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1 INTRODUCTION

The objective of the SMARTPORT project is to promote innovative practices and tools to reduce CO_2 emissions and improve energy efficiency in the public sector.

In particular, activity A.T3.4 (Environmental Energy Planning in Port Areas) intends to develop or update a document for the port energy plan. Port authorities play an important role in climate impact due to the high energy requirements of ports. There are many sources of emissions directly and indirectly related to port operations. For example, these sources include energy consumption of buildings, port administration vehicles, power plants supplying administrative offices and buildings used for maintenance, cargo handling facilities powered by various fuels, ship movements, trucks, railway locomotives. These sources of emission produce what are called greenhouse gases (GHGs). The unit of measurement of GHG emissions is expressed in quantities of CO_2. All emission sources together generate the carbon footprint, which considers the emissions that have a negative impact on climate. All port infrastructure and port activities have a significant environmental impact in terms of water and air quality, atmospheric emissions, land and resource consumption and waste production.

Legislative Decree No 169 of 4 August 2016, a recent reform of port legislation, introduced significant changes, both in the administrative organisation of port management and in the content of port planning and management tools. In particular, in response to a need increasingly felt in ports around the world, a new document was introduced for energy planning in port areas. This document, known as DEASP (*Documento di Pianificazione Energetico e Ambientale del Sistema Portuale* - Document of Energy and Environmental Planning of the Port Network) was defined in terms of content and methodology with the issue of Specific Guidelines. This document, which forms the **Energy Plan** for the AdSPs, supports the current and prospective assessment of the port system's energy demands, providing the tools to ensure concrete environmental sustainability over time, through the identification of technical and organisational solutions for the supply and use of energy, whatever form it takes.

The AdSP MI prepared this document, which was adopted by the Management Committee in first issue with Resolution No 12/19 of 18.12.2019. In August 2022, a further update of the DEASP was adopted and published.

Therefore, this document gathers the information contained in the 2022 update of the DEASP in the part identifying the interventions and measures to be implemented in pursuit of the CO_2 emission reduction targets, analysed using the Cost-Benefit Analysis tool.

2 COST-BENEFIT ANALYSIS TECHNIQUES

Cost-benefit analysis (CBA) is a tool that can guide project choices towards the goal of efficient use of available resources in relation to specific project objectives. Cost-benefit analysis is therefore the process of evaluating the effects of a public investment calculated over its entire service life.

The specific public nature of the investment lies in the fact that its predominant purpose, beyond profit alone, is the well-being of the community. Aggregate welfare is a more complex variable than profit, understood as the simple difference between revenues and costs, since it must reflect not only the tangible part of transactions but also what are known as the externalities, i.e. the additional social benefits of a good or service beyond private or market benefits.

If the port network is to be competitive, it must guarantee high performance in terms of functionality, security and quality of electricity, business continuity and promote adequate innovation in compliance energy and environmental sustainability.

The CBA approach can be applied in different ways, more or less simplified according to the complexity of the project. In the context of a public policy of financial support for projects, CBA has three supplementary purposes:

- to assess whether the project is worthy of public financial support (socio-economic viability);
- to assess the level of public funding the project requires, which could be equal to the economic value of the public benefits or, alternatively,
- to verify the adequacy of the public funding previously assigned to the project (financial viability of the project).

The project CBA envisages two main stages:

- **Financial Analysis** to assess profitability;
- **Economic and Social Analysis** that takes the data from the project business plan data and transforms it into social costs and benefits to analyse the socio-economic and environmental effects of the project, quantifying its costs and benefits for the community.

The CBA requires the adoption of a common, monetary unit of measurement and is concluded with the calculation of indicators such as the benefit-cost ratio (B/C), the economic net present value (NPV) and the socio-economic internal rate of return (IRR).

CBA is particularly suitable for assessing the social utility of projects that are costly for the community but rich in both direct and indirect positive environmental effects, such as energy and environmental port improvements.

In the field of CBA analyses relative to energy and environmental improvements in ports, the Guidelines define certain simplifications that limit the analysis to the environmental benefits related to the reduction of fossil fuel consumption and CO_2 emissions, these being the objectives of Art. 5 of Legislative Decree 169/2016. The analysis focuses on the profitability of the interventions less in relation to the amortisation time of the investment and more in relation to the "Technical Life" of the projects, as defined in Table 2 of Annex A to the resolution of the Authority for Electricity and Gas of 27 October 2011 EEN 9/11 (Guidelines for energy efficiency certificates).

The Guidelines classify energy and environmental improvement interventions in ports according to a scale of complexity that varies in relation to the type of intervention, the financial dimension and the presence/absence of forms of pricing that constitute sources of economic revenue.

Table 2.1: Economic Evaluation Techniques Required According to the Categories of Energy and Environmental Interventions

Categories of energy and environmental interventions		**Evaluation techniques required**	**Interventions envisaged by the AdSP Ionian Sea**
Interventions supported by private entities	1. Energy and environmental interventions (other than public works or public utilities), supported by private parties operating in ports, which do not entail public contributions specifically intended for ports, but which can draw on the incentive mechanisms for energy efficiency and renewable sources	Non-mandatory assessment procedure; port authorities collect from these entities the necessary information to complete the overview of energy and environmental data (CO_2 savings)	**Photovoltaic Systems in areas and buildings managed by Concessionaires**
	2. Energy and environmental interventions (other than public works or public utilities), supported by private entities operating in ports, also with the financial support (including guarantees) of the Energy Efficiency Fund proposed by the 2015 National Strategic Plan for Ports and Logistics	Cost-benefit analysis, with the depth of analysis proportionate to the size of the intervention (total investment):	--
	2.(a) investments of less than EUR 10 million	2.(a) **simplified cost-benefit analysis** of the project	**Relamping outdoor spaces and interior lighting of buildings managed by Concessionaires**

Categories of energy and environmental interventions		Evaluation techniques required	Interventions envisaged by the AdSP Ionian Sea
	2.(b) investments over EUR 10 million	2.(b) full cost-benefit analysis of the project.	--
Interventions supported by the public or public-private sector	3. Energy and environmental interventions concerning public works or public utilities fully financed with public funds or partially state-funded:	Different CBA methods, modulated by type and size of investment, depending on the case (a, b, c, d):	--
	3.(a) capital renewal (e.g. extraordinary maintenance, recovery and renovation)	3.(a) **cost-effectiveness analysis**;	**Relamping outdoor spaces and interior lighting of AdSP-owned buildings**
	3.(b) new works, without service pricing, with investments of less than EUR 10 million;	3.b) **simplified cost-benefit analysis;**	**Photovoltaic facilities in areas and buildings managed by AdSP**
	3.(c) new works, without service pricing, with investments over EUR 10 million;	3.(c) cost-benefit analysis (full);	--
	3.d) new works of any size, for which service pricing is envisaged (excluding type a) works, "capital renewal").	3.d) **cost-benefit analysis (full).**	**System for the distribution and supply of electricity to ships in the dock.**

This classification involves the application of one of the 3 different cost-benefit analysis methods set out in Leg. Decree 228/2011 and in the Prime Min. Decree of 3 August 2012, specifically

- Full cost-benefit analysis;
- Simplified cost-benefit analysis;
- Cost-effectiveness analysis

Full cost-benefit analysis is understood to be analysis that includes at least the following stages, which can be inferred from the body of legislation made up of Leg. Decree No. 228/2011 and subsequent implementing provisions:

- analysis of needs and supply;
- economic and financial analysis (including the Business Plan, the profitability analysis of the work and its viability);
- socio-economic feasibility analysis (cost-benefit analysis in the strictest sense);
- sensitivity and risk analysis (both financial and socio-economic).

Simplified cost-benefit analysis consists of the following stages:

- needs analysis;
- economic and financial analysis;
- simplified socio-economic feasibility analysis (analysis of costs and main benefits).

A careful analysis of needs is required because energy and environmental improvements presuppose the subsistence and maintenance of energy-consuming activities over time, to prevent the contribution from being wasted despite project implementation.

The socio-economic feasibility analysis can be simplified, as envisaged by the Prime Min. Decree of 3 August 2012, by using a single indicator that avoids several stages and estimates of benefit items in the socio-economic analysis by calculating the following Benefit / Cost ratio:

$$\frac{C_{ext} evitati}{C_{inv_{+}} C_{es}}$$

Where:

- Avoided **Cext** are the external environmental costs avoided by the energy and environmental improvement in the reference period compared to the scenario without improvements (appropriately discounted to the base year of the analysis),
- **CInv + Cop** are the investment and operating costs over the reference period of the project directly deduced from the Business Plan (also discounted to the base year of the analysis and calculated in differential terms with respect to the chosen reference scenario).

Cost – effectiveness analysis is a simplified evaluation procedure for calculating one or more indicators that relate the economic costs of an intervention to benefits deemed most representative of the main expected results of a project, expressed in a non-monetary unit of measurement. Simplification occurs mainly at two levels:

- the representation of results with a physical unit of measurement avoids a much more complex reconstruction of benefits in economic terms;
- in terms of costs, it is possible to refer only to investment costs, avoiding the complexities and uncertainties of prior evaluation of operating costs.

In the case of energy and environmental projects, the cost-effectiveness indicator is given by the ratio between the investment cost and the total emissions of CO2eq saved over the project's technical lifetime.

Given that in many cases energy and environmental improvements aimed at reducing CO2 emissions may entail significant co-benefits for other pollutant factors (particulate matter, NOx, SO2, noise pollution, etc.), to take into account these factors of merit of a project, it is desirable to use multiple indicators, for example related to the same cost item (initial investment± increase/decrease in operating costs over the technical lifetime), using appropriate equivalence factors between pollutants. This work recommends taking into consideration the following three pollutant parameters: CO2, PM2,5, NOx.

The reference formula for cost-effectiveness analysis is therefore as follows:

$$\frac{a \times ton\ CO_{2evitate} + b \times tonPM_{2,5evitate} + c \times ton\ NO_{xevitate}}{C_{inv}}$$

where:

- **tonnes of CO2 saved, tonnes of PM2.5 saved, tonnes of NOx saved** are the cumulative amounts of annual emissions saved by the project over the reference period, compared to the alternative scenario,
- **while parameters a, b, c** express the factors of equivalence to CO2 emissions:
  a = 1 **b = 2193** **c = 120**

3 INTERVENTIONS COORDINATED WITH THE PLANNING OF THE PORT NETWORK OF THE IONIAN SEA

It was immediately clear to the AdSP MI that most of the emissions (not only CO2) pertaining to the scope of the analysis, come from both stopover and resident ships (about 90%). This is why AdSP MI began some years ago to assess the feasibility of implementing dock electrification systems (cold ironing).

The **POT 2020-2022** (December 2021 revision) includes, within Plan Objective No 2 “Sustainability”, certain strategies aimed at achieving the objectives. Some of these are currently being implemented, some planned and some under evaluation.

Action No 6 of the 2021 revision of the POT ("Supply of Energy from Renewable Sources and Development of Alternative Fuels and LNG"), identifies three strategies in particular:

1. Reducing the energy consumption of vessels, from large ships to small service boats
2. Reducing the energy consumption of buildings, facilities and infrastructure
3. Incentives for carrying out energy efficiency improvements and installing plants to produce renewable energy.

For the implementation of the first strategy, as part of the National Recovery and Resilience Plan (PNRR), AdSP MI obtained funding for the construction of cold ironing systems at:

- the public docks;
- the Multi-Purpose Pier
- the Oil Jetty

There are two main **criteria** used in the selection of the most promising project areas in terms of reducing consumption and emissions, with the greatest potential for cost-effectiveness and efficiency:

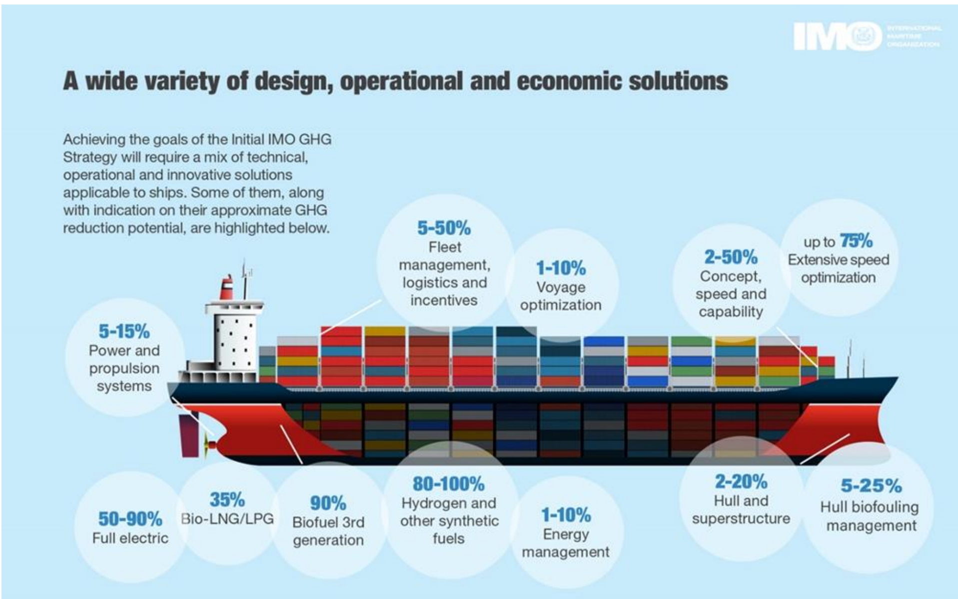
- Percentage weight of consumption and emissions of the activity as a proportion of the total; finding effective solutions to reduce the consumption and emissions of these activities would have a significant impact on the results;
- Difference between the current energy efficiency of the activity and the state of the art, combined with the simplicity of intervention; the simpler and more effective it is to carry out the intervention, perhaps due to obsolescence of the technology currently in place, the greater the cost-effectiveness and benefit/cost ratio.

AdSP MI, moreover, is knowledgeable about the best practices and state-of-the-art technology for reducing emissions in ports and intends to pursue a strategy towards adopting these criteria in order to make the Port of Taranto increasingly smart and green.

As far as ground structures (buildings, lighting, installations) are concerned, the solutions - and limits - for energy efficiency and renewable energies are well known and time-tested: heat pumps, LEDs, insulation, photovoltaics, etc. The use of such solutions has therefore been evaluated where it is actually cost-effective.

The situation is much more complex when it comes to the reduction of consumption and emissions from resident ships and ships stopping over in the Port of Taranto. Although both the European Union and the IMO(International Maritime Organisation) have set progressive and ambitious emission reduction targets , the current technology does not provide a clear path towards these objectives.

There exists a wide variety of useful solutions, but their level of technological development is not yet sufficient to assess their impact.

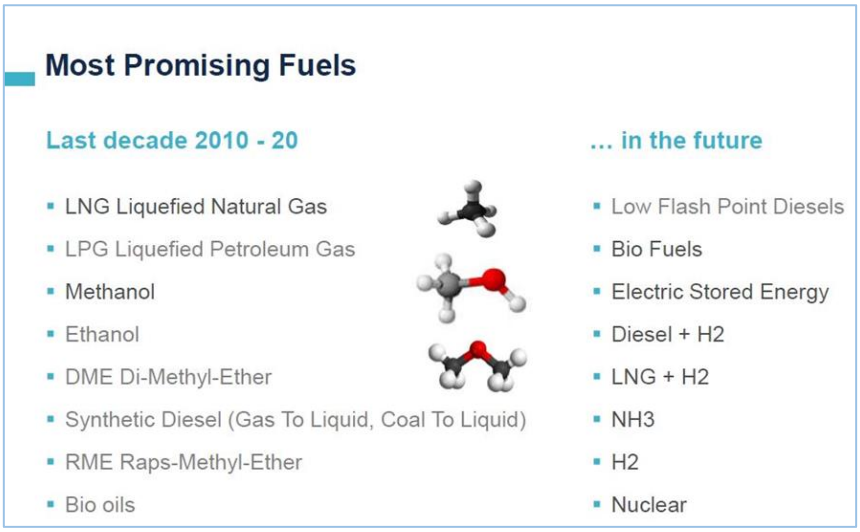


Source: IMO (2021)

Figure 3.1: Examples of Solutions for Reducing Ship Consumption and Emissions

In addition to the technological development that is yet inadequate for large scale interventions, another uncertainty is the need to converge the needs of those who have to build the infrastructure (mainly the Port Network Authorities) with those who have to convert/build ships suitable for the new technologies (ship-owning companies and shipyards). Whilst the authority can in fact decide autonomously on its own investments in the necessary infrastructure, it is not in a position to influence the investment decisions of third parties, such as ship-owning companies, which would have to modify their own ships or build new ones equipped with specific technologies in order to be able to exploit the infrastructure. At present, therefore, there appears to be the need for economic lever in the form of incentives or regulations.

The most promising technologies can be summarised in the following image on alternative fuels for ships.

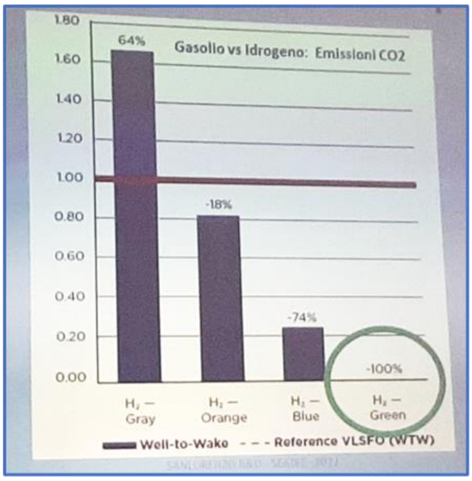


Source: RINA presentation at Sea-tec (2022)

Figure 3.2: Examples of alternative fuels for ships

The real impact in terms of reducing well-to-wake emissions, however, depends in all cases on the “origin” of these fuels or energy vectors. Some of these can achieve carbon neutrality, but only if they come from renewable energy.

See, for example, the case of hydrogen (or more simply that of electricity) shown in the following figure.



Source: Cantieri San Lorenzo presentation at Sea-tec (2022)

Figure 3.3: Comparison of CO2 emissions from alternative fuels

The only fixed point in these cases is that **energy must be produced from renewable sources to ensure a significant impact of the fuel or energy carrier replacing the fossil fuels that are currently used.**

In other cases, there is still a reduction in emissions due to the improved chemical characteristics of the fuel and greater combustion efficiency (e.g. LNG), but without achieving carbon neutrality.

The **AdSP MI strategy** includes:

- **Modularity**. The interventions analysed are modular as far as possible, in both their implementation steps and scalability over time;
- **Priority is given to interventions with a high degree of technological maturity:** all the technologies for improving the efficiency of ground structures, cold ironing;
- **Focus on the installation of plants for energy production from renewable sources with mature technologies**: photovoltaics and wind power (in progress);
- **Medium-term vision**. This includes feasibility studies or the preparation of infrastructure - always with a modular logic - to deal with the most promising and strategically important alternative energy carriers (mainly LNG and hydrogen);

Supporting all stakeholders (concessionaires, consignees, citizens, etc.) in the undertaking of interventions and implementation of measures for the reduction of consumption and the production of renewable energy.

Below is a summary table of interventions, broken down by class (Interventions in progress, interventions being planned, long-term interventions) and by type of interventions, for the Port of Taranto.

Table 3.1: Summary Table of Interventions in the Port of Taranto

	Type of intervention	Stakeholder	Estimated Investment
Interventions in progress	Wind Power Plant	Concessionaires	-
	Charging stations	AdSP	-
	PV installation logistics platform	Concessionaires	-
Interventions being planned	Cold Ironing Public Docks	AdSP	€35,000,000
	Cold Ironing Multi-Purpose Pier	AdSP	€12,000,000
	Cold Ironing Oil Jetty	AdSP	€8,000,000
	Exterior Lighting	AdSP	€400,000
	Exterior Lighting	Concessionaires	€800,000
	Interior Lighting	AdSP	€12,000
	Interior Lighting	Concessionaires	€150,000
	PV canopy installation multi-purpose pier	AdSP/Multi-Purpose Pier	€360,000
	Building-integrated PV installation Adsp headquarters	AdSP	€65,000
	Building-integrated PV installation conc. buildings	Concessionaires	€2,000,000
Long-term interventions	LNG	AdSP	-
	Hydrogen	AdSP	-
	Electrification of permanent ships	Concessionaires	-
	Land vehicle electrification	Concessionaires	-
	Floating PV installation	AdSP	-
	Wave power plant, storage, microgrid	AdSP	-

4 INTERVENTIONS IN PROGRESS (PUBLIC AND PRIVATE)

Interventions in progress are all the interventions, both public and private, currently being carried out within AdSP MI and, in particular, in the Port of Taranto.

4.1 Wind Power Plant

Wind power has become increasingly important over the years and is now one of the best established and proven technologies for generating renewable energy.

In particular, marine wind farms are one of the most interesting frontiers of the entire industry, in terms of both technology and business.

Offshore turbines are of interest because:

- they are better able to exploit air currents, given that these currents are much stronger at sea and the absence of obstacles such as buildings or high ground;
- Suitably positioned, they have no negative impact on the landscape and do not interfere with human activities.

On the other hand, the downsides are:

- the need for ad hoc “foundations” that are adapted to the marine environment, which involves significantly higher costs than for shoreside turbines;
- they require ad hoc infrastructure for connection to the electricity grid.

At the end of April 2022, the first offshore wind farm in Italy and the entire Mediterranean was inaugurated in Taranto. “Beleolico” is a wind farm built by Renexia, a Toto Group company operating in renewable energies, off the Multi-Purpose Pier in Taranto.

Beleolico is an innovative and sustainable infrastructure, consisting of ten 3-MW wind turbines with a total capacity of 30 MW. This ensures the production of 58,000 MWh and, in environmental terms, will save 730,000 tonnes of CO_2 over its 25-year service life.

It is an environmentally and socially sustainable plant, insofar as it is part of a context marked by the presence of heavy industry and is designed to contribute to the revitalisation of Taranto.

Figure 4.1: “Beleolico”, Taranto

AdSP MI and Renexia signed an agreement for the purchase of part of the electricity that will be produced by the Wind Farm once it is operational, so that it can be used to meet the energy demands and improve the energy efficiency of the Port of Taranto.

The agreement stipulates that AdSP MI must purchase at least 10% of the energy produced annually by the wind farm and, in any case, at least 220 MWh per year. In addition, the purchase price shall not exceed 300,00 €/MWh and in any case shall always be 10% lower than the price obtained by applying the best contractual conditions provided for in the conventions and framework agreements made available by Consip SpA.

Beleolico was conceived with the involvement and discussion of multiple associations, as well as local and national stakeholders. It is the result of a new green and socially conscious business model that seeks to create a real benefit for all.

4.2 Photovoltaic Systems

Solar energy is the main renewable energy source on the planet and photovoltaics continue to drive investments today. There are already some solar installations in the Port of Taranto. In particular, photovoltaic panels have been installed on the roofs of two buildings inside the Logistics Platform and on the roofs of two buildings that will house the technical and nautical services.

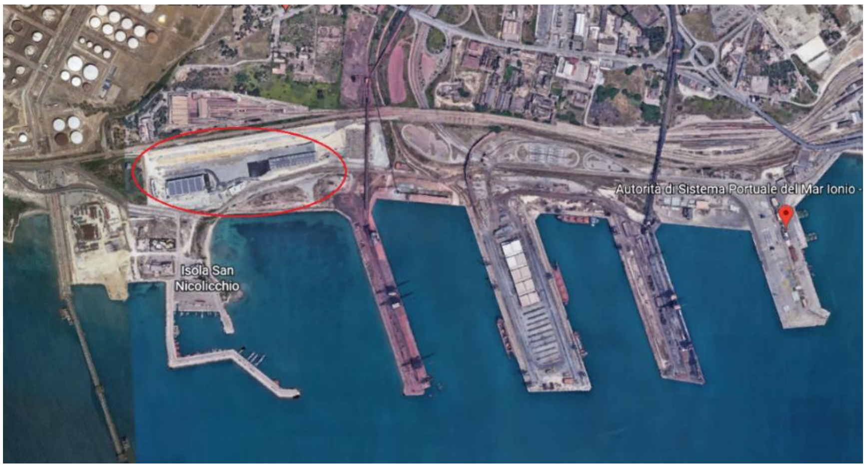


Figure 4.2: map showing the location of the Buildings with PV Systems within the Port of Taranto

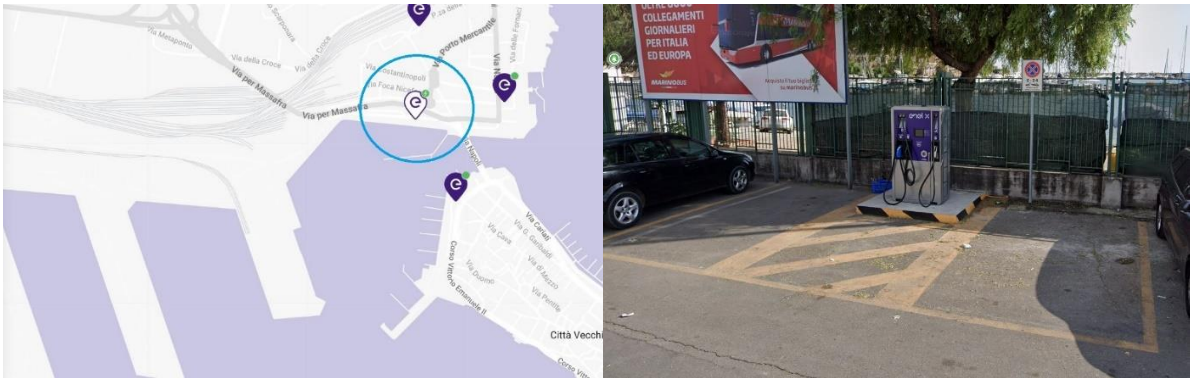
4.3 Charging Station

Considering that urban mobility is growing rapidly, we need to search for effective and viable solutions for the development of sustainable mobility systems. Throughout Europe, transport continues to contribute to air pollution and all that this implies. Enel X s.r.l. (EX) and AdSP of the Ionian Sea have set as one of their main objectives the remediation and protection of air quality, recognising the great potential of e-mobility in terms of reducing both air and noise pollution.

This is why we installed 1 EX Fast Recharge electric recharging station, located in the state-owned maritime area of the AdSP MI district.

Enel X took care of identifying useful areas and requesting them from AdSP, as well as taking charge of the design of the charging station and all necessary authorisations. EX is also responsible for the maintenance of the electric charging infrastructure and testing.

The Port Network Authority of the Ionian Sea, on the other hand, guaranteed maximum cooperation with Enel X to ensure the success of the project, which helps reduce fuel consumption and consequent emissions.



5 INTERVENTIONS BEING PLANNED

Interventions under planning are all interventions that have been subject to an initial economic or cost-benefit analysis and which envisage the use of sufficiently mature technologies so that they can be implemented by public or private entities or through forms of public-private collaboration, such as Public Private Partnerships (PPPs).

The pursuit of energy and environmental sustainability is closely linked to reducing the energy requirements of the regular activities that take place in the port area.

In this paragraph, in terms of reducing the energy consumption of and emissions produced by AdSP MI's own infrastructure, the projects evaluated include relamping (both exterior lighting and interior lighting), the installation of photovoltaic systems and the installation of dock electrification facilities (cold ironing), on both Adsp MI's own buildings and concessionaire buildings.

NB: the drafting of this document ran from the end of 2021 to mid-2022. During this period, world events brought enormous and sudden changes in energy supply and, consequently, in energy commodity prices. However, given the unpredictability of the most recent prices, and as a conservative estimate of the economic return, an electricity price of 0.18 €/kWh was considered in the evaluations.

5.1 Relamping AdSP Exterior Lighting

The consumption analysis showed that a large proportion of electricity is consumed by exterior lighting.

The energy requalification proposal foresees the replacement of all lighting fixtures (864 units), of the operational parts of the port under the direct control of AdSP MI, namely MH (Metal Halide) and HPS (High Pressure Sodium) lamps installed on light towers with mobile crown or fixed crown, floodlights, on street lamp posts, etc. The new lighting fixtures will be with LED technology of suitable power and luminous flux.

LED lighting systems reduce energy consumption, increase lamp life and reduce the hazardousness of future waste (by eliminating mercury). The choice of LEDs over high-pressure sodium vapour lamps is due to the improved performance in terms of luminous efficacy with equivalent installed power and better colour rendering index rating with equivalent luminous efficacy.

There are a total of 864 lighting fixtures to be replaced, which, according to the bills for 2021, consume approximately 1,241.52 MWh/year of electricity.

With relamping, the use of LEDs could reduce energy consumption to about 555.68 MWh/year, with energy savings of about 682.32 MWh/year. Savings after LED relamping are estimated to be around 55%. Considering an average cost of electricity of 0.18 €/kWh (derived from the PODs of 2021, taking into account costs and consumption from January to September), relamping would lead to savings of approximately €122,909.99 per year.

Table 5.1: Analysis of LED relamping AdSP MI Exterior lighting - Energy and cost savings

EXTERIOR LIGHTING AdSP									
	Before intervention			After intervention			Savings		
No of lamps	Installed power	Electricity consumption	Annual cost of electricity	Installed power	Electricity consumption	Annual cost of electricity	Achievable annual energy savings	Annual cost savings	savings
	[kW]	[MWh]	[€]	[kW]	[MWh]	[€]	[MWh/year]	[€]	[%]
864	222.6	1,241.52	223,472.70	99.17	558.68	100,562.72	682.83	122,909.99	55%

Table 5.2: Analysis of LED relamping AdSP Exterior lighting - Reduction of CO2 emissions

AdSP EXTERIOR LIGHTING – emissions of Co2eq$_{eq}$		
Before intervention	**After intervention**	**Emissions reduction**
[tCO2eq]	*[tCO2eq]*	*[tCO2eq]*
3.16E+02	1.42E+02	1.74E+2

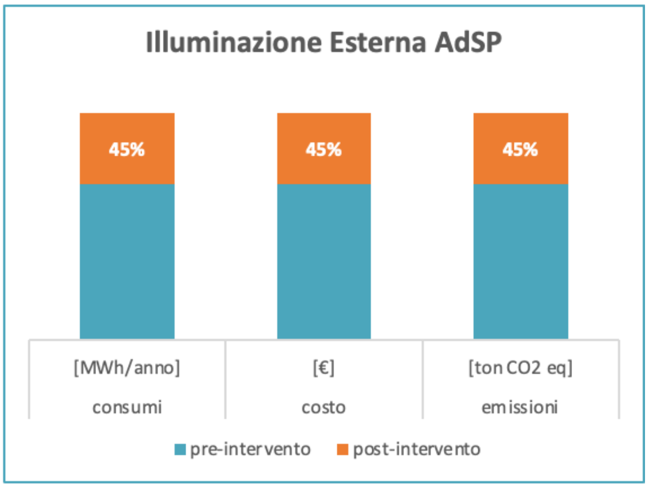


Figure 5.1: Comparison of consumption, costs and emissions of electric lighting of outdoor spaces, before and after the intervention

5.1.1 Analysis of the cost-effectiveness of the intervention

The project is expected to cost around €400,000 for the replacement of the fixtures currently in use with LED lamps. Please note that no operating costs have been taken into account as they are conservatively assumed to be the same as those for the existing system.

Table 5.3: Economic and financial data, exterior lighting intervention

ECONOMIC AND FINANCIAL DATA	
Price of energy saved	0.18 €/kWh
Installation costs	€400,000.00
Annual savings	€122,909.99
Simple PBT	3.3 years
Nominal system life	10 years
Annual interest rate	2%
NPV	€704,049.39
IRR	28%
Annual deviation in energy cost	2%
NPV (with energy drift)	€829,099.85

Below is a simplified estimate of the cumulative cash flow of this intervention. The X-axis shows the years and the Y-axis shows the investment cash flows.

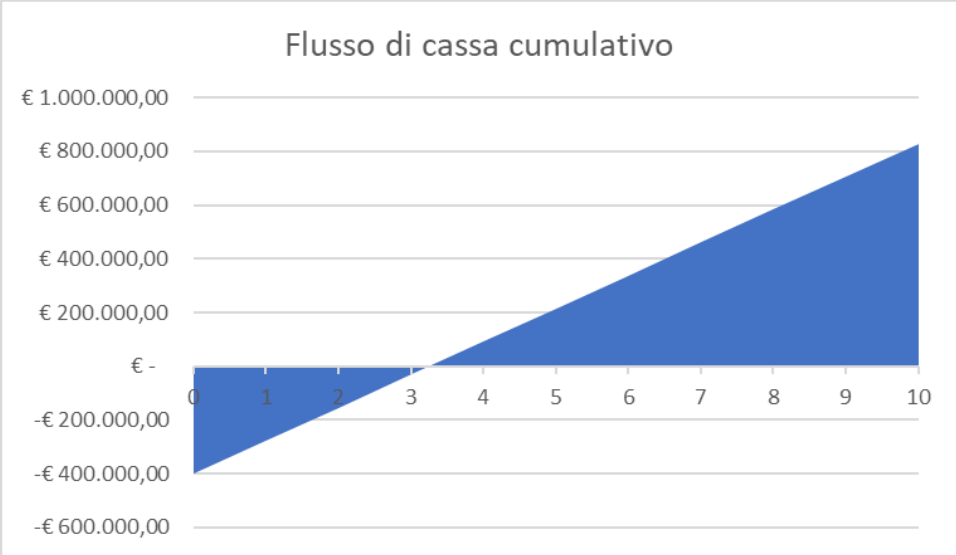


Figure 5.2: Cumulative Cash Flow of the Intervention

The cost-effectiveness analysis procedure is also applied to the Relamping project for the outdoor spaces of AdSP buildings.

The project is expected to cost around €400,000 for the replacement of the fixtures currently in use with LED lamps. Please note that no operating costs have been taken into account as they are conservatively assumed to be the same as those for the existing system.

Projects to improve energy efficiency the end use of electricity are beneficial to the environment in terms of the reduced emissions associated with energy savings. Taking into account auxiliary consumption and network losses, the standard unit benefit for CO2, NOx and PM2.5 in 2015 is 620.4 gCOeq saved/kWh.

The annual energy savings are 682.84 MWh/year, equivalent to 6,828.4 MWh of energy saved over the 10-year service life of the system (RSL). Consequently, we can make the following estimates:

AdSP Exterior LIGHTING – Cost-Effectiveness Indicator					
investment cost [€]	Energy savings [kWh saved]	Unit benefit [g $CO2_{eq}$ saved]	Emissions saved [tonnes $CO2_{eq}$]	Effectiveness of the investment	RSL
400,000	682,840	620.40	424	4236	10
Cost-Effectiveness Indicator			**0.01059**		

5.2 Relamping interior lighting, AdSP buildings

In order to reduce consumption, it is also beneficial to replace the current interior lighting with LED lamps.

Replacing old lighting fixtures with LED devices means analysing several parameters, such as light type, temperature, intensity and wattage. Another factor to take into account is the width of the light beam: in some cases, LED lamps have a narrow beam or a high level of dispersion that may not be ideal for large rooms. By carefully analysing all elements, we can achieve high quality lighting with maximum savings and efficiency.

With LED relamping, it is possible to roughly halve the consumption. The Port Network Authority of the Ionian Sea has 146 ceiling lights with neon bulbs of 18 W, 36 W and 58 W, in addition to unrecorded halogen lighting fixtures. It was decided to estimate the average wattage of the current lighting fixtures at 58 W (to take into account the halogen lamps that were not recorded) and, considering 1,830 hours of use per year, the resulting electricity consumption is 15.50 MWh/year.

Table 5.4: Analysis of LED relamping AdSP Interior lighting – Energy and cost savings

INTERIOR LIGHTING – AdSP Buildings										
	Before intervention					After intervention		Savings		
No	Power	Installed power	Hours/year	Electricity consumption	Annual cost of electricity	Electricity consumption	Annual cost of electricity	Achievable annual energy savings	Annual cost savings	savings
	[W]	[kW]	[h]	[MWh]	[€]	[MWh]	[€]	[MWh/year]	[€]	[%]
146	58	8.468	1830	15.496	2,789.36	6.973	1,255.21	8.523	1,534.15	55%

Table 5.5: Analysis of LED relamping AdSP Interior lighting - Reduction of emissions

INTERIOR LIGHTING AdSP buildings – $CO2_{eq}$ emissions		
Before intervention	After intervention	Emissions reduction
[tCO2eq]	*[tCO2eq]*	*[tCO2eq]*
3.95E+00	1.78E+00	2.17E+00

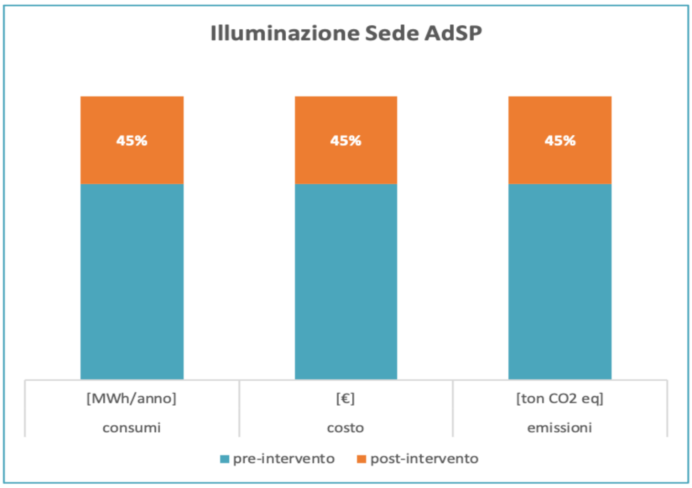


Figure 5.3: Comparison of consumption, costs and emissions of electric lighting of outdoor spaces, before and after the intervention.

5.2.1 Analysis of the cost-effectiveness of the intervention

The project is expected to cost around €12,000 for the replacement of the fixtures currently in use with LED lamps. Please note that no operating costs have been taken into account as they are conservatively assumed to be the same as those for the existing facility.

Table 5.6: Economic and financial data, interior lighting intervention

ECONOMIC AND FINANCIAL DATA	
Price of energy saved	0.18 €/kWh
Installation costs	€12,000.00
Annual savings	€1,534.15
Simple PBT	7.8 years
Nominal system life	10 years
Annual interest rate	2%
NPV	€1,780.61
IRR	5%
Annual deviation in energy cost	2%
NPV (with energy drift)	€3,341.48

Below is a simplified estimate of the cumulative cash flow of this intervention. The X-axis shows the years and the Y-axis shows the investment cash flows.

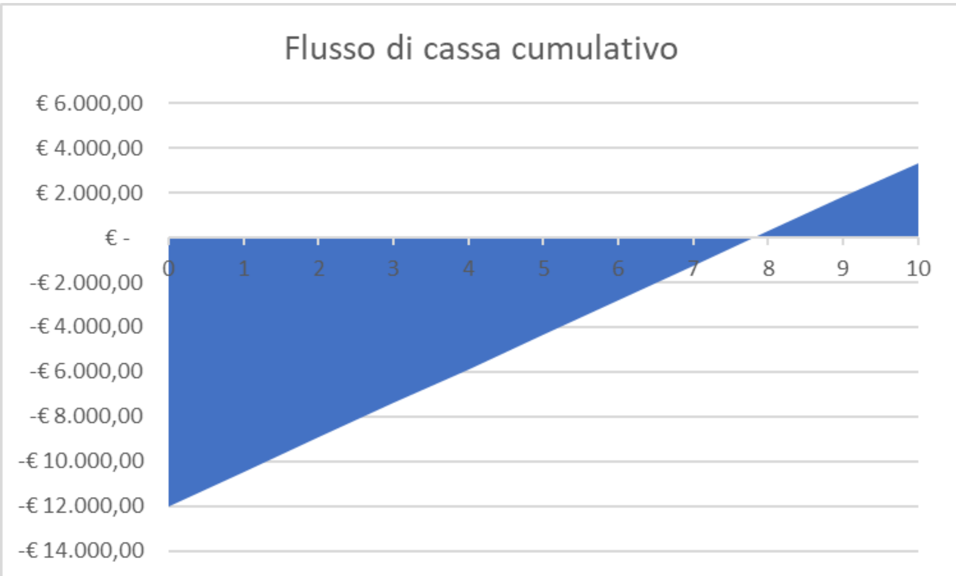


Figure 5.4: Cumulative cash flow of the intervention

The cost-effectiveness analysis procedure is also applied to the Relamping project for the interior lighting of AdSP buildings.

The project is expected to cost around €12,000 for the replacement of the fixtures currently in use with LED lamps.

Please note that no operating costs have been taken into account as they are conservatively assumed to be the same as those for the existing facility.

Projects to improve energy efficiency the end use of electricity are beneficial to the environment in terms of the reduced emissions associated with energy savings. Taking into account auxiliary consumption and network losses, the standard unit benefit for CO2, NOx and PM2.5 in 2015 is 620.4 gCOeq saved/kWh.

The annual energy savings are 8.52 MWh/year, equivalent to 85.23 MWh of energy saved over the 10-year service life of the system. Consequently, we can make the following estimates:

AdSP Interior LIGHTING – Cost-Effectiveness Indicator					
investment cost [€]	Energy savings [kWh saved]	Unit benefit [g $CO2_{eq}$ saved]	Emissions saved [tonnes $CO2_{eq}$]	Effectiveness of the investment	RSL
€12,000.00	8,523	620.40	5	53	10
Cost-Effectiveness Indicator			**0.00441**		

5.3 Development of a Photovoltaic Installation for the Multi-Purpose Pier

For the Port of Taranto, the proposal is to install a photovoltaic system with the aim of producing electricity locally and feeding it into the grid, net of self-consumption, and/or selling it in part or in full to the POD of the Multi-Purpose Pier. The PV system will be grid-connected with installation on a canopy (area of approximately 2,000m^2) and will consist of 908 monocrystalline photovoltaic solar panels. The peak power of the installation is 345 kWp, with the production of over 520 MWh/year in total.

According to the bills for POD 811 at the Multi-Purpose Pier, the annual consumption in 2020 was approximately 996 MWh, while the energy produced and self-consumed by the PV system would lead to savings in electricity consumption of approximately 514 MWh. Considering an average energy price of 0.18 €/kWh (obtained by dividing the costs of the bills by the consumption in reference to the period January to September 2021), the cost savings that would be achieved with this PV system total approximately €92,531.92.

The AVERAGE monthly consumption of the Port's Multi-Purpose Pier was taken from the bills for 2020, while the average monthly production of the photovoltaic system was obtained using the PVGIS tool, entering the geolocation data of the Multi-Purpose Pier and a peak power of 345 kWp.

Table 5.7:Analysis of energy consumption POD 811 and electricity production with 345-kWp PV.

MONTH	AVERAGE monthly consumption (from grid) [kWh]	AVERAGE monthly producti on [kWh]	Average production /	Energy produced and self-consumed [kWh]	Energy produced and self-consumed [%]	Annual savings (cash flow - CF)

			average consumption [%]			
January	112,292	30,097	27%	30,097	100%	€5,417.37
February	36,363	30,933	85%	30,933	100%	€5,567.92
March	92,492	42,906	46%	42,906	100%	€7,723.03
April	78,030	47,118	60%	47,118	100%	€8,481.20
May	64,999	53,595	82%	53,595	100%	€9,647.06
June	47,288	54,064	114%	47,288	87%	€8,511.84
July	61,531	58,750	95%	58,750	100%	€10,575.04
August	89,178	57,305	64%	57,305	100%	€10,314.94
September	99,751	46,786	47%	46,786	100%	€8,421.50
October	105,092	39,941	38%	39,941	100%	€7,189.43
November	118,367	30,426	26%	30,426	100%	€5,476.73
December	90,617	28,921	32%	28,921	100%	€5,205.85
TOT	**996,000**	**520,843**	**52%**	**514,066**	**99%**	**€ 92,531.92**

Table 5.8:Analysis of CO2eq emissions reduction. Through production and self-consumption of renewable electricity 345-kWp PV

PV installation Multi-Purpose Pier – emissions of $CO2_{eq}$		
Before intervention	After intervention	Emissions reduction
[tCO2eq]	*[tCO2 eq]*	*[tCO2eq]*
2.54E+02	1.48E+002 *of which* 2 *.57E+01 from renewable EE* 1 *.23E+02 from grid EE*	1.05E+02

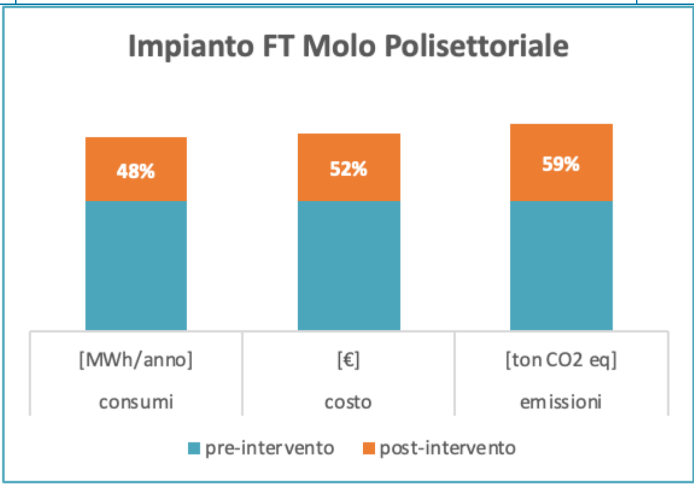


Figure 5.5: Comparison of consumption, costs and emissions of the installation of the PV system at the Multi-Purpose Pier before and after the intervention

5.3.1 Cost-benefit analysis of the intervention

For the installation and maintenance of the proposed photovoltaic system, we estimate an investment of €360,000.00 (without considering the cost of constructing the special solar canopies) and €5,175.00 in annual maintenance costs. In the last year of the system's nominal life, €20,700.00 was added to maintenance to account for the costs of disposing of a 345-kWp photovoltaic system.

Table 5.9:Economic and Financial Data for the Installation of a PV System

ECONOMIC AND FINANCIAL DATA	
Price of energy saved	0.18 €/kWh
Installation costs	€360,000.00
Annual savings	€92,531.92
Annual maintenance costs	€5,175.00
Disposal costs	€20,700.00
Simple PBT	4.1
Nominal system life	30
Annual interest rate	2%
NPV_{30}	€1,585,089.68
IRR	24%
Annual deviation in energy cost	2%
NPV_{30} (with energy drift)	€2,260,707.48

Based on the data obtained by analysing consumption in 2020 and observing the system's production, we estimate a simple payback time of 4.1 years; the net present value (NPV30) is €1,585,089.68 with an annual interest rate of 2%; and the internal rate of return (IRR) is 24%. Considering the annual deviation in energy cost of 2%, the net present value, again considering 30 years of service life, is €2,260,707.48.

Below is a simplified estimate of the cumulative cash flow of this intervention. The X-axis shows the years and the Y-axis shows the investment cash flows.

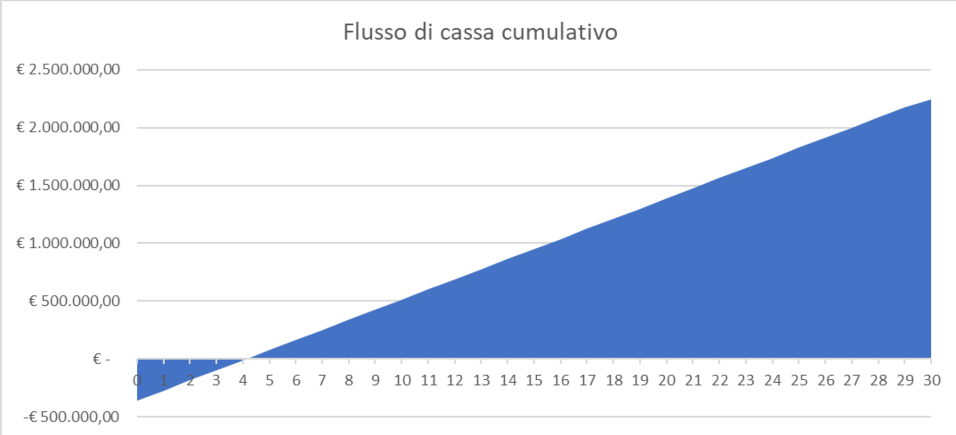


Figure 5.6: Cumulative cash flow of the intervention

The simplification of the socio-economic feasibility analysis, foreseen by Prime Ministerial Decree of 3 August 2012, suggests adopting the simplified cost-benefit analysis for the evaluation of this intervention.

Based on the described methodology, an environmental benefit of 45.4 €/MWh is thus obtained for 2022. The annual energy savings are 514 MWh/year, which over the 30 years of reference service life result in a consumption reduction of 15,422 MWh. Thus, we can estimate as follows:

C_{ext} saved = €588,708.38

C_{Inv} + C_{op} = 360,000.00 + (5,175,00x30) = €515,250.00

Consequently, the Benefit/Cost ratio is 1.14.

Under these conditions and assumptions, the intervention is both environmentally and economically/financially viable.

5.4 Installation of a photovoltaic system at the AdSP MI headquarters

Given the energy benefits of installing photovoltaic systems, this solution is also proposed for the Headquarters of Port Network Authority of the Ionian Sea.

The system has a peak power of 60 kWp; thanks to the use of the PVGIS Tool, its annual electricity production is estimated at 88.8 MWh.

According to the bills for the PODs of the AdSP MI headquarters, the annual consumption in 2021 was 249.17 MWh, while the energy produced and self-consumed by the PV system would lead to savings in electricity consumption of 88.8 MWh. Considering an average energy price of 0.18 €/kWh (obtained by dividing the costs of the bills by the consumption in reference to the period January to September 2021), the cost savings that would be achieved with this PV system total approximately €15,983.21.

Table 5.10: Analysis of energy consumption AdSP headquarters and electricity production with PV 60 kWp

MONTH	AVERAGE monthly consumption (from E-Distribution) [kWh]	AVERAGE monthly production [kWh]	Average production / average consumption [%]	Energy produced and self-consumed [kWh]	Energy produced and self-consumed [%]	Annual savings (cash flow - CF)
January	21,797	5,316	24%	5,316	100%	€956.79
February	18,629	5,405	29%	5,405	100%	€972.83
March	21,173	7,389	35%	7,389	100%	€1,329.98
April	20,111	8,043	40%	8,043	100%	€1,447.70
May	19,402	9,038	47%	9,038	100%	€1,626.75
June	23,290	9,053	39%	9,053	100%	€1,629.58
July	26,363	9,774	37%	9,774	100%	€1,759.28
August	25,152	9,536	38%	9,536	100%	€1,716.53
September	18,835	7,912	42%	7,912	100%	€1,424.23
October	17,929	6,889	38%	6,889	100%	€1,240.00
November	17,282	5,383	31%	5,383	100%	€968.87
December	19,206	5,059	26%	5,059	100%	€910.66
TOT	**249,169**	**88,796**	**38%**	**88,796**	**100%**	**€ 15,983.21**

Table 5.11: Analysis of CO2eq emissions reduction. Through production and self-consumption of renewable electricity PV 60 kWp

PV installation at AdSP headquarters – emissions of $CO2_{eq}$		
Before intervention	After intervention	Emissions reduction
[tCO2eq]	*[tCO2 eq]*	*[tCO2 eq]*
6.34E+01	4.53E+001 *of which 4.44E+00 from renewable EE 4.08E+01 from grid EE*	1.82E+01

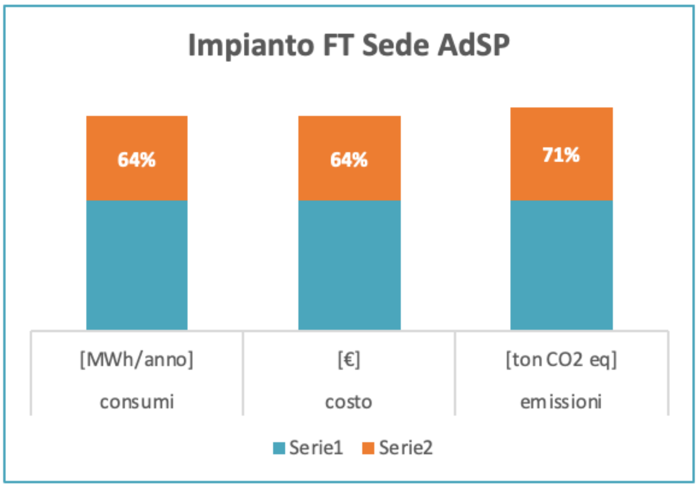


Figure 5.7: Comparison of consumption, costs and emissions of the installation of the PV system at the AdSP Headquarters before and after the intervention

5.4.1 Cost-benefit analysis of the intervention

For the installation and maintenance of the proposed photovoltaic system, we estimate an investment of €65,000.00 and €900.00 in annual maintenance costs. In the last year of the system's nominal life, €3,600.00 was added to maintenance to account for the costs of disposing of a 60-kWp photovoltaic system.

Table 5.12: Economic and financial data for the installation of a 60kWp PV system

ECONOMIC AND FINANCIAL DATA	
Price of energy saved	0.18 €/kWh
Installation costs	€65,000.00
Annual savings	€15,983.21
Annual maintenance costs	€900.00
Disposal costs	€3,600.00
Simple PBT	4.3
Nominal system life	30
Annual interest rate	2%
NPV_{30}	€270,855.20
IRR	23%
Annual deviation in energy cost	2%
NPV_{30} (with energy drift)	€387,496.24

Based on data obtained by analysing consumption in 2021 and observing the system's production, we estimate a simple payback time (PBT) of 4.3 years; the net present value (NPV30) is €270,855.20 with an annual interest rate of 2%; and the internal rate of return (IRR) is 23%. Considering the annual deviation in energy cost of 2%, the net present value, again considering 30 years of service life, is €387,496.24.

Below is a simplified estimate of the cumulative cash flow of this intervention. The X-axis shows the years and the Y-axis shows the investment cash flows.

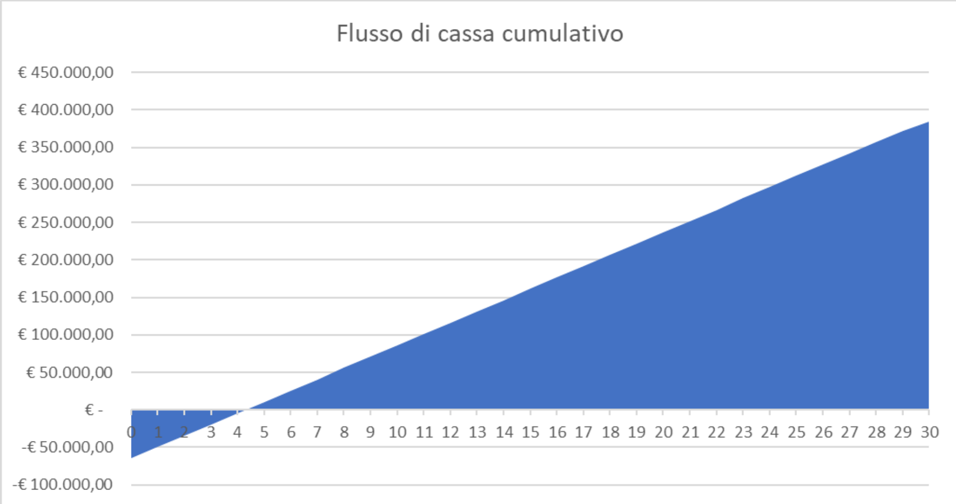


Figure 5.8: Cumulative cash flow of the intervention

The simplification of the socio-economic feasibility analysis, foreseen by Prime Ministerial Decree of 3 August 2012, suggests adopting the simplified cost-benefit analysis for the evaluation of this intervention. Based on the described methodology, an environmental benefit of 45.4 €/MWh is thus obtained for 2022. The annual energy savings are 88.8 MWh/year, which over the 30 years of reference service life, result in a consumption reduction of 2,664 MWh. Thus, we can estimate as follows:

C_{ext} saved = €101,689.00

$C_{Inv} + C_{es}$ = 65,000.00 + (900.00x30) = € 92,000.00

Consequently, the Benefit/Cost ratio is 1.11.

Under these conditions and assumptions, the intervention is both environmentally and economically/financially viable.

5.5 Cold Ironing (Public Docks - Multi-Purpose Pier - Oil Jetty)

While at berth, ships shut down their propulsion engines but use auxiliary engines to ensure continuity of services and power to all electrical equipment on board, such as lighting, heating and load handling interventions.

On-board electricity is supplied by generators consisting of a transformer coupled to a diesel engine or a turbine (gas or steam).

Thus, keeping a ship at berth involves substantial fuel consumption, generating exhaust gases (such as SOX, NOX, atmospheric particulate matter and volatile organic compounds), noise and vibration.

The topic of sustainability has become a major issue at national, European and international level, and the electrification of docks is one of the fast-spreading technological solutions in this field.

Cold Ironing, also known as “Alternative Marine Power” (AMP), “onshore power supply” (OPS) or “shore-to-ship" power (STS), is a particularly effective solution for reducing pollutant emissions from ships in ports.

Electrifying docks means connecting ships to the dock and supplying them with the power they require while at berth via a power line connected to the national grid, thus enabling them to turn off their on-board engines. The ship can remain at berth with its engines switched off, but can continue all loading/unloading interventions and all passenger services are guaranteed. This would significantly reduce pollutant emissions produced during mooring, considering that emissions from the electrified docks are significantly lower than those produced by marine fuels. If the boats were powered by electricity from renewable energy sources, emissions could even be completely eliminated.

Cold ironing also mitigates the problem of noise, which disturbs the harbour and surrounding residential neighbourhoods. The rumble generated by ship engines during mooring accounts for a majority of the noise pollution; it is a low-frequency noise (< 100Hz) that travels over long distances. Connecting ships to shoreside power would also reduce noise pollution as they would switch off their engines while berthed.

When defining the green tech solution of cold ironing at a regulatory level, we must first refer to Art. 4 of the European Directive "on the deployment of alternative fuels infrastructure" - DAFI 2014/94/EU - which foresees, in point 5, the installation of shore-side electricity supply by 2025, giving priority to the ports in the TEN-T network.

Figure 5.9: The 39 Italian Ports of the TEN-T (Trans-European Transport Network)

To date, not many ports are equipped with cold ironing infrastructures, and there are also few ships equipped to receive shore-side electricity. The reasons why the deployment and installation of the facilities has been prevented can be identified by comparing the perspectives of the two main stakeholders involved in the maritime sector: Port Network Authority and ship owners. For the authorities, given the few ships equipped for electrification, the investment has a certain risk of being unprofitable. For shipping companies, on the other hand, it is equally risky to adapt ships when cold ironing facilities are not yet developed in all ports.

Another complication in deploying these facilities is that the ships to be serviced are very different from each other and the infrastructure has to be adapted to the ships requiring power. For example, power, frequency, connection and interface must be taken into account. As far as the connection is concerned, there is no single connection point for all boats, which can vary in height as well as the length of the cables required.

The actual use of cold ironing is closely related to the type of ships and boats and also to the actual power available from the electrical grid to which it is connected in order to transfer sufficient energy.

Ministerial Decree 330 of 13/08/2021 approves the programme of port infrastructure improvements that are synergistic and complementary to the National Recovery and Resilience Plan (PNRR), which foresees the financing of cold ironing facilities in 37 Italian ports. This addresses two of the main obstacles mentioned above: on the one hand, it supports investments by authorities, thus mitigating the associated risk; and on the other hand, it provides for the creation of a network of ports equipped for cold ironing, reassuring shipping companies that ships converted to this technology can be used everywhere.

The technical reference standard for the deployment of cold ironing facilities is IEC8005-1: “Design. Standard for Shore to Ship Power”. It focuses on standards for plugs, sockets and ship couplers for high voltage shore connection systems (HVSC systems).

The elements that make up the system are:

- Substation for connection to the national medium-voltage grid or transformer substation connected to the high-voltage grid;
- Medium-voltage cable distribution within the port area;
- Converter substation 50 Hz --> 60 Hz;
- Distribution to ship connection points;
- Ship connection system;
- On-board connection and interface panel;
- On-board MV/LV transformer;
- Ship distribution network.

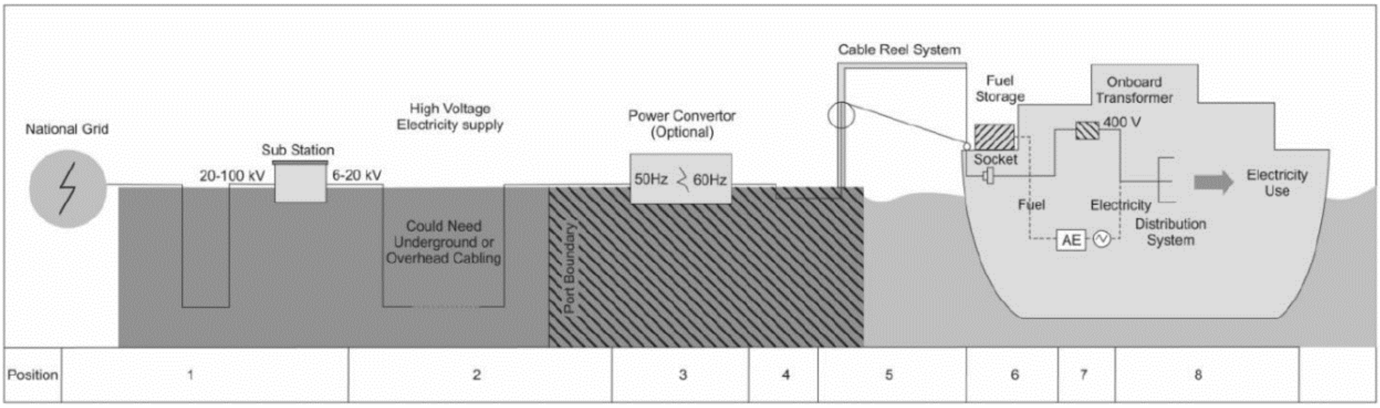


Figure 5.10: Representative diagram of the architecture required for cold ironing

In terms of electrics, below we provide the diagram according to IEC 80005 - 1:

- HV or MV system master switch;
- Power conditioning devices (transformers and frequency converters);
- Safety devices;
- Circuit-breaker and earthing switch;
- Shore-side control equipment;
- Connection and interface equipment;
- On-board control equipment;
- Safety devices;
- On-board transformer (where applicable);
- On-board main switchboard.

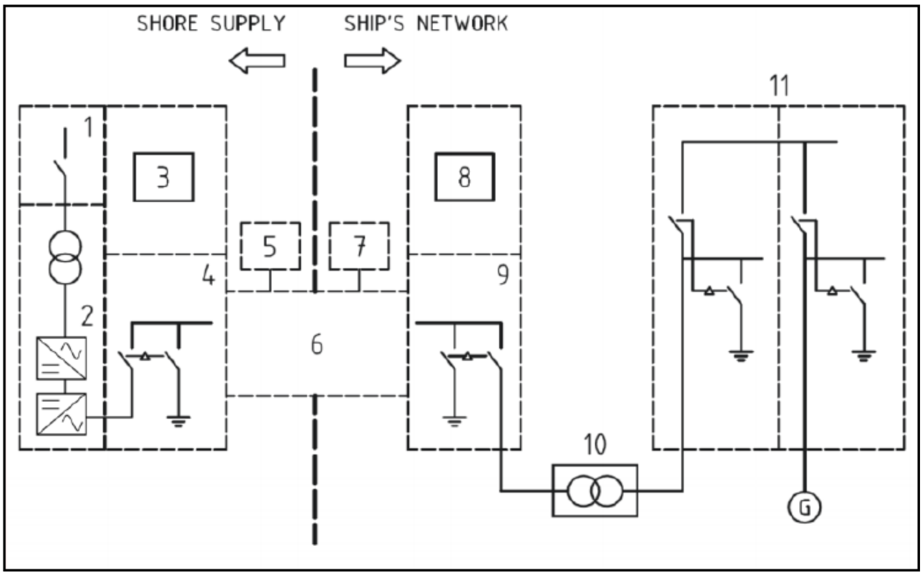


Figure 5.11: Diagram IEC 80005 – 1

Following the technical regulations, the electrification of the berths foresees the following shore works:

- Construction of a primary station for the transformation of electrical energy from 150 kV to 20 kV;

- Installation of static converters (suitably housed, possibly in the primary station) to adapt the national grid frequency (50 Hz) to that of the electrical systems on board some ships (60 Hz);
- Connection between the electricity transmission network and the primary station;
- Installation of a station to house the integrated safety and control systems and possible transformer to adapt the distribution voltage to the supply voltage required by the ships;
- Construction of underground cable ducts for the transmission and distribution of electricity;
- Construction of connection boxes for connecting dock to ship (possibly with devices for handling the connection cables).

There are various types of ship-to-dock connections, which depend on the ship and the space available on the dock for loading and unloading.

- **Barge power supply system**: made by adapting a barge to house the connection system and, where required, the transformer system for adjusting voltage levels;
- **Mobile power supply system**: consists of a trolley equipped with a cable reel whose power supply cable has at one end a connector for the dock connection box and at the other end a connector for the ship;
- **Fixed supply system**: consists of fixed cable cranes built close to the connection boxes..

The Port Network Authority of the Ionian Sea recognises the importance of improving air quality and protecting the environment and sees the electrification of the docks as an important means of significantly reducing the atmospheric emissions and noise pollution generated by ships at berth.

Ministerial Decree 330 of 13/08/2021 approved the programme of infrastructural works in ports, synergic and complementary to the National Plan for Recovery and Resilience (PNRR), allocating EUR 55 million to the AdSP of the Ionian Sea for the construction of cold ironing facilities. This amount is distributed between three separate interventions that will be carried out at the following docks:

- **Public docks** in the port of Taranto, i.e. the surrounding berths (EUR 35 million):
    - at Darsena Taranto (Calata 1 and I Sporgente (Molo San Cataldo) where Passenger/Cruise ships dock,
    - the Darsena Servizi and the IV Sporgente, expanded as part of the recent works on the “Piastra Portuale”; 11,
    - the “Rinfuse Terminal Area” (BULK);
- **Oil jetty** in the port of Taranto under concession to ENI Spa with exclusive use (EUR 8 million), where Liquid Bulk Ships dock;
- **Multi-Purpose Pier** in the port of Taranto under concession to Yilport with exclusive use (EUR 12 million), where mainly container ships dock.

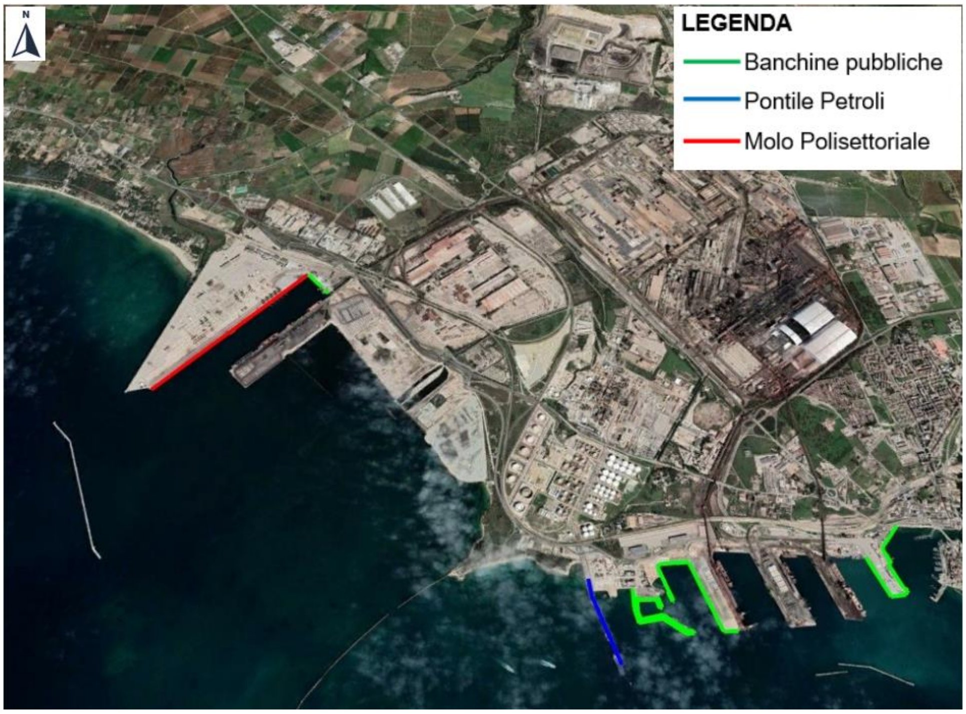


Figure 5.12: Areas of Cold Ironing Installation

To estimate the electricity required to power moored ships, we started with the data recorded for the arrival, departure and time at berth of stopover ships, for the year 2021 (data in line with the last three years). For a more detailed description of the methodology for estimating consumption, see the chapter on Carbon Footprint calculation.

From March 2023, the first year of continuous monitoring of ship movements via AIS will be available, which, when interfaced with information on on-board engines and generators from relevant databases, will make consumption estimates more accurate.

The amount of diesel consumed by stopover ships berthed at the docks for which the works are planned alone is approximately 9,120 tonnes/year. For on-board electricity generation, the specific consumption during mooring was calculated, based on the type of ship taken from inventory and the type of fuel according to the tabular values in 1-a-3-d navigation EMEP/EAA 2021.

The electricity requirements of the ships at berth, useful for the purpose of the cost-benefit analysis of the cold-ironing installation, are limited to the consumption only for the ships expected to berth at the docks concerned, i.e. Passenger/Cruise, Liquid Bulk Ships and Containers. Consequently, extrapolating the data from the table below, the calculated consumption is approximately 41,457 MWh/year[1].

Table 5.13: Fuel consumption and CO2eq emissions of stopover ships (2019-2021)

[1] the ships that stop over at the three docks for which the works are planned include only containers, liquid bulk ships and passenger ships.

YEAR 2019	TOTAL Fuel Consumption	At berth		YEAR 2019	CO2eq	CO2eq at berth
	[tonnes]	*[tonnes]*			*[tonnes]*	*[tonnes]*
Containers	27.58	19.69		Containers	88.67	63.3
Dry bulk carriers	2157.68	1862.47		Dry bulk carriers	6,936.92	5,987.84
General Cargo	587.49	473.74		General Cargo	1,888.78	1,523.08
Liquid bulk ships	9995.1	9760.58		Liquid bulk ships	32,134.18	31,380.21
Others	397.23	384.19		Others	1,277.10	1,235.16
Passenger/Cruise	40	11.46		Passenger/Cruise	129.31	37.1
Ro Ro Cargo	6.07	3.74		Ro Ro Cargo	19.6	12.09
Pusher Tugs	1376.18	884.2		Pusher Tugs	4,571.88	2,937.26
TOTAL consumption 2019	**14587.33**	**13400.07**		**TOTAL emissions 2019**	**47,046.45**	**43,176.03**
	[tonnes]	*[tonnes]*			*[tonnes]*	*[tonnes]*
Containers	133.68	85.25		Containers	429.76	274.08
Dry bulk carriers	1374.86	1141.81		Dry bulk carriers	4,420.18	3,670.90
General Cargo	418.23	313.97		General Cargo	1,344.61	1,009.42
Liquid bulk ships	9319.37	9110.49		Liquid bulk ships	29,961.72	29,290.17
Others	141.9	125.6		Others	456.2	403.8
Passenger/Cruise	753.86	640.67		Passenger/Cruise	2,432.05	2,066.36
Ro Ro Cargo	4.57	2.89		Ro Ro Cargo	14.74	9.33
Pusher Tugs	1555.5	1080.2		Pusher Tugs	5,167.47	3,588.26
TOTAL consumption 2020	**13701.97**	**12500.88**		**TOTAL emissions 2020**	**44,226.73**	**40,312.32**
	[tonnes]	*[tonnes]*			*[tonnes]*	*[tonnes]*
Containers	97.98	45.46		Containers	315.01	146.15
Dry bulk carriers	2174.82	1909.68		Dry bulk carriers	6,992.04	6,139.61
General Cargo	699.38	566.53		General Cargo	2,248.52	1,821.38
Liquid bulk ships	8833.51	8616.92		Liquid bulk ships	28,399.68	27,703.35
Others	10.34	7.81		Others	33.25	25.11
Passenger/Cruise	764.55	458.15		Passenger/Cruise	2,468.70	1,478.81
Ro Ro Cargo	0	0		Ro Ro Cargo	0	0
Pusher Tugs	1636.13	1080.1		Pusher Tugs	5,435.43	3,588.01
TOTAL consumption 2021	**14216.72**	**12684.64**		**TOTAL emissions 2021**	**45,892.62**	**40,902.40**

To assess the viability of the intervention, the following additional estimates and assumptions were made: considering the total electricity requirements of the ships at berth, it was assumed that only half of this would be supplied by cold ironing, considering that not all ships will be able to berth at the same time and that not all ships will be equipped for shore-side electricity supply.

Considering an average 'turnkey' construction cost of 1,000,000 €/MW of power, we can estimate a total installation power of approximately 55 MW. Considering the annual hours (8,760), the energy delivered by the converters of the cold ironing installation at full capacity would amount to approximately 481,800 MWh. However, if we also consider maintenance outages and the technical time of berthing/unberthing/plugging-in, we can estimate a theoretical supply potential of about 385,000 MWh/year.

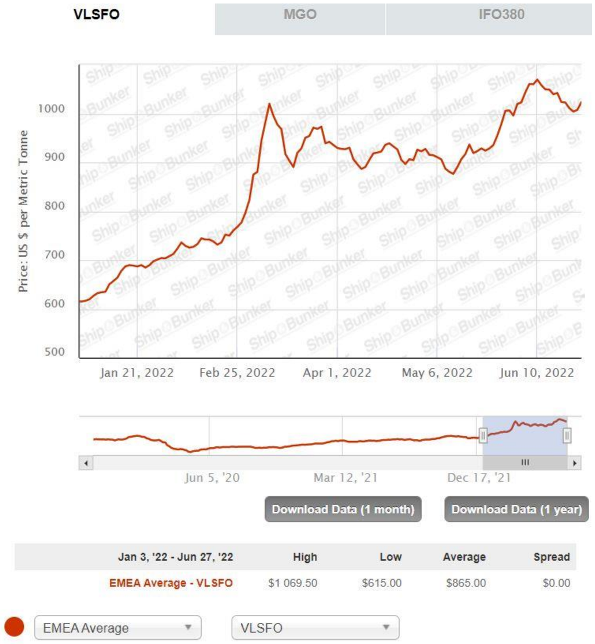
Table 5.14: Characteristics of cold ironing installation

COLD IRONING	
Expected entry into service	2026
Power	55 MW
Electricity required by ships at berth per year at the docks where cold ironing will be installed	41,457 MWh
% coverage of requirements by cold ironing	50%
Expected supply of electricity to ships per year	22,312.5 MWh
Theoretical hours/year	8,760
Electrical energy supplied by converters at full capacity	385,000 MWh
Investment	€55,000,000
Cost per MW	€1,000,000

As extensively documented in numerous recent national and international studies, the viability of cold ironing facilities depends on various factors. In addition to those already mentioned in this chapter, it depends on fuel and energy market performance and the current sudden and extraordinary price fluctuations prevent reliable assessment.

Analysis of the project viability was undertaken using the following assumptions:

- The initial investment is covered by public capital funds;
- Maintenance and running costs for on-board power generation (generators, etc.) equal to 20% of the fuel cost;
- Cost of running cold ironing facilities (maintenance, special staff to provide the service, etc.) of 1 million €/year;
- Electricity requirements of “resident" ships not taken into account (prudent estimate);
- Average fuel purchase price, in line with recent increases, of 900 €/tonne



Under these assumptions, we valued the break-even price to cover the costs of operating the cold ironing service, as well as the price of electricity that would make the total cost to the ship owning companies equal to the current cost of purchasing fuel.

The measures being prepared by the government and ARERA to define the exemption of certain tariff components for electricity used for cold ironing will be decisive in this respect.

Table 5.15: Economic characteristics of cold ironing installation[2]

COLD IRONING	
Diesel consumption for on-board electricity generation	9,120.52 tonnes/year
Average fuel price	900 €/tonne
Estimated current purchase cost	8,208.470 €/year
Total electricity requirements	41.457 MWh_{el}/year
Cost of on-board electricity production, including O&M	*237.6 €/MWh*
Expected supply of electricity to ships per year	22,312.5 MWh
Cold ironing running costs	1,000.000 €/year
Break-even price for running costs	*48.24 €/MWh*
Break-even price for shipowners	*189.36 €/MWh*

To calculate emissions of CO2eq. in the scenario with the installation in place, we considered the external environmental costs of energy taken from the grid; in the alternative scenario (pre-intervention), we quantified the external costs associated with atmospheric emissions from the self-production of electricity by ships berthed in the

[2] The current situation of high variability of energy and fossil fuel prices, as well as the prices of raw materials (which are reflected in the construction cost of many finished works) makes the cost-benefit assessment over the long service life of cold ironing installations particularly uncertain. The assumptions underlying this assessment are all set out in the document, so that the impact of these parameters can be assessed.

port, taking into account the specific features of the fuels used, obtained from the inventory data provided by AdSP for the different vessels stopping over at the different docks concerned by the electrification project.

Table 5.16: Analysis of CO2eq emissions reduction. Following the construction of the cold ironing facility

Cold Ironing facility – emissions of $CO2_{eq}$		
Before intervention	After intervention	Emissions reduction
[tCO2eq]	*[tCO2 eq]*	*[tCO2 eq]*
5.87E+03	5.35E+03	5.11E+02

For the electrification of the three docks, which is currently in the planning stage, AdSP has not yet completed a complete project CBA and therefore a simplified socio-economic feasibility analysis has been prepared as part of the simplified cost-benefit analysis.

The economic-social feasibility analysis considered, as a reference for the evaluation of the status quo consumption, the specific consumption data of the ships that stopped over in 2021, as taken from the inventory used to calculate the Carbon Footprint.

The parameters used for the monetary valuation of the benefits of reducing CO2 and other greenhouse gas emissions are derived from the central value in Table A4_12 of the MIT Guidelines discounted to the value of the prices in the reference year of the CBA prices based on the EU Harmonised Index of Consumer Prices (HICP) for 2021.

The parameters for the marginal costs of pollutant emissions saved are taken from Table A5_12 of the MIT Guidelines.

Table 5.17: Analysis of environmental costs of the Cold Ironing installation

Pollutants	**NO_x**	**SO_x**	**VOC**	**$PM_{2,5}$**	**$CO2_{eq}$**
Emissions saved [tonnes]	496.62	50.38	9.76	26.01	511.25
Factor for calculating the marginal costs of pollutant emissions saved [€/tonne]	€10,824.00	€9,875.00	€1,242.00	€197,361.00	€105.00
External environmental costs saved [€]	€5,375,465.96	€497,549.12	€12,120.81	€5,134,175.63	€53,681.50

Table 5.18: Socio-economic feasibility analysis according to the Guidelines

Socio-economic feasibility analysis calculation (DEASP G.L.)	
Technical lifetime of the operation [years]	15
Total external environmental costs saved (Cext_saved) [€]	€166,094,895.35
Investment cost (Cinv) [€]	€55,000,000.00
Operating cost (Cop) [€] (estimated)	€30,000,000.00
Investment and operating costs [€]	€85,000,000.00
Difference benefits - costs [€]	€81,094,895.35

Socio-economic feasibility analysis (Cext_saved/(Cinv+Cop)	1.95

In addition to reducing polluting emissions, the project also provides significant benefits in the reduction of noise pollution and noise generated by ships berthed in the port, which, as a precautionary measure, have not been quantified in the cost-benefit analysis.

5.6 Exterior lighting (concessionaires)

The proposed actions towards achieving environmental and energy sustainability at the Port include the replacement of outdated lights with new, high-efficiency lighting in the areas currently under concession. To date, the best solution is LED lighting systems, which, compared to old lamps, consume less energy, have longer lamp life and produce less hazardous waste. LED lighting fixtures also perform better in terms of luminous efficacy with equivalent installed power and better colour rendering index rating with equivalent luminous efficacy.

In addition to savings in terms of reduced electricity consumption, the replacement of current lighting fixtures with suitably designed LED technologies also reduces light pollution: achieved via rational lighting without light dispersion into the sky and by adjusting the amount of light according to need.

In order to maximise useful illuminance and minimise light pollution, the most important factor to take into account is the useful light cone generated by each installation and its compatibility with the type of road to be illuminated.

Within the port of Taranto, the streets and squares is already partly illuminated by LED lighting fixtures; the intervention concerns the complete replacement of the SAP fixtures with suitable LED lamps.

From the analysis carried out and the questionnaires completed, we can estimate an electricity consumption by concessionaires for outdoor lighting of about 2,665 MWh/year (with reference to 2021).

With relamping, the use of LEDs could reduce energy consumption to about 1,200 MWh/year, with energy savings of about 1,465 MWh/year; indeed, the estimated savings by LED relamping are 55%.

Considering an average cost of electricity of 0.18 €/kWh (derived from the PODs of 2021, taking into account costs and consumption from January to September), relamping would lead to savings of approximately €263,835.00.

Table 5.19: Analysis of LED relamping, exterior lighting - concessionaires

EXTERIOR LIGHTING - Concessionaires						
Before intervention		After intervention		Savings		
Electricity consumption	Annual cost of electricity	Electricity consumption	Annual cost of electricity	Achievable annual	Annual cost savings	savings

				energy savings		
[MWh]	[€]	[MWh]	[€]	[MWh/year]	[€]	[%]
2,665.00	479,700.00	1,200.00	215,865.00	1,465.00	263,835.00	55%

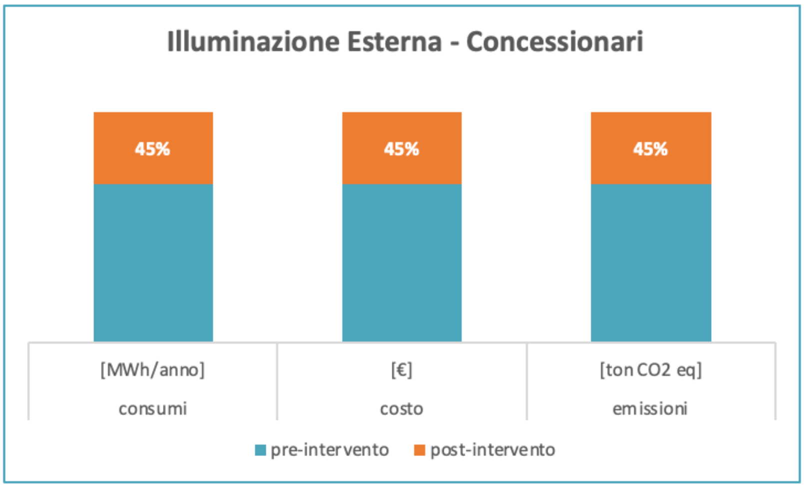


Figure 5.9: Comparison of consumption, costs and emissions of electric lighting of outdoor spaces managed by concessionaires, before and after the intervention

5.6.1 Cost-benefit analysis of the intervention

The project is expected to cost around €800,000 for the replacement of the fixtures currently in use with LED lamps. It is specified that no operating costs have been taken into account as they are conservatively considered to be the same as those envisaged for the existing Please note that no operating costs have been taken into account as they are conservatively assumed to be the same as those for the existing facility.

Table 5.20: Economic and financial data, exterior lighting intervention

ECONOMIC AND FINANCIAL DATA	
Price of energy saved	0.18 €/kWh
Installation costs	€800,000.00
Annual savings	€263,835.00
Simple PBT	3.0 years
Nominal system life	10 years
Annual interest rate	2%
NPV	€1,569,920.32
IRR	31%
Annual deviation in energy cost	2%
NPV (with energy drift)	€1,838,350.00

Below is a simplified estimate of the cumulative cash flow of this intervention. The X-axis shows the years and the Y-axis shows the investment cash flows.

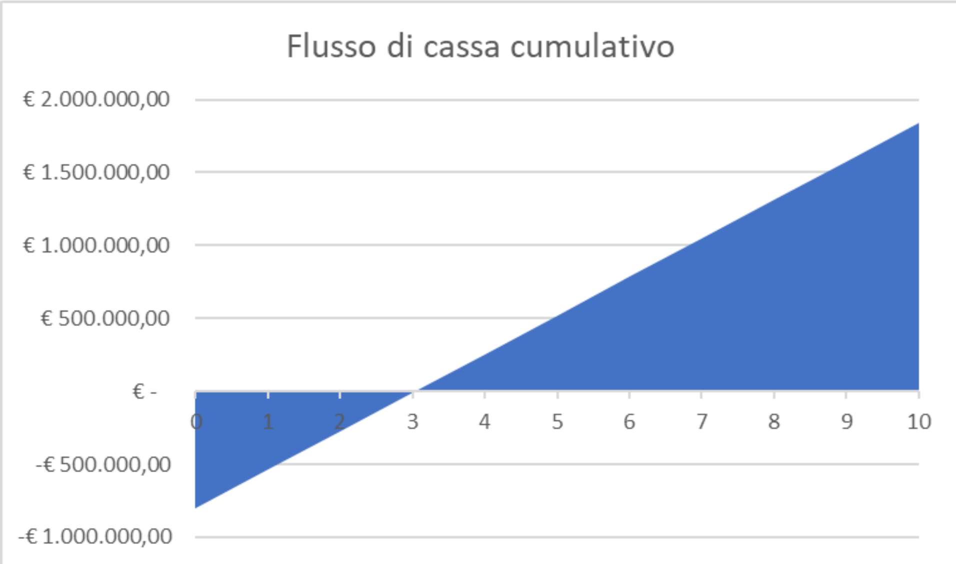


Figure 5.10: Cumulative cash flow of the intervention

In accordance with the Guidelines, the simplified cost-benefit analysis methodology is applied to the relamping by calculating the external costs saved to be considered as environmental benefits of projects improving energy end-use efficiency, calculated for the period 2015-2030 on the basis of the 2030 targets of the National Energy Strategy. From this table, an environmental benefit of 52.7 €/MWh is thus obtained for 2022. The annual energy savings are 1,465.00 MWh/year, which over the 10 years of reference service life result in consumption savings of 14,650.00 MWh. Thus, we can estimate as follows:

C_{ext} saved = €1,005,576.00
C_{Inv} + C_{op} = €800,000.00

Consequently, the Benefit/Cost ratio is 1.26.

Under these conditions and assumptions, the intervention is both environmentally and economically viable.

5.7 Interior lighting (concessionaires)

In addition to the replacement of the concessionaires' exterior lighting fixtures, LED relamping is also proposed for all interior lights in the buildings under concession.

This intervention and replacing all outdated lamps with new LED lighting fixtures roughly halves energy consumption. The concessionaires provided the data on electricity consumption for the buildings under their management. This consumption amounts to approximately 965 MWh/year (reference 2021) and includes all activities that require electricity within the port buildings. It is estimated that 30% of this total consumption is attributable to interior lighting; therefore, the proposed intervention starts from a current consumption of approximately 230 MWh/year of electricity used to light the indoor spaces.

Table 5.21: Analysis of LED relamping, interior lighting - concessionaires

INTERIOR LIGHTING - Concessionaires						
Before intervention		After intervention			Savings	
Electricity consumption	Annual cost of electricity	Electricity consumption	Annual cost of electricity	Achievable annual energy savings	Annual cost savings	savings
[MWh]	[€]	[MWh]	[€]	[MWh/year]	[€]	[%]
230	41,400	105	18,900	125	22,770	46%

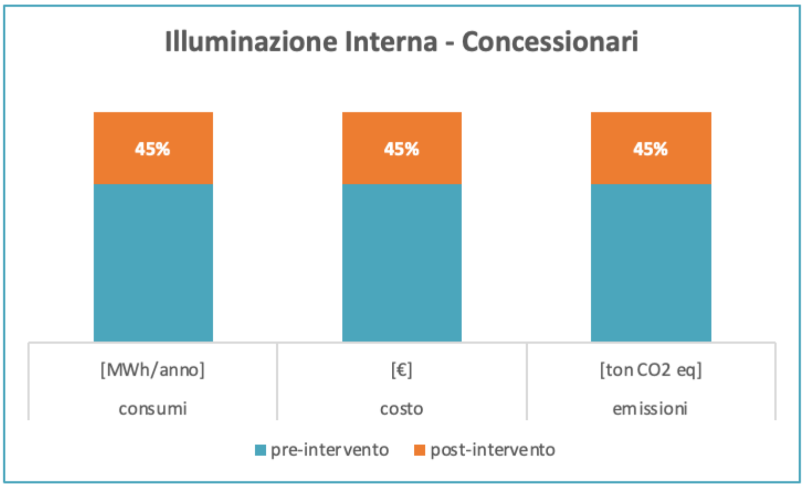


Figure 5.11: Comparison of consumption, costs and emissions of electric lighting of buildings managed by concessionaires, before and after the intervention

5.7.1 Cost-benefit analysis of the intervention

The project is expected to cost around €150,000.00 for the replacement of the fixtures currently in use with LED lamps. Please note that no operating costs have been taken into account as they are conservatively assumed to be the same as those for the existing facility.

Table 5.22: Economic and financial data, interior lighting intervention

ECONOMIC AND FINANCIAL DATA	
Price of energy saved	0.18 €/kWh
Installation costs	€150,000.00
Annual savings	€22,770.00
Simple PBT	6.6 years
Nominal system life	10 years
Annual interest rate	2%
NPV	€54,533.46
IRR	8%

Annual deviation in energy cost	2%
NPV (with energy drift)	€77,700.00

Below is a simplified estimate of the cumulative cash flow of this intervention. The X-axis shows the years and the Y-axis shows the investment cash flows.

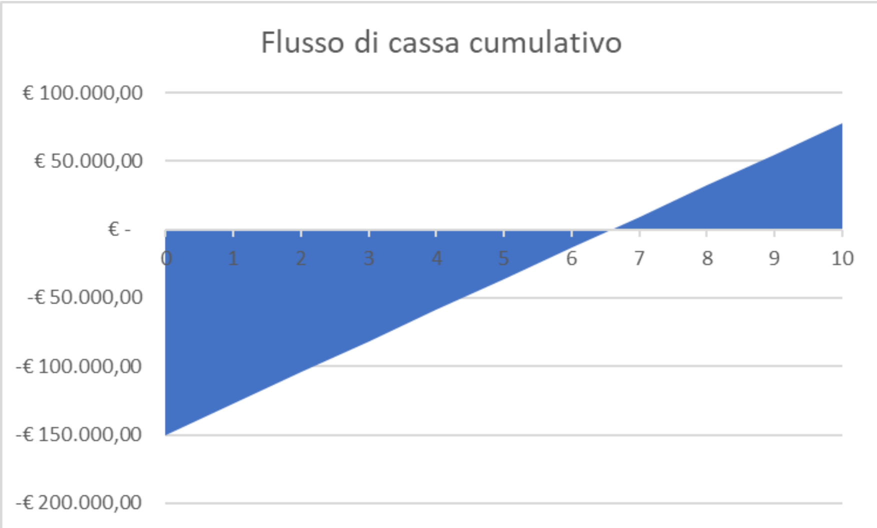


Figure 5.12: Cumulative cash flow of the intervention

In accordance with the Guidelines, the simplified cost-benefit analysis methodology is applied to the relamping by calculating the external costs saved to be considered as environmental benefits of projects improving energy end-use efficiency, calculated for the period 2015-2030 on the basis of the 2030 targets of the National Energy Strategy. From this table, an environmental benefit of 52.7 €/MWh is thus obtained for 2022. The annual energy savings are 125 MWh/year, which over the 10 years of reference service life would lead to estimated consumption savings of 1,250 MWh. Thus, we can estimate as follows:

Cext saved = €85,500

Cinv + Cop = €150,000.00

Consequently, the Benefit/Cost ratio is 0.57

Under these conditions and assumptions, the intervention, although it reduces energy consumption and CO2 emissions, and is of modest economic and financial viability, is not viable in terms of environmental costs vs benefits.

5.8 Installation of Photovoltaic Systems on Concessionaire Buildings

In addition to the photovoltaic systems already analysed, which will be installed in areas under the direct control of the Port Authority, this chapter also analysed the impact of the installation of photovoltaic systems on the roofs of the buildings managed by concessionaires. Considering the limited space available on the roofs of these buildings, a total capacity of about 2 MWp would still be possible.

In order to evaluate this intervention, we first start with the total annual electricity consumption of the concessionaires, from which we detract the share of consumption for exterior lighting for a more realistic evaluation of the share of self-consumption/shared energy. This results in a consumption of approximately 15,680 MWh/year, compared to a total of 22,958 MWh.

The photovoltaic system's production capacity was simulated using the PVGIS tool, which allows photovoltaic panels to be oriented and tilted whichever way provides as much energy as possible. The total annual production of a 2-MWp installation is 3,132 MWh.

It was also assumed that this electricity would be exploited as if the users of the Port of Taranto constituted an energy community, so we are not referring to energy produced and self-consumed, but energy produced and shared. Estimating sharing of 40%, and considering an average energy sharing price of 110 €/MWh, we estimate potential savings of over €300,000.00 per year.

Table 5.23: Analysis of concessionaire energy consumption and electricity production with 2-MWp PV

	AVERAGE monthly consumption (from grid) [MWh]	**AVERAGE monthly production [MWh]**	**Energy produced and shared [MWh]**	**Energy produced and shared [%]**	**Annual savings (cash flow - CF)**
Annual TOTAL	**15,680**	**3,132**	**1,252**	**40%**	**€ 306,967.48**

For the installation and maintenance of the proposed photovoltaic system, we estimate an investment of €2,000,000.00 and €30,000.00 in annual maintenance costs. In the last year of the system's nominal life, €33,600.00 was added to maintenance to account for the costs of disposing of a 2-MWp photovoltaic system.

Table 5.24: Economic and financial data for the installation of a 2-MWp PV system

ECONOMIC AND FINANCIAL DATA	
Price of energy saved	0.11 €/kWh
Installation costs	€2,000,000.00
Annual savings	€306,967.48
Annual maintenance costs	€30,000.00
Disposal costs	€120,000.00
Simple PBT	7.2
Nominal system life	30
Annual interest rate	2%
NPV_{30}	€4,136,841.29
IRR	14%
Annual deviation in energy cost	2%

NPV_{30} (with energy drift)	€6,309,024.33

Table 5.25: Analysis of CO2eq emissions reduction. Following the installation of the PV system

Concessionaire PV system installation – emissions of $CO2_{eq}$		
Before intervention	After intervention	Emissions reduction
[tCO2eq]	*[tCO2 eq]*	*[tCO2 eq]*
3.99E+03	3.35E+03 *of which* 1 *.57E+02 from renewable EE* 3 *.20E+03 from grid EE*	6.41E+02

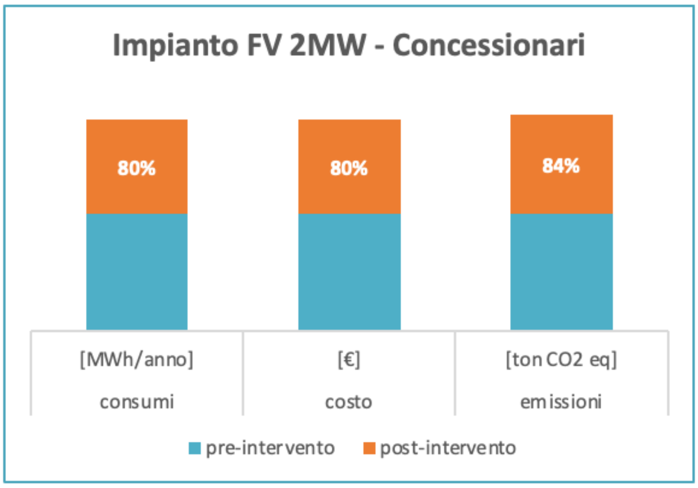


Figure 5.13: Comparison of consumption, costs and emissions of the installation of the PV system on the buildings managed by concessionaires, before and after the intervention

Based on data obtained by analysing consumption in 2021 and observing the system's production, we estimate a simple payback time (PBT) of 7.2 years; the net present value (NPV30) is €4,136,841.29 with an annual interest rate of 2%; and the internal rate of return (IRR) is 14%. Considering the annual deviation in energy cost of 2%, the net present value, again considering 30 years of service life, is €6,309,024.33.

Below is a simplified estimate of the cumulative cash flow of this intervention. The X-axis shows the years and the Y-axis shows the investment cash flows.

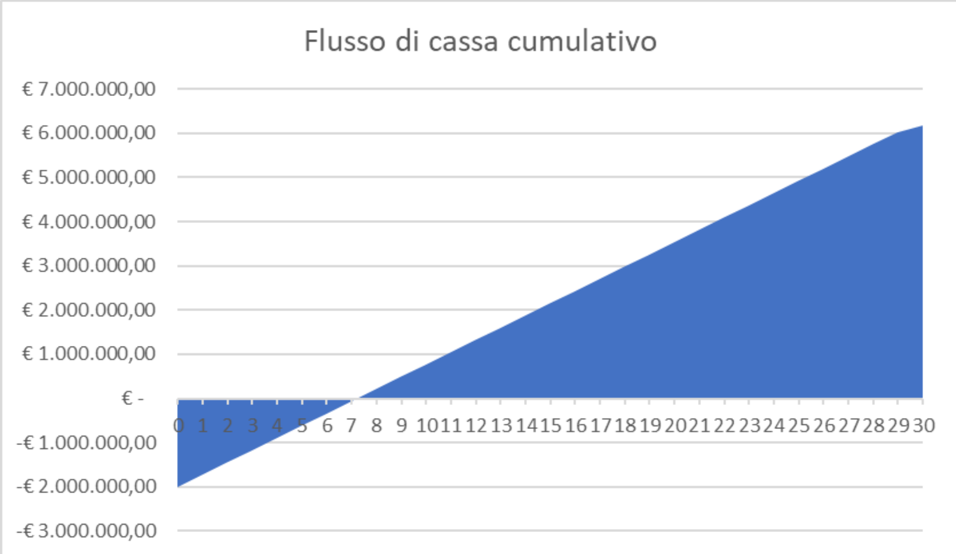


Figure 5.14: Cumulative cash flow of the intervention

In accordance with the Guidelines, the simplified cost-benefit analysis methodology is applied to the new 2-MW photovoltaic systems by calculating the external costs saved to be considered as environmental benefits of projects improving energy end-use efficiency, calculated for the period 2015-2030 on the basis of the 2030 targets of the National Energy Strategy.
From this table, an environmental benefit of 45.4 €/MWh is thus obtained for 2022

The annual energy savings are 3,132 MWh/year, which over the 30 years of reference service life result in a consumption reduction of 93,960 MWh. Thus, we can estimate as follows:

C_{ext} saved = €3,586,766

C_{Inv} + C_{op} = 2,000,000.00 + (30,000.00x30) = €2,900,000.00

Consequently, the Benefit/Cost ratio is 1.24.

Under these conditions and assumptions, the intervention is both environmentally and economically viable.

5.9 Conclusions on planned interventions

The interventions proposed in this paragraph aim to reduce energy consumption both by the Port Network Authority of the Ionian Sea and by the entire port network. The interventions include improvements to lighting (interior and exterior), the installation of photovoltaic systems and cold ironing. Below is a table summarising the interventions and the results of the cost-benefit analysis.

Table 5.26: Summary of AdSP MI interventions

Description of Interventions	Energy Savings [MWh_{el}/year]	Emissions Reduction [kgCO2eq]	Initial investment cost [€]	Cost Savings [€/year]	PBT	NPV
Exterior LED relamping - AdSPMI	682.83	1.74E+02	400,000.00	€122,909.99	3.3	€704,049.39

Interior LED relamping - AdSPMI	8.52	2.17E+00	12,000.00	€1,534.15	7.8	€1,780.61
345-kWp Photovoltaic System	520.84	1.05E+02	360,000.00	€87,356.92	4.1	€1,585,189.68
60-kWp Photovoltaic System	88.79	1.82E+01	65,000.00	€15,083.21	4.3	€270,855.20
Exterior LED relamping - concessionaires	1,465.00	3.73E+02	800,000.00	€263,835.00	3.0	€ 1.569.920,32-
Interior LED relamping - concessionaires	125.00	3.18E+01	150,000.00	€22,770.00	6.6	€54,533.46
2-MWp Photovoltaic System	3,132.00	6.41E+02	2,000,000.00	€276,967.48	7.2	€4,136,841.29
Total	**6,022.98**	**1.86E+03**	**€3,787,000.00**	**€790,456.75**	**-**	**-**

As a result of the different proposed interventions, we estimate total annual energy savings of over 6,000.00 MWhel/year. The total initial cost of investment is approximately €3,787,000.00, while the achievable cost savings are €790,456.75 per year. It should be noted that the NPV refers to two different periods: in the case of the lighting improvements, we consider the 10 years of LED life, while for the two photovoltaic systems the nominal life of the installation is estimated at 30 years.

The cold ironing installations on the three docks requires a separate mention. In this case, the investment is covered by a state grant, but the plan for operating the facilities, and consequently the revenue plan, is still under study. In any case, the facilities have a very significant positive impact on the reduction of emissions (as well as on the reduction of primary energy consumption), which is ultimately the parameter by which to measure the effectiveness of the intervention in terms of energy and environmental sustainability objectives.

Lastly, three graphs are shown below which compare the energy consumption (primary energy) in the current state with that expected under the various improvement scenarios, to give an idea of the result that could be achieved if they were all implemented.

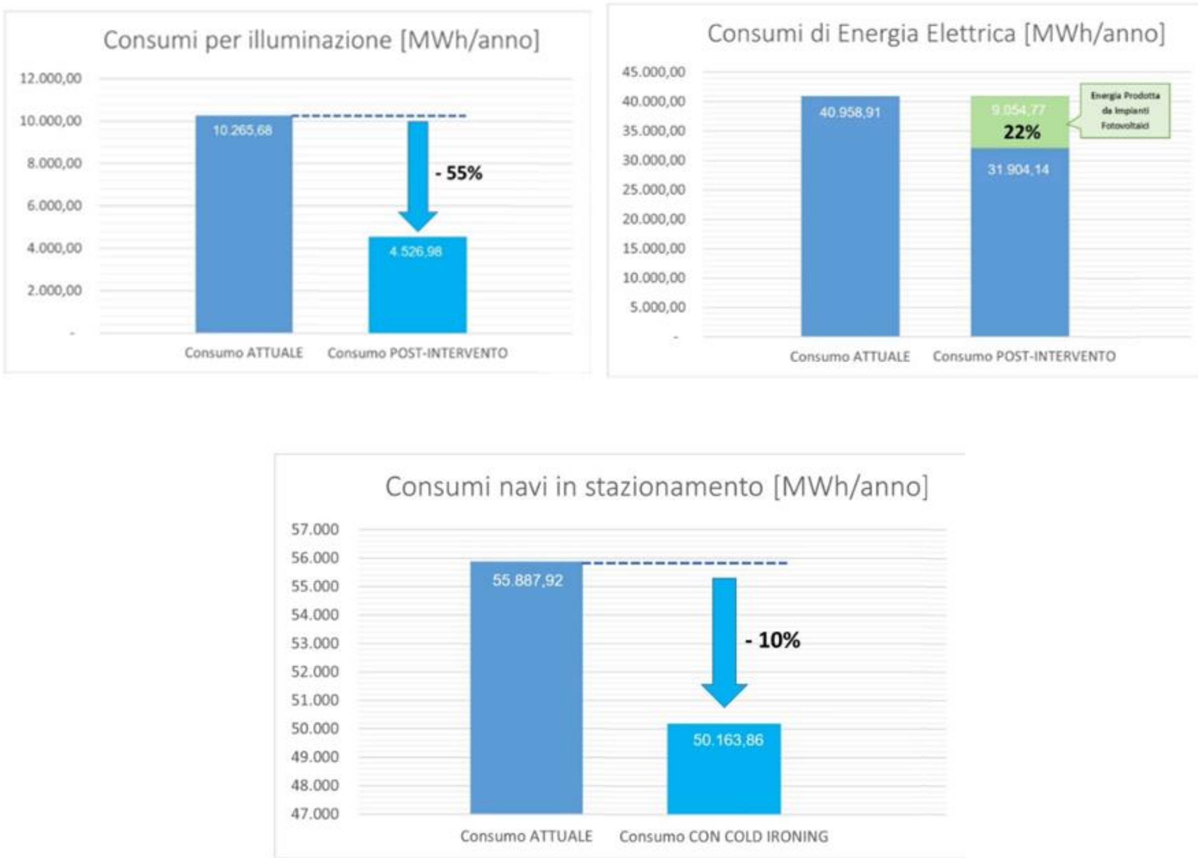


Figure 5.15: Comparison scenario: Current state vs after planned interventions

6 LONG-TERM INTERVENTIONS

Long-term interventions are all innovative interventions that potentially improve the energy efficiency of the Port of Taranto.

These interventions are currently lacking from a regulatory and implementation perspective, but it is to be hoped that these investments will ensure excellent results by achieving the strategic objectives of AdSP over a longer time horizon. The Port of Taranto envisages setting up multiple areas for the production of renewable electricity and/or the construction of related energy infrastructure: about 50 hectares divided between shore-side and off-shore.

6.1 Liquefied Natural Gas Facilities

Maritime transport and port activities are still heavily dependent on fossil fuels. In the shipping industry, liquefied natural gas (LNG) is a viable and economical alternative to overcome new regulations lowering the maximum sulphur content in fuels.

There are currently limits on the sulphur content in marine fuels:

All ships moored in EU ports (and at least two hours before mooring): 0.10%;

Ships within a SECA (Sulphur Emission Control Area) for both navigation and mooring: 0.10%;

Passenger ships operating a scheduled service within the territorial waters of Member States: 1.50%;

Any ship sailing outside territorial waters: 0.5%.

As of 1 January 2020, the new IMO (International Maritime Organisation) regulations came into force. These regulations forcibly encourage the adoption of new greener technologies and fuels.

The use of LNG is an integral part of the EU's broader energy and environmental policy design, which aims at the gradual transition to a low-carbon economy through the substantial reduction of pollutant emissions, the use of clean fuels and the use of renewable sources.

It will therefore be essential to allocate the necessary space in ports for LNG facilities, facilitating the creation of the infrastructure required to refuel ships that use LNG. In this regard, Leg. Decree 257/2016 invites Member States to ensure the installation of an adequate number of LNG bunkering points in the maritime ports of the TEN-T central network and an adequate number of public LNG refuelling points for heavy road vehicles. Both provisions must be met by 31 December 2025. Furthermore, the same Leg. Decree dictates the bureaucratic procedures for small-scale LNG storage and transport infrastructures (less than 50 tonnes m/m).

Four main bunkering options are defined for LNG refuelling:

1. **SHIP-TO-SHIP (STS) refuelling:**

   the transfer of LNG from a ship or barge, carrying LNG, to another ship for use as fuel. STS offers a wide range of applications and bunkering interventions can be carried out at the port or, alternatively, at sea. The main advantages of this type of transfer include the possibility of operating at sea even without entering the port if the weather and wave conditions allow, as well as the possibility of transferring rapidly large volumes of product.

   From back in 2013, the Stockholm ferry Viking Grace has refuelled daily with around 60 tonnes of LNG. The bunkering intervention is carried out using the bunker vessel Seagas, which was specially built to carry out this type of refuelling.

   In 2020, the first LNG cruise ship refuelling in Italy took place in La Spezia. The ship in question is the Costa Smeralda, owned by Costa Crociere, and the tanker used for refuelling is the Coral Methane (owned by Shell, the Costa Group's LNG supply partner), with a capacity of 7,600 m^3. The refuelling took about five hours, with a total of 2,400 m^3 of LNG. During the refuelling, navigation was blocked for a radius of 100 metres from the hose connection point, in order to prevent wave motion and potential risks.

Figure 6.1: Example of ship-to-ship refuelling (La Spezia, October 2020)

2. **TERMINAL/PIPELINE-TO-SHIP (PTS) refuelling (from coastal storage):**

   LNG is transferred from a stationary onshore storage tank via a cryogenic pipe with loading arms (in the case of a regasification terminal storage tank), with a flexible end or the pipe of a ship moored at a nearby dock or pier. The proximity is dictated by the installation and operating costs of a cryogenic pipeline. The onshore tank can be a buffer storage, at an LNG terminal or at an onshore storage facility. It can be a small pressurized tank fed by tanker, train, shuttle vessel or mini liquefaction facility. Another option is to use a large tank at ambient pressure (especially if there is a regasification plant nearby). The PTS solution guarantees higher flow rates, suitable for refuelling large ships, than the Truck-to-Ship solution.

   This type of bunkering is not commonly practised, mainly due to limited operational flexibility. The most common PTS operations use previously imported LNG stored in the tanks of a terminal, which is reloaded onto LNG tankers for re-export of the product, with the aim of exploiting possible commercial opportunities.

   Typically, coastal terminals equipped with PTS solutions not only provide bunkering services to ships, but are often also equipped with a refuelling station for trucks, used to send LNG inland. In addition, a regasification infrastructure is often in place to send the liquefied gas, converted back to gas, to local networks and energy centres via pipelines.

   In Sweden (Port of Gothenburg), TPS bunkering operations have been implemented at the Swedwgas facility. Thanks to its strategic location, the LNG terminal will serve as a distribution platform to supply LNG to different market segments, such as the maritime industry, off-grid solutions, heavy road transport and the regasification of this LNG in the transmission system.

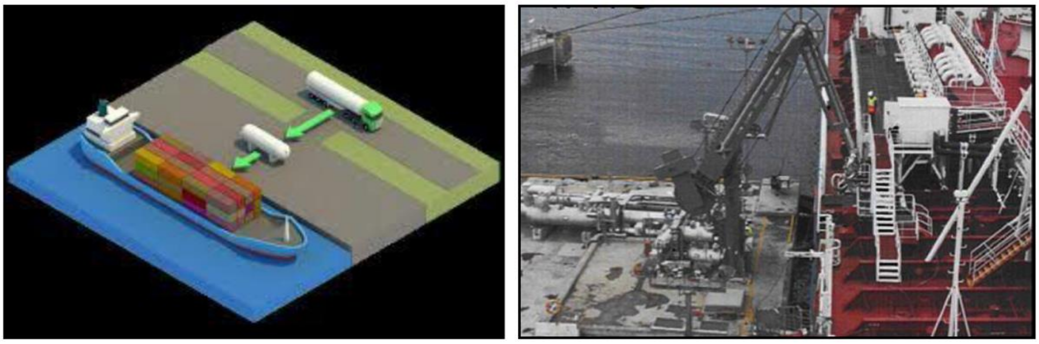


Figure 6.2: Terminal/pipeline-to-ship (PTS) system

3. **TRUCK-TO-SHIP refuelling:**

   This is the transfer of LNG from a tanker to a ship moored at the dock or pier. This normally involves connecting a special LNG cryogenic pipe. A tanker of this type can carry 40-50 m^3 and transfer a full load in about an hour. This mode of transfer offers great geographical flexibility and is particularly attractive in the start-up phase due to the low investment; on the down side, only small quantities can be transferred. This type of operation is suitable for vessels with small tanks, such as tugboats, fishing boats, etc., but is not a viable solution for larger vessels, such as ferries, which have 400 m^3 tanks.

Figure 6.3: Truck-to-ship

4. **Refuelling from mobile tanks or cryogenic ISO containers:**

   These tanks can be used as mobile fuel storage and the amount of product transferred is flexible as it depends on the number of tanks. Mobile tanks include ISO containers, which are standard-sized mobile cryogenic tanks equivalent in size to an ISO container (1 twenty-foot equivalent unit (TEU)) or a double container (2 twenty-foot equivalent units TEU)2. They are used as mobile fuel storage and the amount of product transferred is flexible as it depends on the number of tanks. They can be loaded onto a vessel using special container cranes or onto a truck in RoRo mode (Roll-on/Roll-off) They are intermodal like all ISO containers, so they can travel by truck, train or ship. The tank is pressurised and has a capacity of between approximately 20 m^3 and 45 m^3.

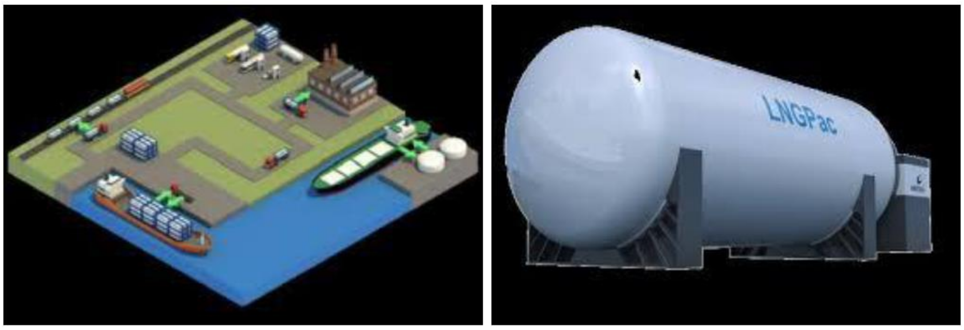


Figure 6.4: Truck-to-ship

It should be noted that there is no single bunkering option that can meet the requirements of all port stakeholders. The Port Authority would need to install infrastructure offering different bunkering methods in order to meet the different needs.

The adoption of an LNG bunkering infrastructure for the port of Taranto can be a competitive advantage in receiving LNG-converted ships in the near future.

Another proposal is the use of an LNG floating storage unit (FSU). A barge FSU offers significant advantages in terms of installation. These include the possibility of storage close to the docks and therefore close to the LNG carrier, reduced shore-side area required for complementary infrastructure, the possibility of even temporarily demobilising the floating storage in case of emergency or necessity, and the possibility of upgrading the storage volume.

The solution under consideration is already being used abroad and is being examined by other Port Network Authorities in Italy. It is an attractive installation idea for small-scale coastal warehouses, especially in ports with heavy traffic but rather restricted layout, confined to a strip of coastline between the sea and the city.

Lastly, the construction of LNG processing infrastructure (bunkering, distribution, refuelling, regasification,etc.) could be strategic for the Authority, especially in light of the ongoing diversification of national gas supply.

6.2 Hydrogen plants

Hydrogen is a fuel with high energy density, which could be emission-free and is presented as a great ally in in responding to the global energy challenge. Its biggest drawback is that it is hard to produce; but thanks to the development of clean hydrogen technologies, with the help of renewables, the path is opening towards a new future.

Due to its characteristics, green hydrogen can play a decisive role in a zero-emission world. Undoubtedly the main, and most efficient, route to decarbonisation is electrification through renewable energies; however, there are some end uses that to date are more difficult to decarbonise through direct electrification. This is where green hydrogen can play a role in achieving total decarbonisation. These sectors are also called “hard to abate” and consist mainly of the industrial, aviation and maritime sectors.

The main problem with this energy carrier is that it is not naturally available on its own, so it must be “extracted” using energy, so that the separation process can begin. However, this means incurring an economic and environmental cost. This is where renewable energies come into play: only “green hydrogen” obtained by separating it from water using electrolysis powered by renewable energy is truly carbon neutral.

The Colours of Hydrogen:

- *Brown*: obtained from coal gasification. More than 20 kg of CO2 are emitted for every kg of hydrogen produced using this method;
- *Grey*: obtained by steam reforming natural gas. More than 9 kg of CO2 are emitted for every kg of hydrogen produced using this method;
- *Blue*: obtained by the same production method as grey hydrogen, but with partial CO2 capture, transport and storage. This method generates 9-10 kg of CO2 for every kg of hydrogen produced and emits up to 5 kg of uncaptured CO2 for every kg of hydrogen
- *Pink*: obtained by electrolysis of water powered by nuclear energy. This has a high environmental impact due to the nuclear waste produced, even though it does not emit CO2.
- *Green*: obtained by electrolysis of water powered by renewable energy. This has a very low environmental impact and generates zero CO2 emissions.

Figure 6.5: The colours of hydrogen

The electrolysis process is performed in the electrolyser, or electrolytic cell, where water is broken down into hydrogen and gaseous oxygen using renewable electricity. Downstream of this process, the hydrogen can also be stored and used later, as a raw material in the steel production process or as a fuel.

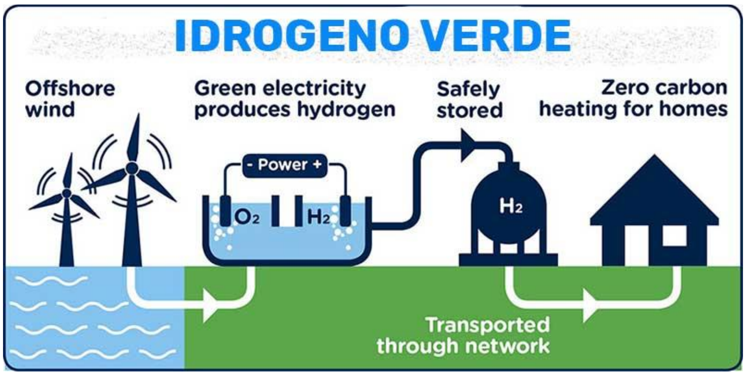


Figure 6.6: Green hydrogen life cycle

The International Energy Agency (IEA) has identified industrial ports as key areas for the short-term deployment of hydrogen as a clean energy source.

The National Strategic Framework for the development of the alternative fuels market in the transport sector and the creation of the related infrastructure (Legislative Decree. No 257 of16/12/2016) focuses on increasing the use of electricity, natural gas and hydrogen as a total or partial substitute for fossil fuels derived from oil.

One of the advantages of hydrogen-based fuels is the fact that they can be used not only to reduce emissions from vessels at sea, but also those produced by port operations (e.g. cargo handling), which today are also carried out using diesel-powered vehicles.

Currently, the use of hydrogen in the maritime and port industry is still very limited, but thanks to industrial development plans and ad-hoc projects, it is hoped that the use of this energy carrier will spread rapidly.

At the beginning of 2021, the Port of Antwerp announced the successful outcome of a feasibility study for a green hydrogen project that aims to create a complete value chain for renewable H2 by the end of the decade. The study lasted one year and analysed the financial, technical and regulatory aspects of the creation of a green hydrogen value chain in Belgium. The promoters that form the Hydrogen Import Coalition are: the Port of Antwerp, Engie, DEME, Exmar, Fluxys, the Port of Zeebrugge and WaterstofNet.

In the Netherlands, there are two projects in particular for the production and use of hydrogen: "H-Vision Rotterdam” and “NorthH2”. The first is a blue hydrogen project, which aims to expand the production and large-scale application of this energy carrier in the industrial area of the port of Rotterdam. NorthH2, on the other hand, plans to use North Sea wind power to produce hydrogen for port logistics and nearby industries in the port of Eemshaven. The project foresees the installation of a wind farm and connected electrolysis plant.

The European H2Ports project aims to demonstrate and validate innovative solutions for the use of hydrogen in the Port of Valencia. The project involves the installation of a mobile hydrogen station to support the decarbonisation of the port logistics chain, which will initially operate at the Grimaldi and MSC terminals in the Port of Valencia, powering a reach stacker and a terminal tractor. The hydrogen-powered Terminal Tractor is already being developed by Atena. The tractor will be powered by a fuel cell supplied by Ballard. It will refuel using the mobile Hydrogen Refuelling Station, developed by CNH2, which will ensure the supply of this fuel under suitable conditions for both this vehicle and the Reach Stacker which will be tested at the MSCTV terminal, also powered by fuel cells. The hydrogen storage system on the terminal tractor has a total capacity of 12 kg and guarantees continuous operation for at least 6 hours before refuelling.

The aforementioned Port of Antwerp-Bruges and the clean technology company CMB.TECH will soon welcome the Hydrotug: the first hydrogen-powered tugboat. The first water launch took place in mid-May 2022 in Spain. The tug consists of two BeHydro V12 medium-speed dual-fuel engines that can run on hydrogen or conventional fuel.

The Belgian shipping giant CMB has already produced a few hydrogen-powered vessels, the latest being the Hydrobingo: the first 80-passenger commercial ferry with a diesel engine and a hydrogen-powered engine, built by Japanese shipbuilder, Tsuneishi.

Figure 6.7: Hydrobingo - the first hybrid diesel/hydrogen ferry for commercial use

In this last year, there is an even tighter partnership between RINA and Fincantieri, who will work together on the development of projects involving CCS (Carbon Capture and Storage), renewables and, in particular, alternative fuels for the maritime industry, where hydrogen and ammonia are of particular interest.

At the start of 2022, Zeus - Zero Emission Ultimate Ship - was launched at the Castellammare di Stabia shipyard, the first hydrogen-powered ship designed by the Fincantieri Group. Zeus is 25 metres long and weighs170 tonnes and is equipped with a unique 130 kW ship fuel cell system. This fuel cell is powered by around 50 kg of hydrogen, contained in eight metal hydride cylinders, guaranteeing eight hours of sailing at a speed of 7.5 knots; all with zero net emissions. The ship is also equipped with a hybrid system consisting of two diesel generators and two electric motors for conventional propulsion. The innovative features of the Zeus ship include it being designed to receive shore-side electrical power (cold ironing).

Figure 6.8: Zeus - the first hydrogen-powered ship designed by Fincantieri Group

6.3 Floating Photovoltaic Installation

Today, the world is taking an increasingly positive view of renewables, primarily photovoltaics. The disadvantages for the application of photovoltaic systems undoubtedly include the surface area required to install the panels, as the roofs of buildings are not always suitable, while ground installation can detract from other uses, e.g. agriculture.

One of the emerging solutions in the world of solar energy is floating photovoltaics, a technology that enables the production of clean energy from solar panels installed "on water", on suitable supports.

However, this technology has its limitations, including: infrastructure built specifically to withstand the aggressive environment in which it will be installed and, additionally, if it is installed at sea, the salinity of the water will entail higher maintenance costs and the application of special precautions.

The Authority is considering identifying areas in the sea potentially suitable for this technology.

There are already several floating PV plants and the technology is an increasingly attractive solution. China has set up a 320-MW floating solar park on the reservoir in the Chinese city and prefecture of Dezhou, in Shandong Province. It was built in two stages: first, 200-MW panels were installed and connected to the grid in 2020; then work was completed on the remaining 120 MW, connected to the national grid in December 2021.

The company that invested in and helped to construct the park is Huaneng Power International, which estimates a production of around 221 million kWh per year, saving over 200,000 tonnes of CO_2 emissions into the atmosphere. The Chinese power plant is significant because it is part of a larger project, which also foresees the installation of a wind farm and battery storage systems.

Figure 6.9: Floating Photovoltaic Installation in Dezhou (China)

6.4 Electrifical conversion of resident ships

Most of the vessels operating within the port (known as “resident ships”) serving port operations or ships in transit generally travel short distances, often at low speeds and are frequently stationed at the dock. In addition, some of these ships are equipped with two separate engines, one for propulsion and one auxiliary engine for generating electricity when docked.

Given the above and considering the planned cold ironing intervention, it is only logical to consider converting these ships to electricity.

There are two options for this conversion: replacing just the auxiliary engine with shore-side power, or also replacing the propulsion unit with a new electric unit (with the possible use of hydrogen).

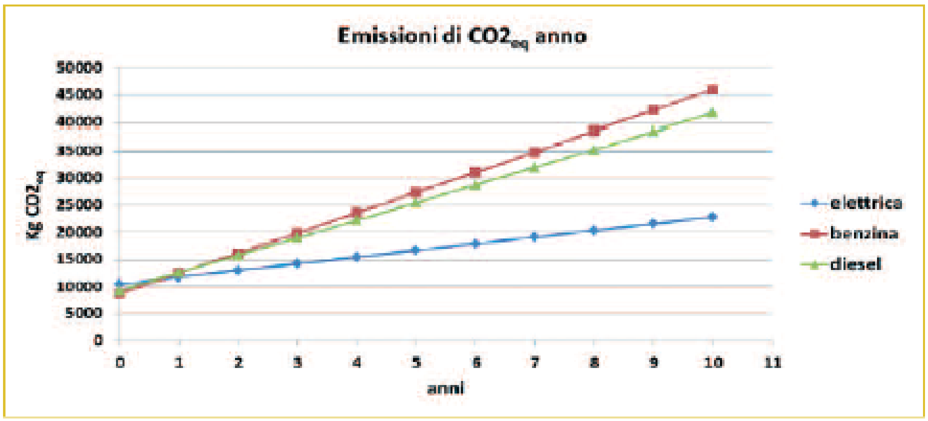
In both cases, the potential shore-side energy and power requirements will have to be established, as well as the willingness of port operators to make the necessary investments in their fleets.

This intervention will be better defined in conjunction with the development of cold ironing in the port, and of the hydrogen supply chain and technologies.

6.5 Electrical conversion of land vehicles

For the purposes of the objectives underlying this document, in the next few years, we will consider the replacement of the land transport vehicles available to the Port Authority's operators with means that are more efficient in terms of energy and consumption and greener, thus with lower emissions.

The most recent studies (see "Auto elettriche e auto tradizionali: un confronto basato sul ciclo di vita dalla city-car due posti al SUV" - Pierpaolo Girardi, Cristina Brambilla RSE - Ricerca Sistema Energetico - 2018) confirm that for all sizes considered, from micro-cars to small cars, compact cars and family vehicles, electric cars are greener than their internal combustion counterparts. This is particularly true when it comes to the greenhouse effect and pollutant emissions that contribute to impact categories such as particulate matter formation, atmospheric acidification or photochemical smog formation.



Source: "Auto elettriche e auto tradizionali: un confronto basato sul ciclo di vita dalla city-car due posti al SUV" – P. Girardi, C. Brambilla - Ricerca Sistema Energetico (2018)

Figure 6.10: Comparison emissions of CO2eq/year

The main environmental benefit of electric mobility is the reduction of local pollution: electric cars have no harmful emissions. Their impact on the environment in general, however, depends largely on the source of the electricity they use. This is why it is a priority to maximise the production of energy from renewable sources, in order to make electric vehicles as green as possible.

The actions necessary to improve energy efficiency in the port involve everyone: AdSPs and concessionaires. With a view to this sharing of objectives, we plan to promote the replacement not only of transport vehicles but also of handling equipment (cranes, forklifts, etc.) powered by diesel, with vehicles powered by electricity.

An analysis of the fossil fuel requirements of the concessionaires' mobile equipment (Section 3.3) shows that diesel is the main source of energy used to power land vehicles. Currently, there are numerous brands and models of electric lifting equipment on the market that are suitable for use even in ports. The electric forklift, for example, is an advantageous solution not only from an economic point of view, given its low running costs, but also from an environmental point of view, since, unlike the diesel forklift, it is silent and has zero emissions harmful to operators. The high performance in terms of compactness, robustness and reliability translates into high vehicle productivity with reduced energy consumption. Finally, it should be pointed out that there are already multiple electric tractor solutions on the market today.

In addition to these electric vehicles, there are also projects to develop hydrogen-powered industrial vehicles: the Atena consortium in partnership with the research agency Enea, Cantieri del Mediterraneo and "Parthenope" University of Naples and University of Salerno has designed and developed a four-wheeled port tractor for freight handling. Using this vehicle will not only mean significant savings in fuel consumption, but will also be instrumental in reducing carbon dioxide emissions. According to a calculation by Enea researchers, the use of hydrogen-powered fleets would save around 500 tonnes of CO2 and 5 tonnes of nitrogen monoxide per year.

Regarding the issue of suitable locations for the construction of electricity storage and recharging stations for electric vehicles, AdSP MI has identified a number of suitable installation locations:

- Darsena - Molo Sant'Eligio;
- Port Authority car park;
- North Gate;
- Multi-Purpose Pier.

6.6 Wave Power Plant

As reported in the publication "Energia dal moto ondoso"[3], the potential and kinetic energy of wave motion can be harnessed for the generation of electricity, using different devices. It is estimated that the energy potential in the planet's seas and oceans reaches 80,000 TWh/year, or about five times the global electricity requirements. However, this source of energy has a limited availability on average (average annual output of 5-10 kW/m) and the technologies are still at an experimental stage.

FAROS, the Blue Economy Accelerator of the CDP National Network, intends to qualify the port of Taranto as a competitive and innovative hub; its aim is to boost the growth of start-ups developing innovative products or solutions in logistics and port automation.

The start-ups participating in the first edition of the programme include Generma, which has developed a modular and floating conversion device that produces electricity from wave motion, achieving greater efficiency and lower production times and costs.

[3] "*Energia dal moto ondoso*" di F. Salvatore – CNR, G. Sannino, A. Carillo – ENEA, M. Peviani, L. Serri – RSE (2017).

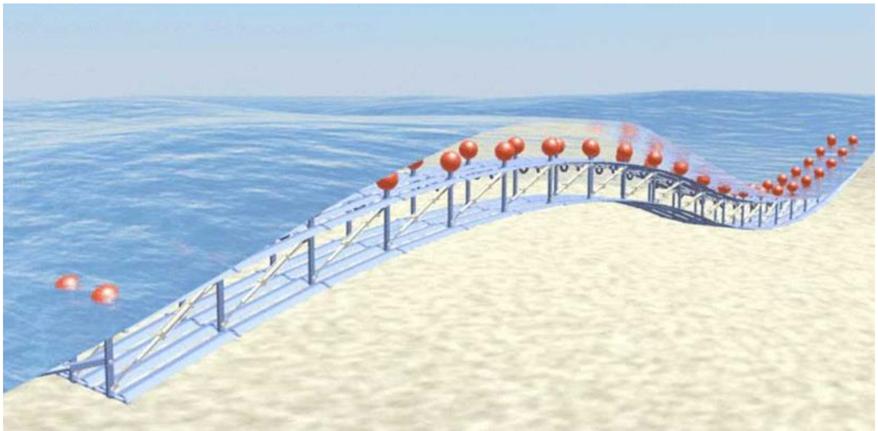


Figure 6.11: Illustrative image of the Generma conversion device

The conversion device consists of interconnected metal sections. The individual sections are formed by two fixed horizontal profiles connected by vertical uprights to form a parallelepiped; a hydraulic piston is placed within this frame diagonally, secured in the bottom and top corners. All sections are then connected together using mobile and articulated supports.

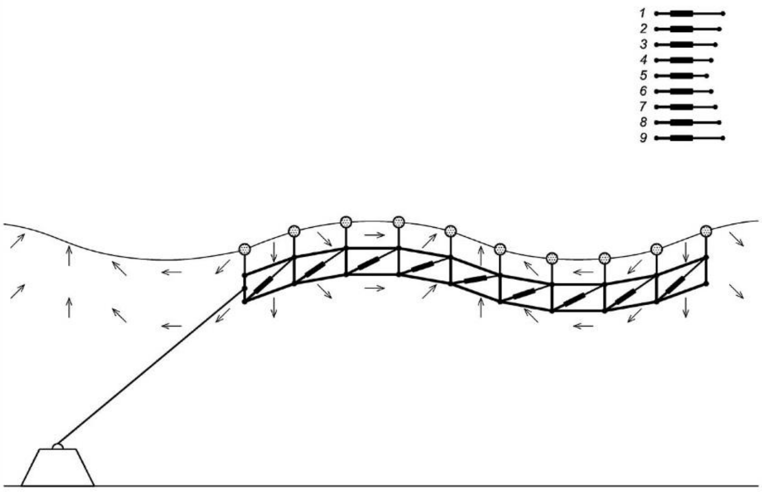


Figure 6.12: Construction diagram of the conversion system

One of the key aspects, besides efficiency, is the natural way in which the structure is incorporated in the marine environment. The fluctuation of the converter works in harmony with the movement of the wave and has no effect on the dynamics of the coast, thus there is no impact on the aquatic plants and marine animals living near the shore. The system does not use polluting or toxic paints, it only uses oil that is 100% biodegradable, in case of breakage. Other advantages include low underwater noise production; even during installation, the system is quieter than other solutions. The high-visibility buoys, installed at an appropriate distance from the shore, will minimise the navigation risk.

Figure 6.13: Illustration of the system operating at sea

Inside the Port of Taranto, within a few months, we are planning to install a reduced-power pilot installation in a dedicated area, in order to analyse the results and assess the effectiveness of the system with local wave motion and meteorological and marine research. The plan is also to install a camera that will show the plant output in real time (via official channels). This first installation, therefore, will enable a prior and preliminary evaluation of the installation; if the response is positive, it can then be expanded and guarantee greater energy production.

6.7 Port Grid: a new horizon for Port Network Authorities (AdSPs)

As far as electricity is concerned, given that hundreds of operators operate independently in every port, it requires unitary management in the port network area, coordinated by the AdSP, from the perspective of a single user integrated as a "portgrid" or port microgrid.

Reinforcing this idea, national legislation through Art.9 of Decree-Law No 50 of 17 May 2022 has recently introduced the possibility for Italian AdSPs to create renewable energy communities together with port concessionaires (excluding installations in protected natural areas). In particular, the second paragraph of the article states: "In order to contribute to the sustainable growth of the country, to the decarbonisation of the energy system and in the pursuit of national energy resilience, the Port Network Authorities may, even in derogation of the provisions of Article 6, paragraph 11 of Law No 84 of 28 January 1994, establish one or more renewable energy communities pursuant to Article 31 of Legislative Decree No 199 of 8 November 2021, consistent with the energy and environmental planning document referred to in Article 4-bis of the same Law No 84 of 1994. The incentives envisaged by Legislative Decree No 199 of 2021 shall apply to renewable plants included in renewable energy communities established by the Port Authorities, pursuant to this paragraph, even for capacity exceeding 1 MW."

According to the article, energy communities are to be established with the main objective of providing environmental, economic or social benefits at community level to its associates or members or to the local areas in which the community operates, without the generation of financial gain.

Many of the elements put in place in the short to medium term are elements that can be used to create or at least enable a portgrid. Planning a portgrid in the long term will allow us to identify a roadmap of modular interventions towards achieving full energy independence of the port in the future. The additional interventions to improve functional and energy efficiency will in turn be facilitated by the coordination in a single portgrid, which can also integrate local generation and possible storage of all individual user electrical systems.

The portgrid must include all stakeholders in energy planning (in addition to the AdSP, service companies, terminal operators and ship owners, local and regional authorities of the contiguous urban areas engaged in their various capacities), foreseeing incentives and/or compensation for the costs of implementing energy innovations.

The portgrid can ensure functional performance, business continuity, fault tolerance and integrate shore-side energy use with the power supply of moored ships and boats, as well as accommodate local power generation and storage useful to mitigate peak loads. The interventions necessary for the construction of an adequate portgrid must contribute to:

- planning combined heat/electricity/CDZ production, wind farms and photovoltaic facilities, efficient lighting systems;
- configuring installations with flexible and partitionable structures;
- implementing non-conventional electrical systems, special voltage levels specifically for port use, possible portions of the DC grid, electric vehicle charging systems, storage systems, refrigerated container parks, shore-side power supply systems for berthed ships (cold ironing).

7 CONCLUSIONS: a ROADMAP to make the Port of Taranto a Smart Green Port

Overall, the current global challenges dictated by climate change require a robust approach with serious and collective commitment from the entire port ecosystem. The will and the need to create real change are increasingly driving the world's ports towards ambitious energy transition projects.

This section of the document presents the Roadmap that the Port Network Authority of the Ionian Sea intends to pursue in the short, medium and long term in order to create a sustainable and innovative port. Through the development of this Roadmap, the Authority intends to restore the confidence of the local community through a relationship of transparency on decisions taken and openness of the port to the city, such as the Portdays events already organised by the Authority. This Roadmap is as a step forward by the Authority towards new milestones in innovation and sustainability.

The Roadmap aims to summarise the strategies and objectives of the POT 2020-2022 with the short/medium/long-term interventions planned by AdSP MI and analysed in the previous paragraphs of the document. The principles of the Roadmap are as follows:

- development of best practices to reduce port emissions;
- modular, long-term planning to carry the port and the city of Taranto to the forefront in environmental sustainability;
- long-lasting sustainability results achieved through the continuous development of innovative solutions;
- improved energy efficiency of buildings, plants and processes in the port of Taranto in order to reduce consumption;
- use and redevelopment of non-productive areas of the port domain for the production of renewable energy;
- engagement of concessionaires in energy production and efficiency initiatives.

The figure summarises the Roadmap to make the Port of Taranto a Smart Green Port in line with the goals of the AdSP MI POT. As can be seen, the Roadmap consists of three phases: Short Term, Medium Term and Long Term.

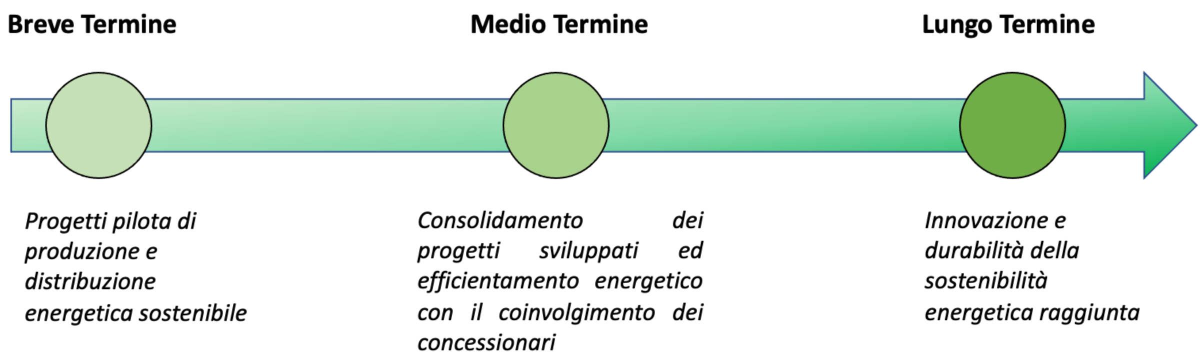


Figure 7.1: The AdSP MI roadmap

Below are the main characteristics of each phase of the Roadmap:

- **Short Term** - in the short term, we are finalising the various interventions planned in recent years by AdSP MI. Specifically, these include the first offshore wind farms in Italy and the whole of the Mediterranean (completed in April 2022), several photovoltaic installations and the first Fast Recharge electric vehicle charging infrastructure located within the Port of Taranto. These interventions serve as an example of how the port can be both a cutting-edge producer of renewable energy and a distributor of this energy internally. From these pilot projects, we develop the subsequent medium-term AdSP strategy.
- **Medium Term** - in the medium term, AdSP MI intends to continue to provide incentives, including through port concessionaires, towards the adoption of renewable energy production and supply solutions. The AdSP strategy focuses on improving energy efficiency in order to reduce consumption and achieve a better balance between energy produced and energy consumption. In the continuation

of the activities introduced by the pilot projects in the previous phase, we therefore plan to increase the production of renewable energy through the installation of new photovoltaic systems both on the Authority's buildings and at the Multi-Purpose Pier, and the construction of a cold ironing facility to supply clean energy to the ships moored at the multi-purpose pier, the oil jetty and the public docks. The actions taken by AdSP mentioned above will act as a driving force for concessionaires, for whom photovoltaic installations on buildings and relamping of interior and exterior lighting are planned.

- **Long Term** - AdSP MI is already looking to the best innovations in energy sustainability. While the interventions planned for the short and medium term are being completed, making the Port of Taranto cleaner and greener, the Authority will look to the frontier of innovations already on the market or under development in order to maintain the environmental sustainability achieved in the short and medium term. The technologies that have been considered for the long term and discussed in more detail in the previous section of the document include solutions that are already well-established, such as LNG, others under consolidation, such as hydrogen, and yet others still under development, such as floating photovoltaics. The systemisation of these additional solutions with the planning and creation of a portgrid will carry the port of Taranto into a new era of zero emissions.

To this end, given the need to follow the evolution of technologies in the coming years, we should also mention here the Taranto Ecoindustrial Park, located in the area bordering the Port of Taranto, which is presented as a new concept of real estate and logistics platform for potential public-private partnerships aimed at uniting the concepts of the new economies, based on circularity, a green approach and sustainable mobility to develop the surrounding area.

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