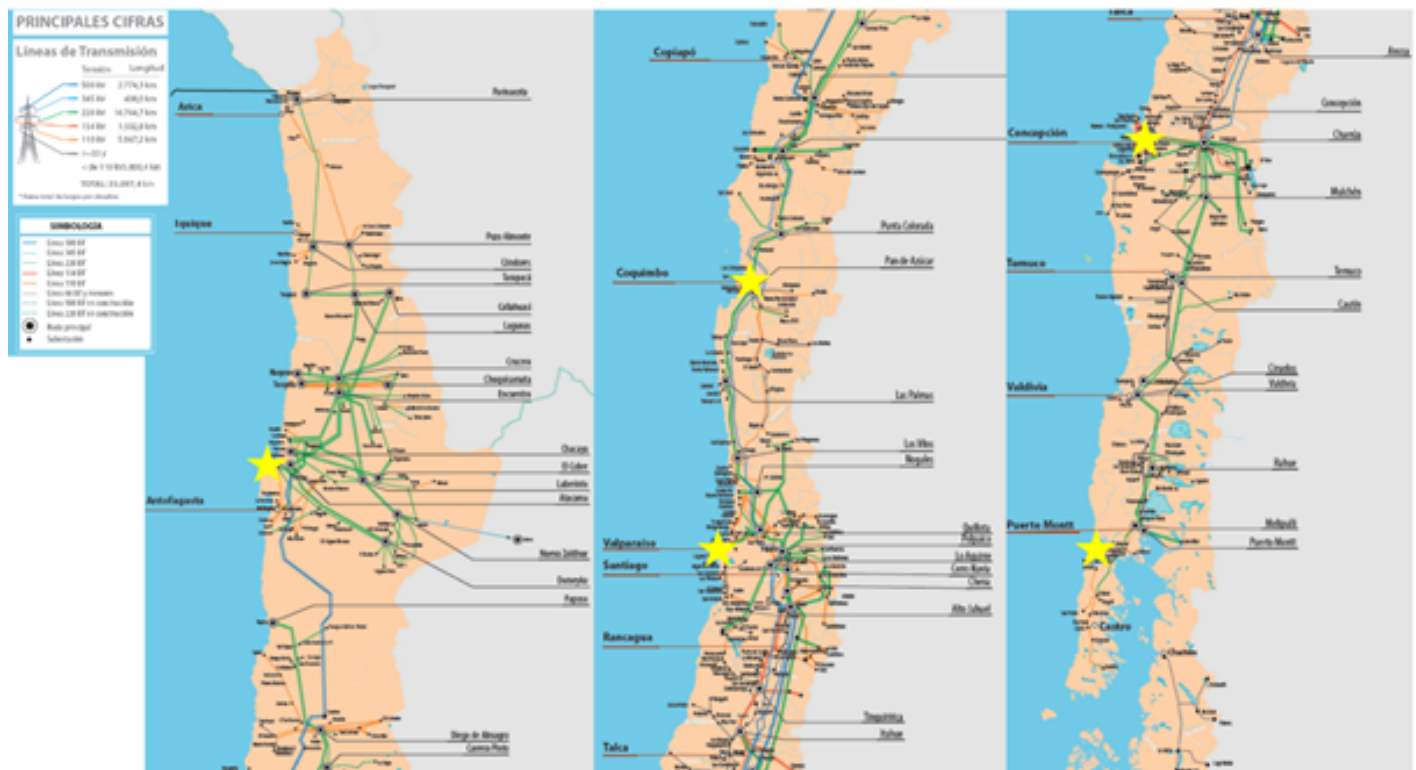


Figure D.1: Chile’s energy grid with chosen locations as yellow stars.

E Capacity Factors Summary Tables

Table E.1: Performance values of different wave energy technologies across Chilean locations.

Technology	TRL	Mejillones	La Serena	Valparaíso	Concepción	Valdivia	Total
Corpower	7–8	56	57	73	66	79	66
Aquabuooy	6	16	16	22	21	29	21
AWS	7	13	14	20	17	23	17
CETO	7–8	12	17	39	29	45	28
OE Buoy	7	22	23	35	26	35	28
Pelamis	6	4	4	7	8	11	7
Seabased AB	7–8	15	19	40	33	49	31
SSG	6	10	11	15	17	24	15
Wavedragon	6	12	12	18	16	24	16
Wavestar	7	28	28	36	36	42	34

Table E.2: Performance values of different wave energy technologies at selected Chilean locations.

Technology	Mejillones	La Serena	Valparaíso	Concepción	Valdivia
Corpower	70	77	77	79	80
CETO	31	43	45	48	47
OE Buoy	35	40	39	41	41

Table E.3: Wave energy values for different technologies and locations.

Technology	Mejillones	La Serena	Valparaíso	Concepción	Valdivia
Corpower	244,758	269,601	2,708,209	2,785,850	2,813,080
CETO	713,716	995,468	1,029,413	1,094,475	1,072,198
OE Buoy	891,980	1,001,046	1,006,307	1,033,019	1,023,920

F Reasoning

Discarted WECs

A lot of WECs and WEC concepts are currently available for exploration. Only 3 have been selected. The choice to exclude other WECs is presented here: The SSG, although conceptually interesting, is an onshore device and is expected to face strong community opposition, similar to the Wavestar, which also relies on nearshore deployment. The Seabased AB system, while technically mature and high capacity factors, was excluded due to its relatively small scale and lower energy output. The Pelamis suffers from poor capacity factors for the chosen locations as can be seen in ({Ap: C_f and AEY}), making it economically unattractive. The Aquabuoy involves significant internal water movement through multiple mechanical components, raising concerns about wear and tear and high maintenance costs. Although the Wavedragon's large offshore footprint makes it suitable for hybrid systems with offshore wind, the absence of such farms in Chile led to its exclusion.

G Social Tables

Site	Description	Sentiment
Mejillones	Inhabitants of Mejillones express concern about the continued development of large-scale energy projects and their impact on local economic, social, and cultural well-being (flechas2024). The commune’s history as a “sacrifice zone,” established during Chile’s dictatorship period, has shaped a lasting sense of environmental injustice and vulnerability (anbleyth-evans2022). In addition, potential benefits of public coordination are threatened by the distrust existing between public and private actors, principally due to unresolved conflicts (vasquez-lavin2013).	Very negative
La Serena	There are worries about undermining the region’s rich cultural heritage and local traditions intrinsically linked to the sea, such as artisanal fishing and coastal festivals, and fears of weakening the unique identity of these communities (cooper2008; unesco2016; araya-pizarro2025). Local residents value the city’s image as a coastal leisure destination and support sustainable development, provided it preserves environmental quality and access to beaches. Engagement and transparent planning are therefore crucial for maintaining trust (selmancaro2024wave).	Indifferent
Valparaíso	Valparaíso’s community sentiment is characterised by strong civic engagement and a long tradition of social and environmental activism. The city’s identity as a UNESCO World Heritage Site fosters strong place attachment but also resistance to infrastructure projects that may alter its visual or cultural landscape (Cáceres-Seguel, 2023). However, experiences from the Open Sea Lab’s pilot of a Wave Energy Converter (WEC) off the coast of Las Cruces demonstrate that early community engagement can foster acceptance. Continuous dialogue and co-benefit creation strengthened relationships with local residents, allowing both the project and the community to benefit from constructive collaboration (Cortés et al., 2022).	Positive
Concepción	In Concepción, public attitudes toward wave energy differ among individuals in the area (Oliva et al., 2024). The Biobío region’s long industrial history—centered on forestry, manufacturing, and energy production—has contributed to growing environmental concern over air and water pollution (mcneill2020concepcion; Broto & Calvet, 2020). A study by Oliva et al. (2024) found that both “status quo” and “emerging energy source” supporters co-exist in the area, though marine energy projects are generally preferred over wind, solar, and biomass alternatives. The research also highlights that social acceptance increases when communities share ownership of the project, underscoring the importance of participatory and locally anchored initiatives.	Moderately positive
Valdivia	Valdivia stands out as one of Chile’s most environmentally aware and mobilised communities. Its civic identity is deeply intertwined with nature, rivers, and wetlands—values strengthened by the Río Cruces environmental conflict and its later recognition as Chile’s first “Wetland City” under the Ramsar Convention (marcachile2023wetlandcity). During a focus group session with twelve ocean energy students in Valdivia (focusgroup2025), participants linked environmental and social sentiment, emphasising that “transparency is the most important thing.” They noted that while some opposition could arise from indigenous groups or NGOs seeking to “protect the green south,” others view marine energy as a promising opportunity, stating that “it is hard to implement, but not impossible.” Overall, participants expressed that community acceptance is related to environmental protection and meaningful public participation.	Moderately positive

Table G.1: Summary of community sentiment across the five study sites.

H Marine Areas & Zones

The maps in this section are shown in the same scale and orientation, as shown in Figure H.1 (Subpesca, 2025).

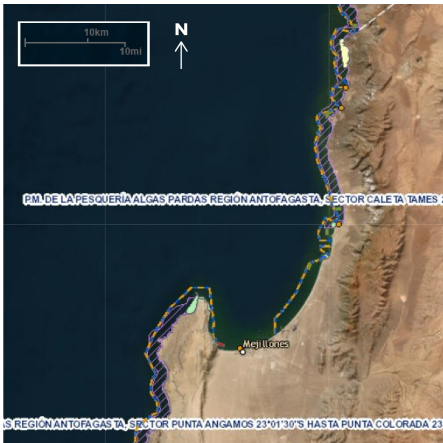


Figure H.1: Marine Areas and Zones Mejillones



Figure H.2: Marine Areas and Zones La Serena

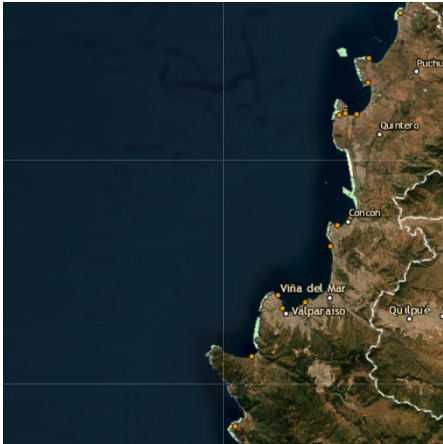


Figure H.3: Marine Areas and Zones Valparaíso



Figure H.4: Marine Areas and Zones Concepción



Figure H.5: Marine Areas and Zones Valdivia



Figure H.6: Legend of Marine Areas and Zones

I Bivariate Matrices

Local Near Shore Data

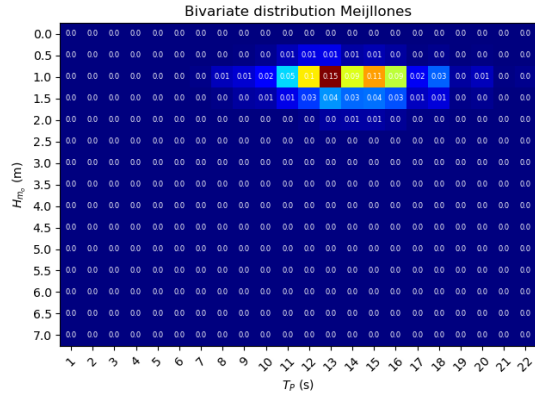


Figure I.1: Bivariate Matrix Mejillones

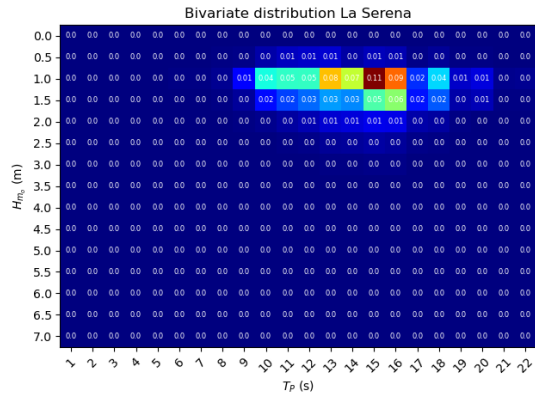


Figure I.2: Bivariate Matrix La Serena

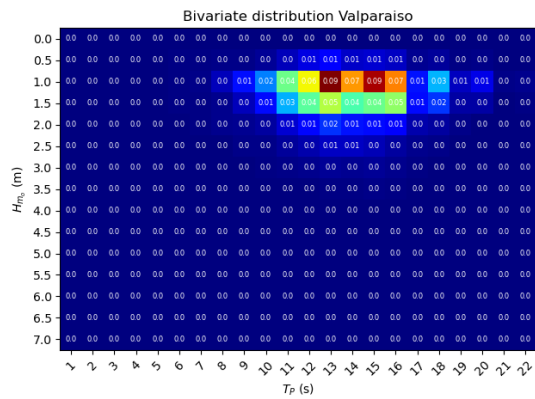


Figure I.3: Bivariate Matrix Valparaíso

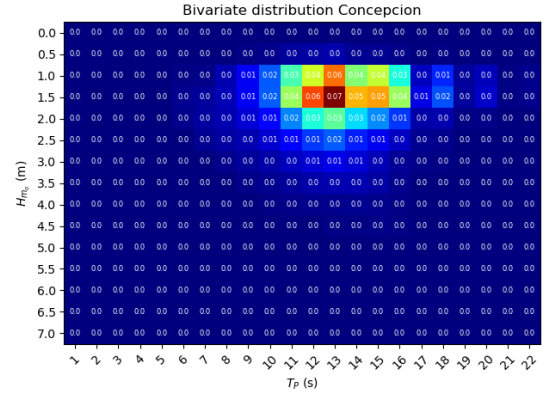


Figure I.4: Bivariate Matrix Concepción

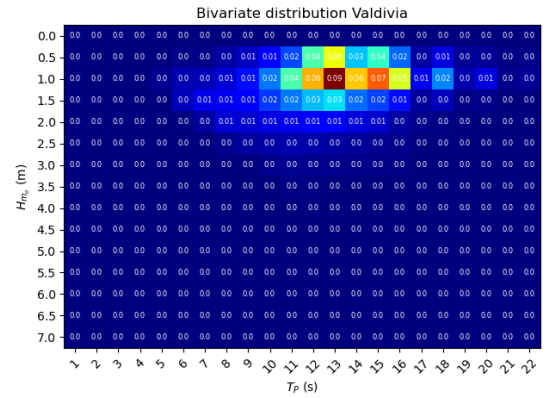


Figure I.5: Bivariate Matrix Valdivia

ERA 5 Offshore Data

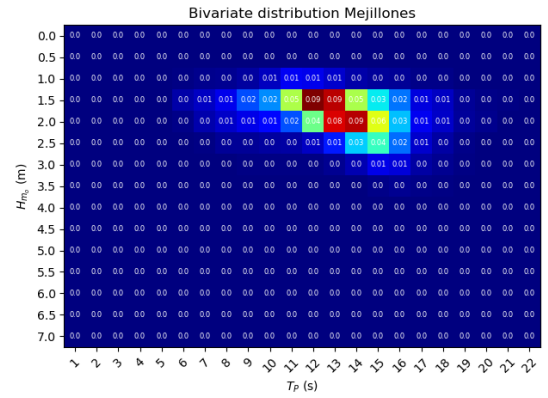


Figure I.6: Bivariate Matrix Mejillones

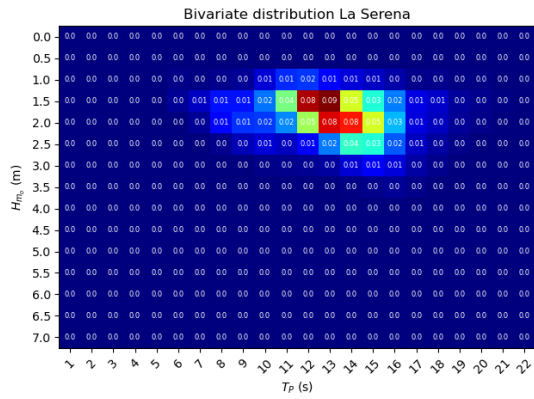


Figure I.7: Bivariate Matrix La Serena

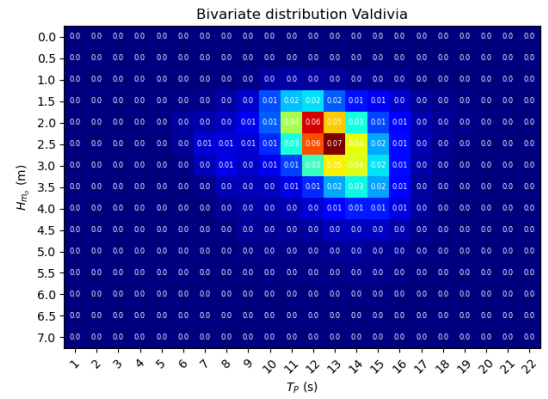


Figure I.10: Bivariate Matrix Valdivia

Local Offshore Data

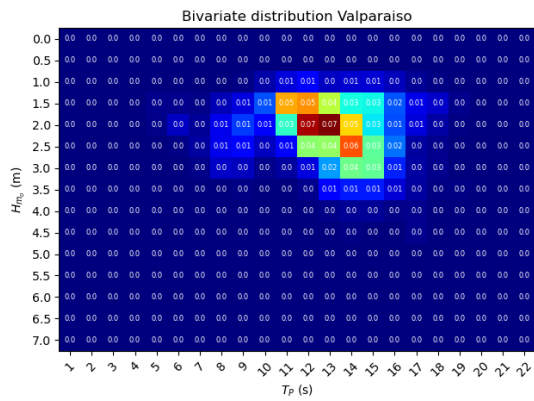


Figure I.8: Bivariate Matrix Valparaíso

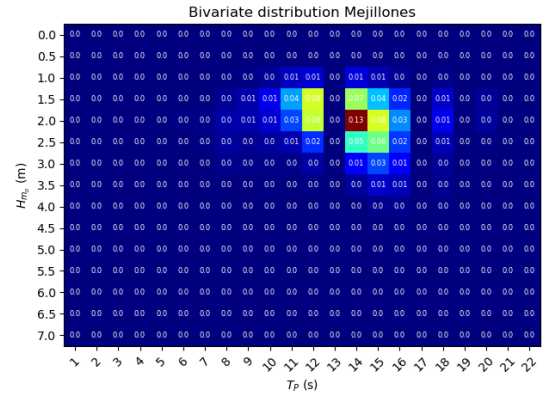


Figure I.11: Bivariate Matrix Mejillones

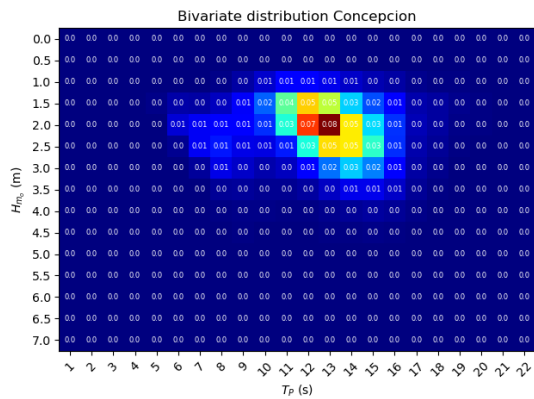


Figure I.9: Bivariate Matrix Concepción

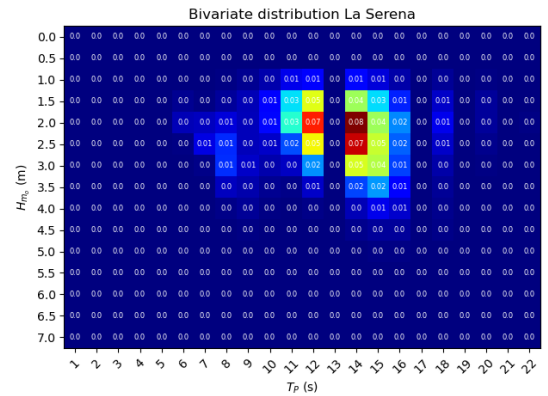


Figure I.12: Bivariate Matrix La Serena

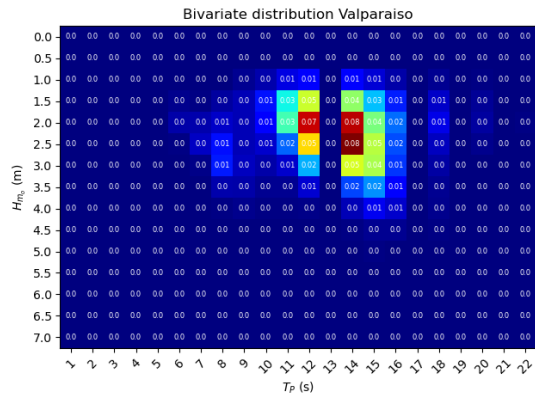


Figure I.13: Bivariate Matrix Valparaíso

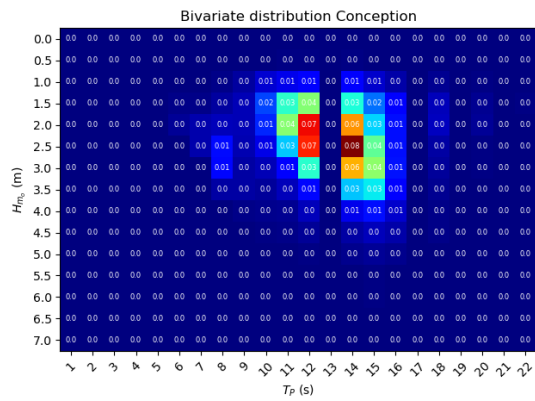


Figure I.14: Bivariate Matrix Concepción

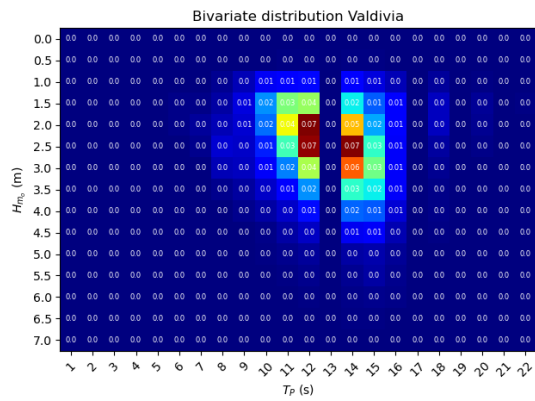


Figure I.15: Bivariate Matrix Valdivia

J Power matrices

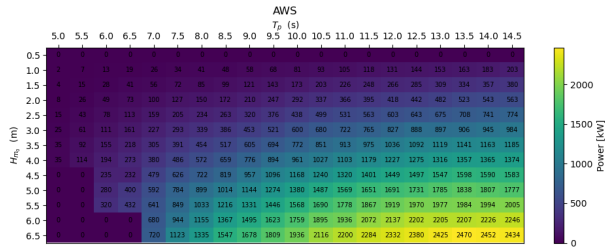


Figure J.1: Power matrices Advanced Archimedes Waveswing (AWS)

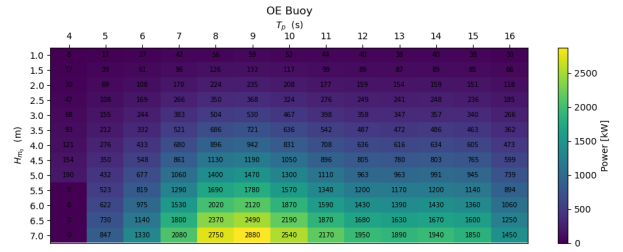


Figure J.5: Power matrix Ocean Energy

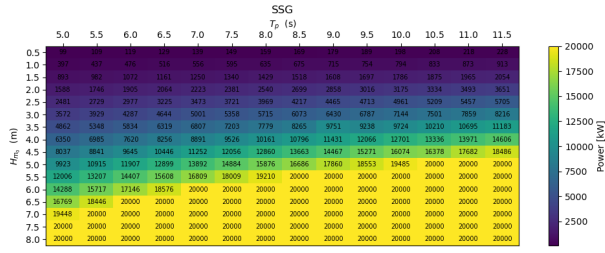


Figure J.2: Power matrix SSG

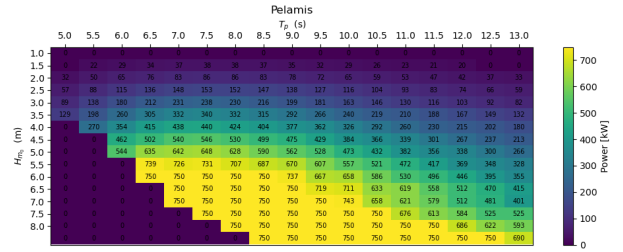


Figure J.6: Power matrix Pelamis

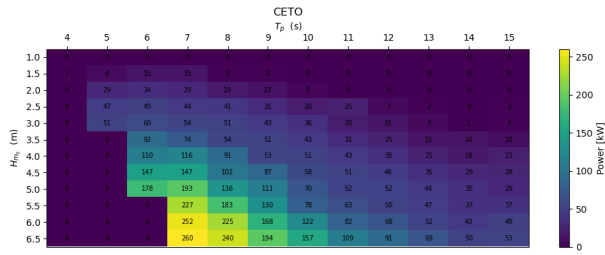


Figure J.3: Power matrix Carnegie Clean Energy Technology

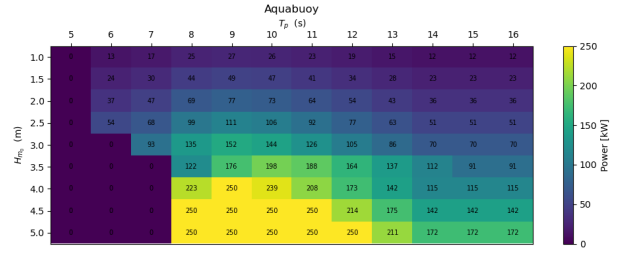


Figure J.7: Power matrix AquaBuOY

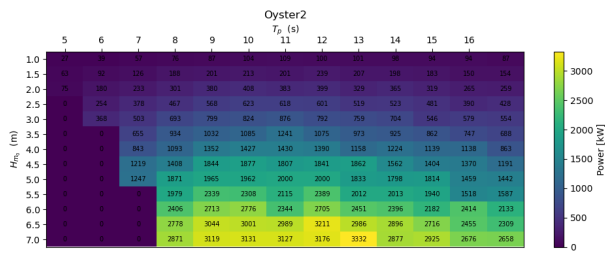


Figure J.4: Power matrix Oyster 2

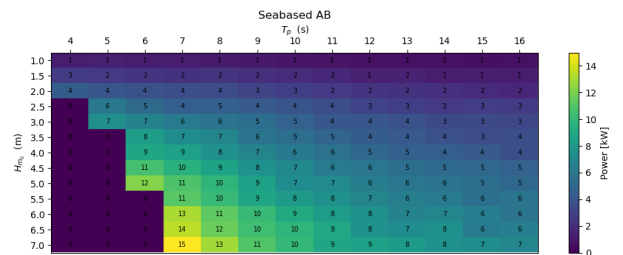


Figure J.8: Power matrix seabasedab

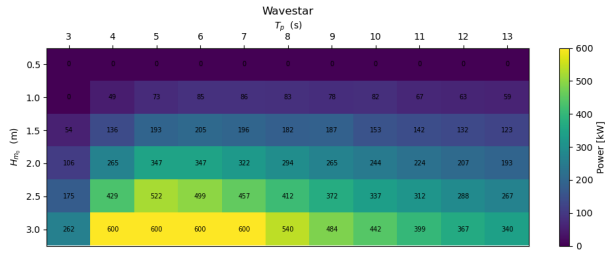


Figure J.9: Power matrix Wavestar

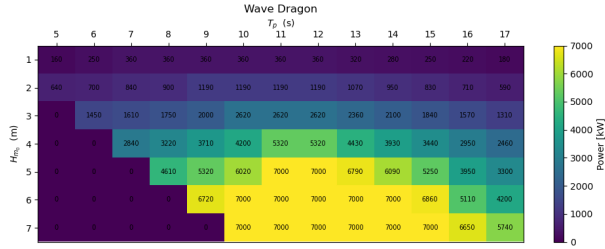


Figure J.10: Power matrix Wave dragon

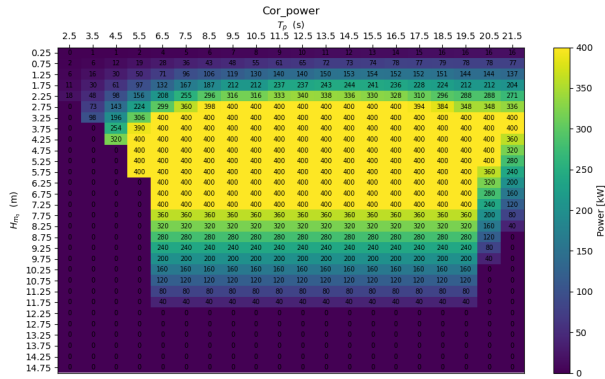


Figure J.11: Power matrix Cor power

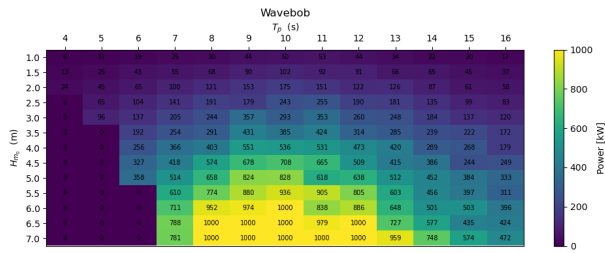


Figure J.12: Power matrix Wavebob

K MCA Details

Table K.1: Technical Factors MCA

Factor	Explanation	Score (0 – 1)
Capacity Factors	Ratio between actual energy output and maximum energy output	
Annual Energy Yield	Energy output in a year	
Installation Complexity	Workability of an installation vessel on the Chilean coast	
Survivability of the Buoy	Resistance of the buoy to its surroundings	

Table K.2: Environmental Factors MCA

Factor	Explanation	Score (0 – 1)
Impact on Marine Ecology	The impact that wave energy will have on the marine ecosystems (flora and fauna)	
Marine Zoning Conflicts	The Chilean sea is divided into zones for aquaculture, fisheries, regulatory activities, and protected marine zones. These zones must be considered when building wave energy farms	
		TOTAL = 1

Table K.3: Social Factors MCA

Factor	Explanation	Score (0 – 1)
Indigenous Community Presence	There are different indigenous tribes in Chile	
Social Acceptance	Bottom-up: The degree to which local communities (inhabitants of the region) are willing to tolerate the development and operation of a wave farm at the site based on visual acceptance, acceptance of the noise, acceptance of the seabed occupation and acceptance of the new industries it might bring.	
Stakeholder Alignment	Institutional scale: The extent to which key actors (municipalities, fishers, NGOs, port authorities, energy agencies and other industries) may co-operate in permitting, operating, and benefiting from a wave energy farm.	
Socio-Economic Community Benefits	Long-term value: The potential of the project to benefit positive local impacts such as jobs, skills development, regional economic growth, and contribution to existing industries while minimising disruption.	
		TOTAL = 1

	Mejillones			La Serena			Valparaíso			Concepcion			Valdivia		
	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO
Technological	0,007	0,006	0,005	0,005	0,005	0,004	0,005	0,005	0,004	0,004	0,004	0,003	0,004	0,004	0,002
Economic	0,079	0,033	0,000	0,085	0,048	0,041	0,085	0,045	0,046	0,087	0,050	0,053	0,088	0,050	0,050
Environmental	0,028	0,028	0,028	0,018	0,018	0,018	0,029	0,029	0,029	0,030	0,030	0,030	0,027	0,027	0,027
Social	0,001	0,001	0,001	0,011	0,007	0,011	0,015	0,014	0,015	0,011	0,010	0,011	0,011	0,009	0,011
Political	0,000	0,000	0,000	0,029	0,029	0,029	0,000	0,000	0,000	0,041	0,041	0,041	0,016	0,016	0,016
TOPSIS Result	0,62	0,45	0,35	0,59	0,47	0,44	0,65	0,54	0,54	0,76	0,63	0,63	0,69	0,57	0,56

Figure L.1: Summary TOPSIS

	Mejillones			La Serena			Valparaíso			Concepcion			Valdivia		
	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO
Technological	0,61	0,47	0,39	0,52	0,40	0,38	0,69	0,59	0,59	0,73	0,62	0,62	0,64	0,53	0,51
Economic	0,68	0,44	0,31	0,61	0,43	0,41	0,76	0,58	0,58	0,82	0,63	0,64	0,74	0,56	0,56
Environmental	0,65	0,54	0,47	0,43	0,32	0,31	0,76	0,68	0,68	0,78	0,69	0,69	0,66	0,58	0,58
Social	0,59	0,46	0,38	0,51	0,38	0,39	0,79	0,66	0,67	0,76	0,64	0,65	0,67	0,56	0,56
Political	0,50	0,39	0,33	0,54	0,45	0,44	0,58	0,50	0,50	0,81	0,71	0,71	0,62	0,52	0,52

Figure L.2: MCA skewed TOPSIS results

				Category weight	Subcategory weight	Subsubcategory weight	Total weight	Mejillones			La Serena			Valparaíso			Concepcion			Valdivia			
								CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	
Technical	Capacity Factors				0,23		0,0439	8	0,8	0	9,4	1,6	2,9	9,4	1,6	2,9	9,8	2	3,5	10	2	3,3	
	Annual Energy Yield				0,23		0,0439	1,8	8,5	0	2,1	9,7	0,3	2,1	9,7	0,3	2,2	10	0,4	2,2	9,9	0,4	
	Installation Complexity	Anchoring			0,20	0,107	0,20	0,107	3	7	4	3	7	4	3	7	4	3	7	4	3	7	4
		Distance to ports			0,20	0,107	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
		Distance to grid connection			0,20	0,107	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
		Port facilities			0,20	0,107	10	10	10	10	10	10	10	10	10	10	10	10	10	10	0	0	0
		Workability of waves			0,20	0,107	10	10	10	10	2,45	2,45	2,45	2,46	2,46	2,46	0,86	0,86	0,86	0	0	0	0
	Survivability of the Buoy	Extreme wave height			0,50	0,268	8	5	10	5,4	3,4	4	4,9	3	6,2	1,7	1	2,1	0,5	0	1	0	1
		Mean wave height			0,50	0,268	8	5	10	3,2	2	6,8	3,2	2	4	2	1,2	2,5	0,5	0	1	0	1
	Economical	Economical Feasibility				0,236		0,2360	9	3,8	0	9,7	5,4	4,7	9,7	5,1	5,2	9,9	5,7	6	10	5,7	5,7
	Environmental, Zoning, Ethical	Impact on Marine Ecology				0,38		0,1114	5,2	5,2	5,2	9,4	9,4	9,4	0	0	0	5	5	5	10	10	10
Marine Zoning Conflicts				0,63		0,1856	7	7	7	0	0	0	10	10	10	8	8	8	6	6	6		
Social	Indigenous Communities				0,30		0,0546	9,1	9,1	9,1	8	8	8	10	10	10	8,6	8,6	8,6	0	0	0	
	Social Acceptance				0,28		0,0501	0	0	0	5	0	5	10	10	10	7,5	6	7,5	7,5	6	7,5	
	Stakeholder Alignment				0,30		0,0546	0	0	0	10	10	10	7,5	7,5	7,5	5	5	5	5	5	5	
	Socio-Economic Community Benefits				0,13		0,0228	4	4	4	0	0	0	10	10	10	8	8	8	6	6	6	
Political, Legal	Regulatory Support				0,091		0,0910	0	0	0	7	7	7	0	0	0	10	10	10	4	4	4	

Figure L.3: Final MCA scoring table

				Category weight	Subcategory weight	Subsubcategory weight	Total weight	Mejillones			La Serena			Valparaiso			Concepcion			Valdivia			
								CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	CorPower	OEBUOY	CETO	
Technical	Capacity Factors			0.03			0.0073	8	0.8	0	9.4	1.6	2.9	9.4	1.6	2.9	9.8	2	3.5	10	2	3.3	
	Annual Energy Yield			0.18			0.0403	1.8	8.5	0	2.1	9.7	0.3	2.1	9.7	0.3	2.2	10	0.4	2.2	9.9	0.4	
	Installation Complexity	Anchoring				0.20	0.0167	3	7	4	3	7	4	3	7	4	3	7	4	3	7	4	
		Distance to ports					0.20	0.0167	10	10	10	10	10	10	10	10	10	10	10	10	10	10	
		Distance to grid connection			0.22	0.38	0.20	0.0167	10	10	10	10	10	10	10	10	10	10	10	10	10	10	
		Port facilities					0.20	0.0167	10	10	10	10	10	10	10	10	10	10	10	10	0	0	0
		Workability of waves					0.20	0.0167	10	10	10	2.8	2.8	2.8	1.3	1.3	1.3	0	0	1.4	1.4	1.4	
	Survivability of the Buoy	Extreme wave height				0.50	0.0220	8	5	10	5.4	3.4	4	4.9	3	6.2	1.7	1	2.1	0.5	0	1	
		Mean wave height					0.20	0.0220	8	5	10	3.2	2	6.8	3.2	2	4	2	1.2	2.5	0.5	0	1
	Economical	Economical Feasibility			0.21	1.00		0.2100	9	3.8	0	9.7	5.4	4.7	9.7	5.1	5.2	9.9	5.7	6	10	5.7	5.7
Environmental, Zoning, Ethical	Impact on Marine Ecology				0.40		0.1120	2	2	2	10	10	10	0	0	0	8	8	8	6	6	6	
	Marine Zoning Conflicts			0.28	0.33		0.0933	7	9	8	0	2	1	8	10	9	7	9	8	6	8	7	
	Indigenous Tribe Zones				0.27		0.0756	10	10	10	10	10	10	10	10	10	10	10	10	0	0	0	
	Social Acceptance				0.42		0.0798	2	2	2	3	0	5	7	4	8	6	10	7	5	9		
Social	Stakeholder Alignment			0.19	0.25		0.0475	10	10	10	1	0	2	5	5	7	7	7	6	6	6	6	
	Socio-Economic Community Benefits				0.33		0.0633	4	4	4	5	0	5	10	10	8	8	8	7	7	7	7	
	Regulatory Support			0.1	1.00		0.1000	0	0	0	7	7	7	0	0	0	10	10	10	4	4	4	

Figure L.4: Midterm MCA scoring table

M Geotechnical Calculations

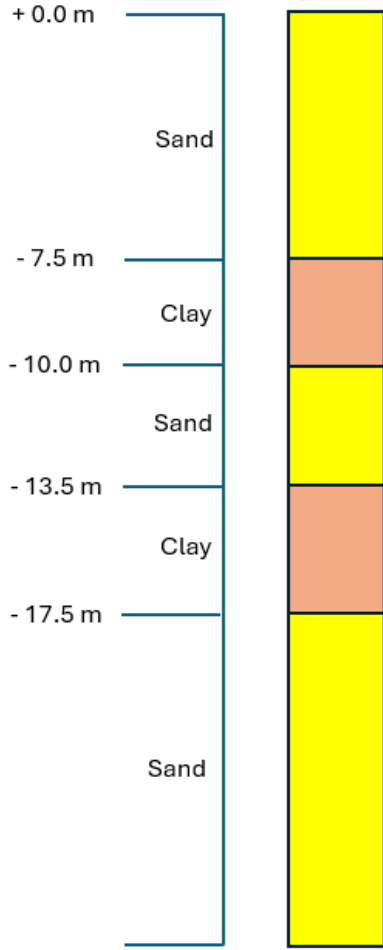


Figure M.1: Hypothetical Soil Profile

Soil Profile

Because no public offshore soil data is available, a hypothetical soil profile was constructed. Although this profile has no real geotechnical significance, It serves as input for the calculations illustrating how the anchoring dimensions can be determined.

Analytical Calculation Anchoring

To determine preliminary anchor dimensions, an analytical calculation is performed. This is done in Python.

The pull-out capacity is calculated in a different manner for different soiltypes. In accordance with Interviewee 4 the following equations are vivid (personal communication, September 15, 2025)

$$\text{Sand: } q_s = 0.012 q_c \quad (\text{M.1})$$

$$\text{Clay: } q_s = \alpha_s \cdot s_u, \quad \alpha_s = \psi \left(\frac{s_u}{p_a} \right)^{0.5}, \quad \psi = 0.5 \quad (\text{M.2})$$

$$\text{Rock: } q_s = \alpha_s \cdot \text{UCS} \quad (\text{M.3})$$

In these equations, q_c is the cone resistance, s_u is the undrained shear strength, ψ is the empirical fitting parameter (here taken as 0.5), α_s is a reduction factor and q_s is the unit shaft resistance. UCS is the Ultimate Compressive Strength and can be derived from Figure M.2. In the analytical calculation, a q_c for sand of 10 is used and s_u for the clay is taken as 20.

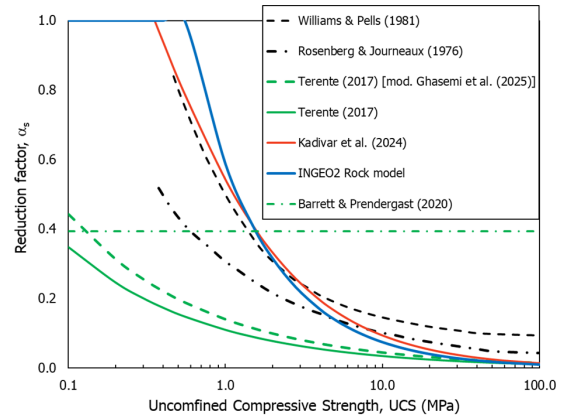


Figure M.2: Reduction Factor UCS Relations

The unit shaft resistance is multiplied by the outer area of the anchor to derive the total pull-out resistance.

Note: the analytical approach constructed in Python only considers 3 soil types and attaches 1 value to each soil type. This is fine, since it is just a preliminary estimation. If a real soil profile becomes available, the code should be extended.

According to this calculation, taking into account a diameter of 1.6, a length of 10.25 m is enough to withstand the ULS force exerted by the buoy (CorPower Ocean, 2022).

PLAXIS Calculation

Table M.1 shows the parameters assigned to the soil types. These follow the Mohr-Coulomb soilmodel.

The simulation consisted of three sequential phases, designed to represent the relevant stages of the installation and removal process:

1. Initial situation – The initial stress state of the soil was generated under gravity loading, ensuring that the in-situ stresses correspond to realistic overburden conditions.
2. WEC installation – The second phase simulated the insertion of the structure (e.g., the anchor or foundation element associated with the Wave Energy Converter), allowing assessment of the stress redistribution and soil displacement during installation.
3. Pull-out phase – Finally, a controlled pull-out analysis was conducted to evaluate the soil's resistance and failure mechanism during extraction.

Boundary conditions were defined to prevent unrealistic lateral or vertical displacements, while the model mesh was refined around the structure to ensure numerical stability and accuracy.

The mesh was generated using a combination of global coarseness control and local refinement near critical regions. The default 15-node triangular elements were adopted, as they provide an optimal balance between computational efficiency and accuracy for geotechnical simulations. Mesh size dependency has been tested by running calculations with different meshes. One of the meshes is visualised in M.3.

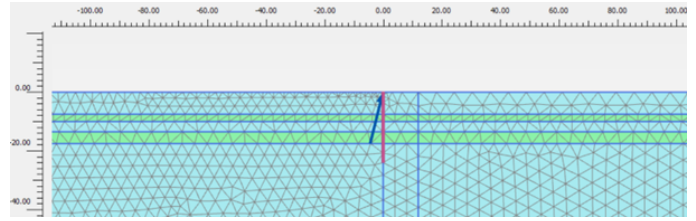


Figure M.3: Mesh in PLAXIS

The displacement of a scenario is shown in M.4.

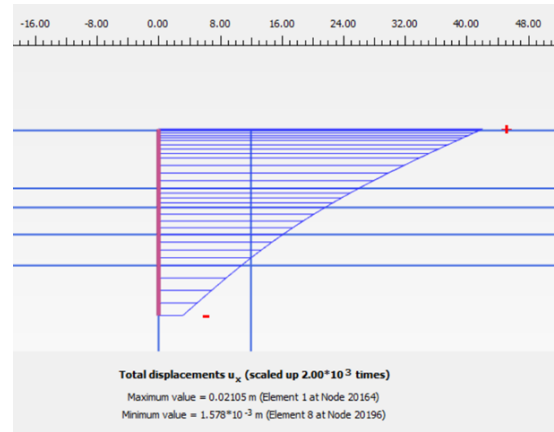


Figure M.4: Displacement calculation

Table M.1: Soil parameters for Mohr-Coulomb materials

Parameter	Clay	Sand
Soil model	Mohr-Coulomb	Mohr-Coulomb
Drainage type	Drained	Drained
γ_{unsat} (kN/m ³)	16.0	17.0
γ_{sat} (kN/m ³)	18.0	20.0
e_{init} (-)	0.5000	0.4286
n_{init} (-)	0.3333	0.3000
E_{ref} (kN/m ²)	15 000	50 000
ν (-)	0.49	0.00
G_{ref} (kN/m ²)	5 034	25 000
E_{oed} (kN/m ²)	256 700	50 000
c_{ref} (kN/m ²)	10.0	0.0
ϕ' (°)	20.0	35.0
ψ (°)	0.0	5.0

N Occurrence Species in Concepción

Table N.1: Species Identified & their Taxonomic Classification (Ocean Biodiversity Information System (OBIS), 2025)

#	Scientific Name	Records	Phylum	Class	Order	Family	Genus	Common Name
1	Bacteria	7866						Bacteria (general)
2	Planctomycetaceae	2177	Planctomycetes	Planctomycetacia	Planctomycetales	Planctomycetaceae		Planctomycetes bacteria
3	Desulfobacteraceae	2014	Proteobacteria	Deltaproteobacteria	Desulfobacteriales	Desulfobacteraceae		Sulfate-reducing bacteria
4	Deltaproteobacteria	1962	Proteobacteria	Deltaproteobacter				Delta proteobacteria
5	Bacteroidetes	1932	Bacteroidetes					Bacteroidetes bacteria
6	Gammaproteobacteria	1901	Proteobacteria	Gammaproteobact				Gamma proteobacteria
7	Proteobacteria	1357	Proteobacteria					Proteobacteria bacteria
8	Acidobacteriaceae	929	Acidobacteria	Acidobacteriales	Acidobacteriales	Acidobacteriaceae		Acidobacteria family
9	Bacteroidales	884	Bacteroidetes	Bacteroidia	Bacteroidales			Bacteroidales bacteria
10	Thalassarche melanophris	734	Chordata	Aves	Procellariiformes	Diomedelidae	Thalassarche	Black-browed Albatross
11	Myxococcales	659	Proteobacteria	Deltaproteobacteria	Myxococcales			Fruiting gliding bacteria
12	Lentisphaerae	638	Lentisphaerae					Lentisphaerae (no common name)
13	Desulfobulbaceae	530	Proteobacteria	Deltaproteobacteria	Desulfobacteriales	Desulfobulbaceae		Cable bacteria (sulfate-reducing family)
14	Verrucomicrobiales	519	Verrucomicrobia	Verrucomicrobiae	Verrucomicrobiales			Verrucomicrobia (no common name)
15	Flavobacteriaceae	503	Bacteroidetes	Flavobacteria	Flavobacteriales	Flavobacteriaceae		Flavobacteria family
16	Acidobacteria	493	Acidobacteria					Acidobacteria (soil bacteria)
17	Lentisphaera	488	Lentisphaerae	Lentisphaerales	Lentisphaeraeae	Lentisphaera	Lentisphaera	Lentisphaera (no common name)
18	Spirochaeta	488	Spirochaetes	Spirochaetes (Class)	Spirochaetales	Spirochaetaceae	Spirochaeta	Spirochetes (spiral bacteria)
19	Thermomicrobia	477	Chloroflexi	Thermomicrobia				Thermophilic green non-sulfur bacteria
20	Rhodobacteraceae	419	Proteobacteria	Alphaproteobacteria	Rhodobacteriales	Rhodobacteraceae		Rhodobacteria (photosynthetic family)
21	Desulfobacterium	419	Proteobacteria	Deltaproteobacter	Desulfobacteriales	Desulfobacteraceae	Desulfobacterium	Sulfate-reducing rod-shaped bacteria (marine)
22	Caldithrix	418	Bacteria incertae sedis				Caldithrix	Thermophilic anaerobic rod bacteria (hydrothermal vent)
23	Flavobacteriales	401	Bacteroidetes	Flavobacteria	Flavobacteriales			Flavobacteria (environmental gliding rods)
24	Chloroflexi	401	Chloroflexi					Green non-sulfur or filamentous bacteria
25	Actinobacteria	379	Actinobacteria	Actinobacteria				Actinobacteria (high G+C Gram-positive bacteria)
26	Caldilineaceae	364	Chloroflexi	Caldilineae	Caldilineales	Caldilineaceae		Thermophilic filamentous bacteria family
27	Diomedea sanfordi	358	Chordata	Aves	Procellariiformes	Diomedelidae	Diomedea	Northern Royal Albatross
28	Planctomyces	304	Planctomycetes					Planctomycetes (unique cell-biology bacteria)
29	Clostridium	296	Firmicutes	Clostridia	Clostridiales			Clostridia (spore-forming anaerobic rods)
30	Lachnospiraceae	296	Firmicutes	Clostridia	Clostridiales	Lachnospiraceae		Lachnospiraceae (gut anaerobic bacteria family)

O Energy Mix Concepción

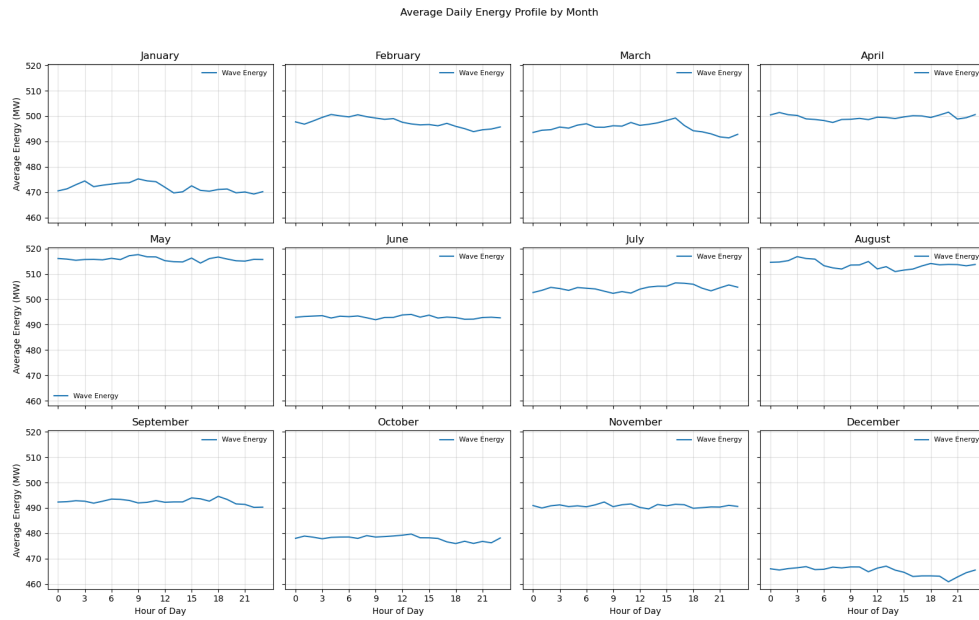


Figure O.1: Average Monthly Wave Energy Production Concepción

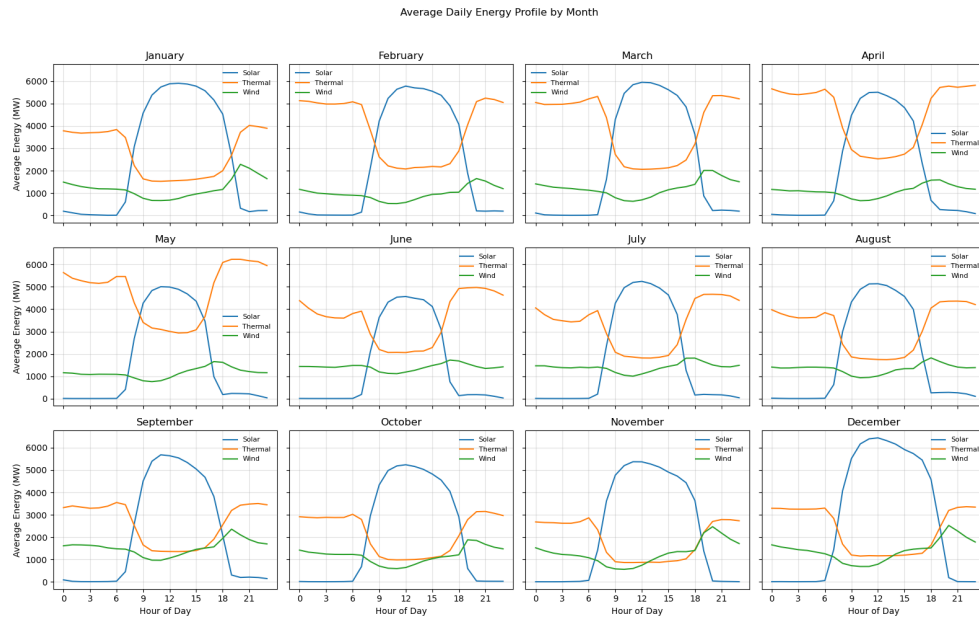


Figure O.2: Average Monthly Energy Production Renewables Concepción

P Forecast Model Output

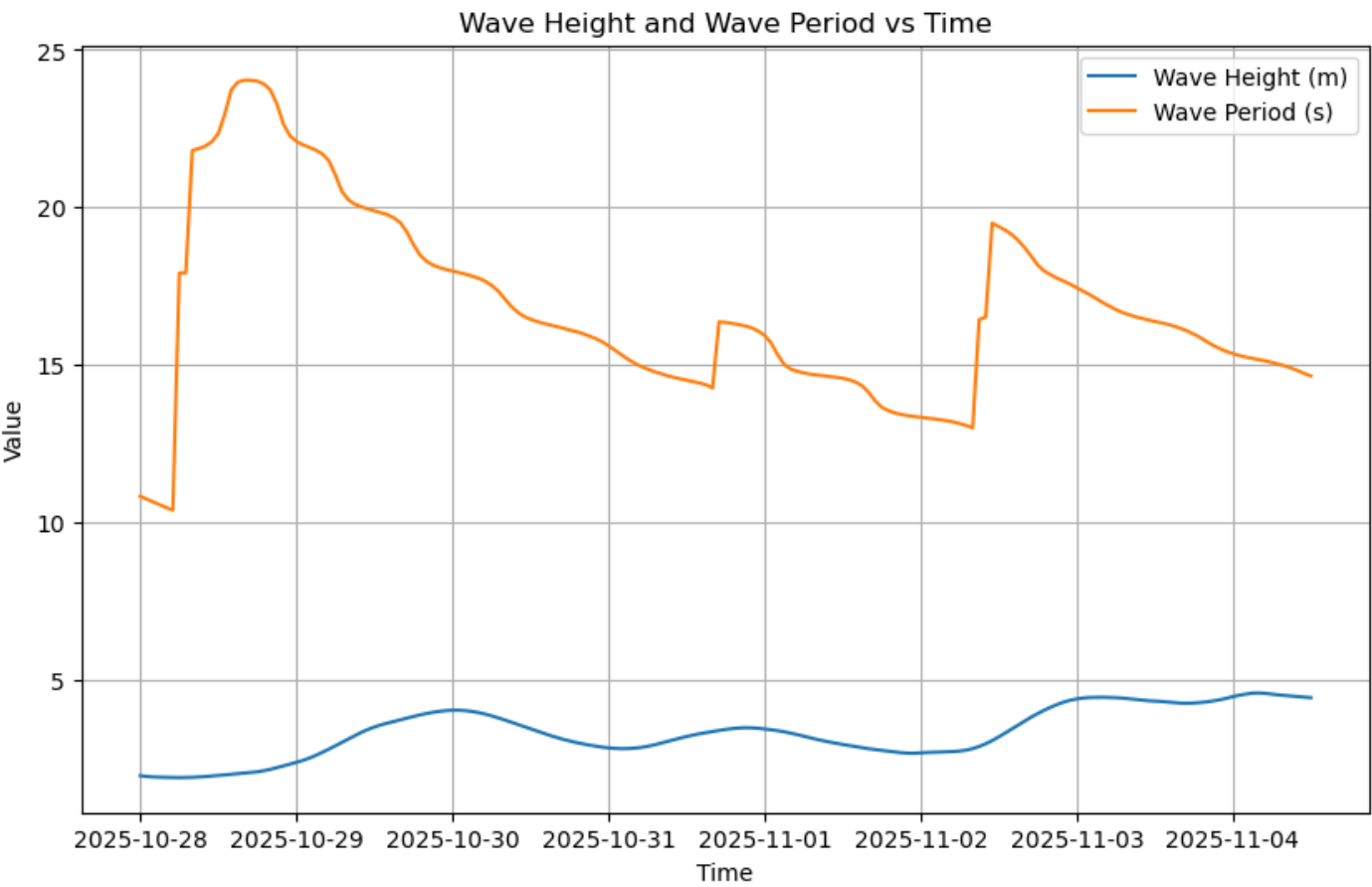


Figure P.1: Wave Parameters in the Coming Days

Hourly Energy Output per Day

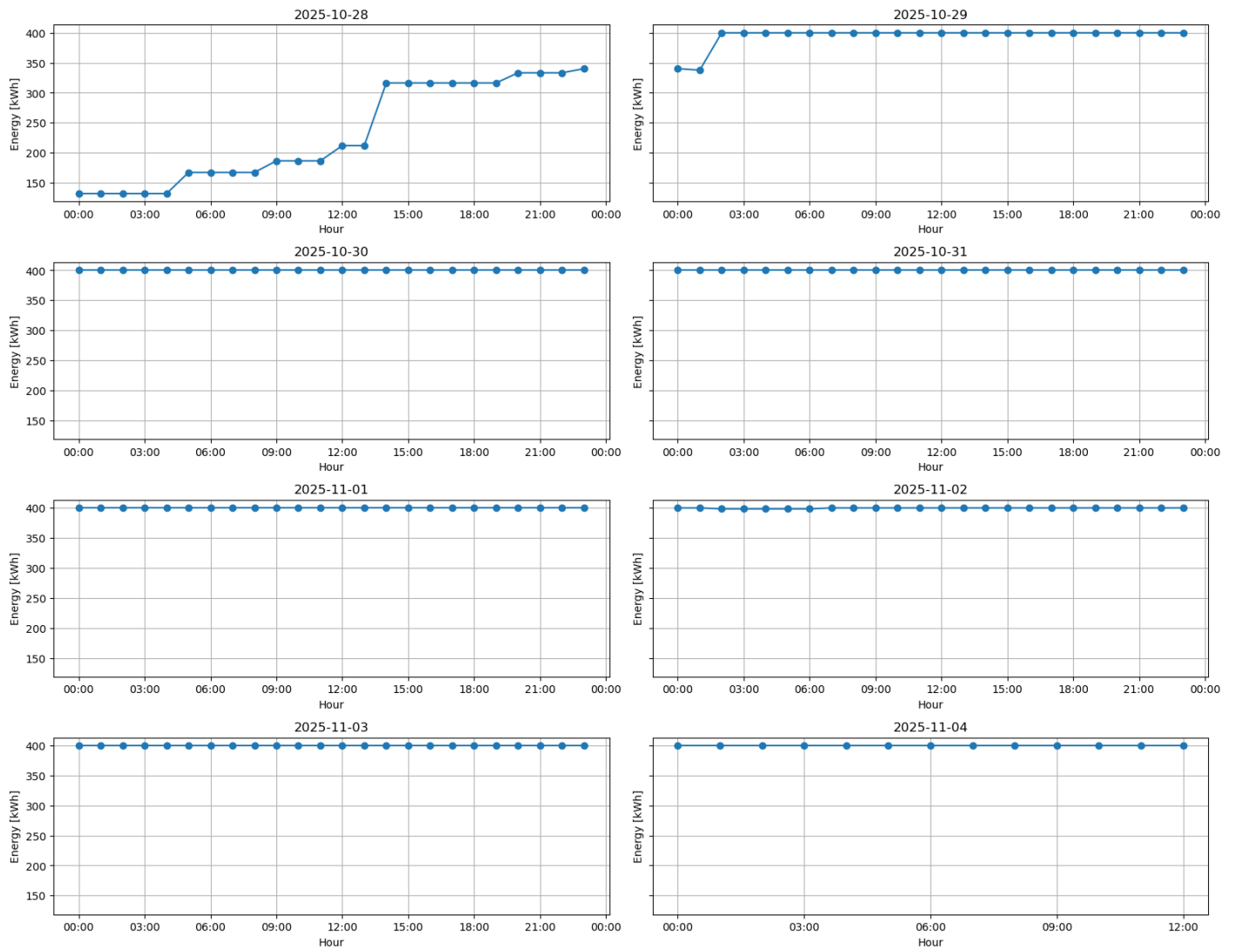


Figure P.2: Power Output in the Coming Days

Q Role Play

Roles

Fisherman

You are a local inhabitant of Concepción, male around 40. Your income is dependent on fishing (the amount and quality of the catch). With your income, you need to care for your whole family. You have a strong interest in wave farm plans, but your power is limited unless you are united with other fishermen.

Indigenous Community Spokesperson

You are the spokesperson, male, 35, of an indigenous community. You are blended into the normal society, but you feel that it is important to protect the heritage of the community. This includes certain parts of nature that shouldn't be affected by big industry. You have relatively high power, and sometimes other parties try to use your power to fulfil their interests.

Environmental Activist

You are a woman of around 35, who is very concerned with the beautiful nature Chile has to offer. The natural beauty of Chile should be conserved, and ecosystems shouldn't be disturbed, as they are difficult to restore. Your impact on projects could be high, as you can shape the perception of many people by relatively simple yet very effective social media or news publications.

Port Authority / Marine Contractor

You are a man around 45, believing that installing a wave farm and all the logistics around it is a big business. Every reasonable challenge can be tackled for a reasonable monetary compensation. You are one of the few players on the market, and fully aware of this fact. You have high standards and want to be involved in the process to mitigate risks that could cause delays. You are willing to take on a new and innovative project if convinced that it can be done successfully, to show that you are the undisputed best party.

Research & Educational Institute

You are a researcher, a woman, mid-twenties, doing a phd in wave energy at the University of Concepción. You strive to put wave energy technologies on the market, and really see the potential in it. You need support (financial/regulatory/etc) to expand interest and drive for future implementation of the technology.

Municipality of Concepción

You are the mayor of Concepción, of the Partido Social Cristiano. You have a typical political agenda: you have to work with other parties (mainly republicans), have to show that you are getting results and stability (for the next elections), and you can't afford any scandals. Partido Social Cristiano: small and local party, Christian values such as family and security, freedom of expression

is also important, even for other religions.

Partido Republicano: republican party, right wing with a strong emphasis on families, security and sovereignty. Want to make permit procedures etc. less bureaucratic and stimulate a free market.

Minister of Energy

You are the Minister of Economy, Development and Tourism and Minister of Energy. You hold a Degree in Business Administration and a Master's and a PhD in Economics. You are a specialist in economic development and international trade, with more than 30 publications in the area. Your focus areas for the energy development of Chile lie in green energy development and economic feasibility.

Energy Company

You are the Eñel President, a woman of around 50 years old. At Enel, you have held various positions within the legal department, including roles with an international focus. Currently, you are the Head of Legal and Corporate Affairs at Eñel Grids, where you lead a team that manages complex legal matters. Eñel is the biggest electricity company in Chile that controls both the generation and distribution of electricity within the country.

CEN

You are a female working in the middle of the organisation, 35, who has to make sure that projects continue flawlessly to impress your supervisor (which is important for promotion). For the CEN, it is important that the grid functions without major malfunctions. There is enough energy, most of it is green, generated in the north. A problem is net congestion. The energy net will face developments, as energy generation sources will become renewable, resulting in intermittency, fewer forecasting possibilities and concentrated energy generation. The best net is stable, secure and of low cost.

WEC Developer

You're a man, mid-30s, with a technical background. You learned business through doing and hate bureaucracy. You are convinced that your technology is superb, but you don't completely understand why others haven't seen this potential as well. You want the technology to be proven in a large project, but don't want your technology to be 'stolen' and want to keep ownership.

R Python Files

All python files used in the research can be retrieved by contacting: R.C. van Eijkeren

S Use of AI

This section provides a short clarification on the use of AI in the process of writing this analysis.

S.0.1 Grammar and language check

While writing the report, AI was used to check grammar and inconsistencies in language. The AI tool was used to identify these, and smoothen parts of text.

In addition, the report was checked for redundant and repetitive statements using Chat-GPT, to ensure clarity of the text.