Project: Sea Harbour Operation with Renewable Energies (SHORE)

The project **Sea Harbour Operation with Renewable Energies (SHORE)** studies the optimisation of maritime transportation with the aim of improving operational efficiency and reducing polluting emissions by implementing technologies which allows for a better integration of renewable energies and storage system into the electrical grid by implementing smart ports microgrids.

Around 90% of global commerce is performed using ship transportation, while this number rises to 96% in Chile. Moreover, the energy demand for maritime shipping, including ports, has increased by 2.6% per year since 2016, and it is expected to increase up to 90% in 2050, when compared to 2008. Since ships use fossil fuel as the primary energy source, maritime transportation contributes around 2.89% of greenhouse emissions, approximately 15% of NO_x (nitrogen oxides) and 5–8% of SO_x (sulphur oxides) worldwide emissions. Of these emissions, 70% are done in a radius of 400km from the cost, thus polluting coastal areas. Conventional marine vessels continue to use their diesel generators to supply their electrical needs at ports, with seaports only providing logistic services, such as loading/unloading. A solution to limit the use of fossil fuels by the ships at the coast, thus reducing the impact on the communities living nearby and improving the air quality, is supplying the ships electrically from the ports and turning off the ship engines. This process is called *Cold ironing*. Cold ironing provides the vessels with electricity for lighting, heating, cooling, and other auxiliary loads. Research on individual ports has concentrated on high voltage shore connections for large vessels such as cruise liners, cargo ships and charging stations for small hybrid and electric ferries.

To carry out energy-intensive logistics services, such as load/unload of goods, ports normally operate by buying energy from the power network. Since electricity is mainly produced from fossil fuels, an increase in ports services, such as the implementation of cold ironing will require increased energy consumption. Consequently, there will produce a surge in the use of fossil fuels. To reduce seaport emissions, port electrification using smart ports microgrids (MG) which include renewable energy sources is proposed in this project. Port electrification also allows an increased level of automatization, improves efficiency, and allows the implementation of peak shaving strategies to reduce energy costs. Moreover, the installation of renewable energies in ports can also allow for the integrated generation of green hydrogen, which then can be used as fuel for ships or as energy storage.

However, due to the variability and intermittency of renewable resources, energy storage needs to be considered to ensure an energy supply which fulfils the quality requirement. Energy storage helps to maintain the grid stability, especially during power outages, such as the connection of ships for cold ironing operations or charging stations, which will be required if electric ferries are implemented. Furthermore, the storage capacity allows peak shaving, thus reducing the port operational costs. The energy storage can be traditional battery systems, newer alternatives such as hydrogen storage, or the storage units available in the electric ferries, which can be used by suppling power or halting its charging during power outages. However, regardless of the storage used, the design of power converters and Energy Storage Systems (ESS), that allows carrying out the aforementioned functions, needs to be studied. Therefore, to optimise seaport operations and reduce CO_2 emissions, this project proposes three research lines which interact as shown in Figure 1:

Line 1 Port Operations: This line studies the integration of renewable energy power sources in the port electrical power system. For this, the implementation of a local MG which uses renewable energies available on the geographical location is proposed. MG stability, load demand response, power sharing, peak shaving, and the integration of ESSs, such as batteries or hydrogen-based storage, will be considered. Notice that in the Magallanes region it is planned to install plants of several GW (mainly wind-energy) to become a global provider of green hydrogen, therefore in this geographical location, it is more likely to implement ESSs based on this technology.

Line 2 Ship-Port Connection: This line studies the required electrical connection between ships and ports. With this aim, the ship-port connection to implement cold ironing technologies will be studied. The converter design requirements and the load impact on the port electric power network will be considered.

Line 3 Hydrogen Generation: This line studies the use of hydrogen produced with seawater and renewable electrical energy as an additional energy storage for the port operations. Hydrogen is produced through desalinization and electrolization of sea water and converted in electrical energy by using fuel-cell technology. The research line will focus on developing innovative and more efficient solutions to the hydrogen production process as well as constructing the electrical interface between the fuel-cell and the electrical grid. Moreover, this line will also study the implementation of hybrid storage systems based on hydrogen augmented with other storage system of smaller size, for instance batteries. This can improve the dynamic response of the system.

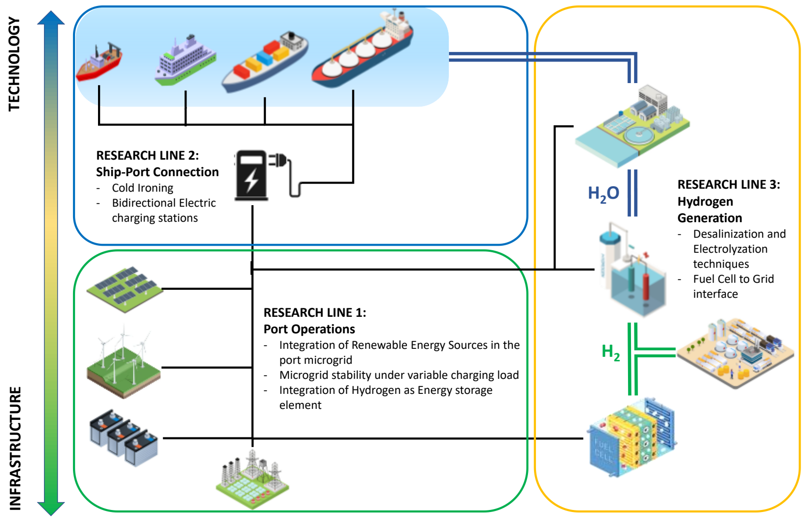

Figure 1. SHORE project research lines.

These three lines will be integrated applying load demand control. Then, the SHORE project objectives are:

- Objective 1: Storage and renewable energies sizing for seaport microgrids considering the Chilean port geographical conditions.
- Objective 2: Design and control of an AC/DC power conversion interface based on multilevel converters for port implementation and control of vessels cold ironing.
- Objective 3: Study, modelling, and innovation in the desalination and electrolization process for hydrogen production
- Objective 4: Develop the power conversion system for the fuel-cell to electrical grid interface.
- Objective 5: Implementation of demand side management control strategies for the ship – interface – port system.
- Objective 6: Training of new experts in ports power consumption and hydrogen generation
- Objective 7: Dissemination of scientific and technological results

To achieve the objectives, the SHORE project will be hosted at three universities, the University of Chile, the University Andrés Bello and the University of Magallanes and its team will be a multidisciplinary network of faculty members, researchers, and students of electrical (power electronics, control, and electromechanical interactions) and chemical engineering. Moreover, the project has the support of 8 international universities which have experience working on port, ships and converter related problems. Moreover, the project has the support of 7 companies working in the field of renewable energy applications, among them three ports located in Magallanes and one port in Arica. This will allow the use of real data and dissemination of the project results to the interested industries.

The expected impact of the proposed activities are: the optimal MG sizing using real Chilean ports consumption profiles; control strategies for power-sharing, demand side management, peak shaving, storage systems; the development of a converter prototypes for the implementation of cold ironing; the study of un innovative desalinization and electrolization techniques; the development of a power conversion stage for fuel-cell to grid interface; the integration of the proposed technologies; the development of international and industrial collaboration; and the dissemination of the obtained results.