

CASE STUDY IDENTIFICATION SHEET

This document has been developed as part of the activities under Task 3.2 of the “GREENPORT Alliances” project, for which MAR.TE. S.c.ar.l. serves as the responsible entity. Task 3.2 focuses on identifying and analyzing case studies that exemplify best practices for behavioral change among operators aimed at reducing the environmental impact of port operations.

The primary objective of this activity is to collect, document, and analyze concrete examples of technological, managerial, or behavioral innovation that have proven effective in contributing to the environmental, economic, and social sustainability of the port services sector. Through a structured selection and evaluation process, the document highlights the specific features of each case study and assesses their performance against key environmental and economic impact indicators.

The information gathered will be integrated into the overall framework of the GREENPORT Alliances project to promote the dissemination of sustainable solutions and the development of curricula for: a. higher education students (future personnel); b. current professionals (professional training); c. educators (train-the-trainer courses).

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1. GENERAL INFORMATION

A. Case study title

Demonstration of the use of biofuel in the pilot boats of the Port of Aveiro to promote the reduction of greenhouse gas emissions in a port.

B. Green practice implemented

The two practices most relevant to this case study are:

1. Practice 2: Active participation of pilots in research and development projects for new green technologies

Description: Directly involve pilots in R&D initiatives to contribute to the development and implementation of innovative ecological technologies that can reduce the environmental impact of the maritime sector.

2. Practice 5: Collaboration with other ports to exchange information and green solutions

Description: Create networks of collaboration between ports to share best practices, technologies, and innovative strategies aimed at reducing emissions and promoting environmental sustainability in port operations.

C. Specific goals

- Demonstrates the use of waste cooking oil biofuels in conventional pilot boats.
- Ensures safe and efficient operation without engine modifications.
- Supports Small and Medium Size Ports (SMP) where full electrification is not viable.
- Expands partnerships with northern Portugal ports.
- Contribute to **GHG emissions reduction strategies** and promote **cross-port cooperation** on sustainable maritime operations, by leveraging networks such as **ESPO (European Sea Ports Organisation)** and **DocksTheFuture**.

D. Direct impact of the practice

The development of this case study is expected to have a direct impact on key aspects of maritime sustainability and operational efficiency, providing valuable insights into the feasibility and benefits of biofuel adoption in port operations.

- **Reduction of GHG emissions** by replacing conventional marine diesel with biofuel.
- **Validation of biofuel feasibility** in conventional marine engines without technical modifications.
- **Lower carbon footprint in port operations**, supporting global sustainability goals.
- **Cost-effective transition to greener maritime fuel**, avoiding large-scale investments in electrification or new vessels.
- **Collaboration with other ports** to scale the adoption of biofuels and share research insights.

E. Place of implementation



- **Port of Aveiro, Portugal** (initial pilot project).
- **Potential expansion to other ports in northern Portugal**, fostering cross-port cooperation.

F. Start and end date or duration of the pilot project

Start Date: [05/2022 - ongoing]

- **Duration:** The pilot case for the “*TRIÂNGULO*” pilot boat has been successfully completed, marking the end of the adaptation period for the use of B15 biofuel. With its continuous and stable operation now assured, the focus is shifting to extending this initiative to the remaining two pilot boats in the Port of Aveiro, “*ESPINHEIRO*” and “*MÓ DO MEIO*”. This next phase aims to demonstrate to other vessel operators that transitioning to biofuels is a safe and reliable step towards energy transition, thus reinforcing the feasibility of using sustainable fuels in maritime operations.

2. CONTEXT AND DESCRIPTION

A. Description of the practice

The project focuses on the **use of biofuels derived from waste cooking oil in pilot boats operated by APA (The Port of Aveiro Administration)**. As most maritime vessels currently run on **marine diesel**, this initiative provides an **entry point for energy transition** in port operations.

By using **biofuels without requiring engine modifications**, this initiative demonstrates that existing vessels can immediately **reduce emissions without significant investment costs**. The project further aims to **extrapolate its findings to other port vessels**, estimating potential **GHG emission reductions at the port level**.

This initiative strengthens the collaboration between the ports of Northern Portugal, facilitating the exchange of knowledge and best practices regarding sustainable fuel adoption and other similar pilots underway.

In addition, the Port of Aveiro is involved in several specialised networks, such as, **ESPO** – European Sea Ports Organisation, and **DocktheFuture**, among others, increasing the scalability and impact of the project.

B. Driving factor behind the adoption of the green practice

The European Green Deal, FuelEU, and AFIR Directives, along with the EU Climate Law, require ports to progressively reduce carbon emissions, which will require investment in energy-efficient infrastructure, renewable energy solutions, shore-side power supply for vessels, and new and net fuels, where advanced biofuels are included.

Capital investments in this transition are higher than can be afforded by SMP. So, the use of these types of advanced blended fuels will therefore ensure a smooth transition without disrupting maritime operations.

In addition, for some boat retrofitting or new boats, the 100% biofuel (B100) could be used as a net fuel.

As far as the market is concerned and also knowing that B15 may be slightly more expensive than regular marine gas oil, let's not forget that fossil fuels are becoming more expensive due to carbon taxation, and also the better efficiency of B15 will allow some savings.

In addition, cooperation and benchmarking between ports is becoming a driver for success, and the APA sees inter-port cooperation as a key factor for sustainable growth.

So, in a nutshell, these are the driving factors that motivate the Port of Aveiro to implement this green practice:

- **Urgency of Energy Transition** – Ports seek alternatives to fossil fuels without high capital investments.
- **Environmental Goals & EU Regulations** – Compliance with GHG reduction targets.

- **Operational Feasibility** – Ensuring a smooth transition without disrupting maritime operations.
- **Cost-Effectiveness** – A **low-cost alternative** to electrification or the purchase of new vessels.
- **Inter-Port Collaboration** – Strengthening cooperation to accelerate green technology adoption.

c. Stakeholders involved

The main stakeholders involved in this project were PRIO, the supplier, TECNOVERITAS, the technological partner, and the practices that operate the boats that have been tested or are planning to be tested. Indirectly, other ports and port networks will also be important to consolidate the green practice described, as well as other suppliers or users:

- **APA (Administration of Port of Aveiro)** – Leading the pilot project.
- **Port pilot boat and tugboat Operators** – Primary users of the biofuel.
- **Fuel suppliers and technology providers** – Ensuring sustainable biofuel sourcing and performance monitoring.
- **Other ports in northern Portugal** – Potential adopters of the demonstrated biofuel solution.
- **Port networks (ESPO, DocksTheFuture, etc.)** – Supporting knowledge dissemination and policy alignment.

3. IMPLEMENTATION

A. Description of the adopted practice

The Administration of the Port of Aveiro (APA) has launched a pilot initiative to test the use of biofuels in port operating vessels, as part of its commitment to the transition to carbon neutrality by 2050. The biofuels, produced locally by PRIO from used cooking oil and other waste-based raw materials, provide a sustainable alternative to conventional marine fuels.

In collaboration with PRIO, which operates in the port, APA asked Tecnoveritas to carry out an analysis of the engine specifications of the *Triângulo* pilot boat to confirm its compatibility with a B15 fuel blend—consisting of 15% biofuel and 85% marine gas oil. As a result, Tecnoveritas issued a certification for the use of biofuels, ensuring compliance with technical and environmental standards.

Notably, most existing engines can run on B15 without modification, providing a cost-effective opportunity for vessels to immediately reduce emissions without significant investment.

After minor adjustments to the oil filters, the *Triângulo* has been successfully run on B15, maintaining the same operational performance while achieving a direct reduction in fuel consumption. As can be seen in the Graph 1 and Table 1, when comparing the average fuel consumption between 2020-Apr 2022, when the Pilot boat was running on marine gas oil, and May 2022-2024, when it was running on B15, the results for the average fuel consumption were 8.20 L/h to the former and 7.20 L/h for the latter, which represents a 12% reduction in fuel consumption.

According to PRIO, a biofuel supplier, the fuel savings from switching from B0 to B15 are estimated to be at least 5%, but it is important to note that the results achieved may be influenced by other variables, such as the human behaviour when manoeuvring the pilot boat and other operational factors. These elements introduce an inherent variability that cannot be fully isolated, making it challenging to attribute the full extent of fuel savings solely to the use of biofuels.

Building on this success, APA plans to extend the project to two other pilot boats, *Espinheiro* and *Mó do Meio*, as well as to tugboats operating under concession in the Port of Aveiro. To further demonstrate the benefits of B15, the greenhouse gas (GHG) emission reductions for these vessels have been extrapolated based on the technical data and fuel consumption records of the pilot boats and tugboats operating in the port in 2024, with the support of the CO₂ Emissions Calculator.

The project is structured in **three key phases**:

1. Pilot boat biofuel adoption

The introduction of biofuels in APA's pilot boats involves a structured testing phase to ensure safe and efficient operation. This process begins with a detailed analysis of each pilot boat's engine specifications to confirm its compatibility with a B15 fuel blend (15% biofuel and 85% marine gas oil). Once compatibility has been established, the vessel undergoes real-world operational testing, during which its performance, fuel efficiency, and emissions are closely monitored.

During this phase, the behaviour of the boat is continuously assessed, and any necessary adjustments are made to optimize performance. In the case of the *Triângulo* pilot boat, minor adjustments to the oil filters were required to ensure smooth operation. This cycle of testing and adjustment will be systematically repeated until the vessel demonstrates stable performance with no any operational issues. Once the process is successfully completed, the findings serve as a blueprint for wider implementation of biofuels in other pilot boats and port vessels.

2. GHG emissions impact assessment

Based on the fuel consumption data of the pilot boats and tugboats operating at the Port of Aveiro in 2024, the GHG emissions of each vessels were calculated in tCO₂/l. Specifically, five vessels used marine gas oil (B0), while the pilot boat *Triângulo* used B15 (a blend of 15% biofuel and 85% marine gas oil).

Emission factors from the RED II Directive were used to determine the environmental impact, as shown in

Table 2.

In addition, the greenhouse gas emission savings were estimated for both B15 and B100 biofuel blends, assuming their use by all vessels operation in the port, including tugboats. The analysis shows that replacing B0 with B15 results in a 15% reduction in GHG emissions, while a full switch to B100 (FAME) results in an 88% reduction.

The results of the calculations, including the savings from using B15 or B100 in all vessels, pilot boats and tug boats are shown in

Table 3.

3. Collaboration and expansion

In order to promote the wider use of biofuels in maritime operations, the Port of Aveiro is committed to sharing the results of this pilot initiative with other ports in northern Portugal and beyond. A key part of this strategy includes publishing the findings on its official website and social media channels, ensuring transparency and accessibility to stakeholders interested in sustainable fuel alternatives.

In addition to digital dissemination, the Port of Aveiro will actively promote the implementation of B15 biofuel through its participation in various sustainability-focused initiatives. This includes presenting results and lessons learned at conferences, webinars, and stakeholder meetings, where best practices can be shared with industry professionals and policy makers.

Particular emphasis is be placed on discussions at Port Community Meetings, where key stakeholders are engaged to explore the feasibility of expanding the use of biofuel to a larger fleet of port and commercial vessels.

Furthermore, the Port of Aveiro will leverage its involvement in international collaborations and sustainability projects to amplify the impact of this initiative. By integrating biofuel adoption into broader environmental strategies, the port aims to contribute to the decarbonization of maritime operations, encourage regulatory support for alternative fuels, and foster inter-port cooperation in transitioning towards cleaner energy solutions.

B. Technologies used (if applicable)

- Diesel-powered boat engines and biofuels use certification

The pilot boat *TRIÂNGULO*, operating at the Port of Aveiro, is a robust and efficient vessel designed for pilot transfer operations. It is powered by two VOLVO PENTA TAMD31P-A engines, each delivering 150 hp at 3900 rpm, ensuring high performance, reliability, and precise manoeuvrability in demanding maritime conditions. These inboard diesel engines are renowned for their fuel efficiency, durability, and smooth operation, making them ideal for continuous port service. See Table 4.

To enhance sustainability, the engines have been certified by Tecnoveritas, a company specialising in maritime engineering and environmental solutions, for use with B15 biofuel, a blend of 15% biodiesel and 85% marine gas oil. This certification ensures compliance with environmental standards while maintaining optimum engine performance, contributing to the reduction of carbon emissions in the maritime sector.

- Biofuels derived from waste cooking oil (B15)

The ECO BUNKERS, by PRIO, is an innovative and advanced marine fuel designed to support the energy transition in the maritime sector. Developed through over a decade of research into biofuels, it incorporates 15% biodiesel produced from recycled raw materials. Aligned with the International Maritime Organization's (IMO) greenhouse gas reduction targets, this fuel helps vessels reduce CO₂ emissions by up to 18% (lifecycle analysis) and lower fuel consumption by up to 10% without requiring engine modifications. PRIO ensures full compliance with ISO 8217 standards, offering a more sustainable, efficient, and cleaner alternative to conventional marine diesel.

Technical sheet source: https://www.prio.pt/downloads/file295_pt.pdf

- Carbon calculator to access the GHG emission reductions

The Port of Aveiro, in collaboration with the University of Aveiro, has developed an online Carbon Emissions Calculator designed for the port community, businesses, and the general public. This tool allows users to calculate the CO_{2eq.} emissions associated with different modes of transport, including ships, heavy and light vehicles, locomotives, and port equipment, as well as different types of fuel.

With three levels of complexity, the calculator allows for individual analyses to assessments of entire fleets or logistics chains, raising awareness about reducing carbon emissions and contributing to the goal of carbon neutrality by 2050.

Source: <https://portodeaveiro.pt/noticia/pt/488>

c. Competencies required

Successful implementation of this practice requires technical expertise in fuel conversion and engine performance assessment, along with specialized third-party certification of engines for biofuel use to ensure compliance with safety and performance standards. A thorough understanding of maritime emissions regulations and sustainability policies is essential to align with environmental objectives. In addition, collaboration within the port community is crucial to facilitate the replication of biofuel use in other vessels and equipment, whenever their engines are compatible, promoting a broader adoption of sustainable fuel solutions.

4. COLLECTED DATA

In order to assess the impact of the pilot initiative, key data has been collected before and after the introduction of B15 biofuel in port vessel operations. This data allows for a comprehensive assessment of fuel consumption, engine performance, and emission reductions, providing a basis

for measuring the effectiveness of biofuels as a transitional energy source. Additionally, a specialized maritime engineering and environmental solutions company validated the use of B15, to ensure compliance with technical and operational standards. The findings of this study will contribute to future scalability assessments for extending the use of biofuel to other port vessels.

A. Before implementation

- Annual fuel consumption [Liters/year]
- Annual engine running time [Hours]
- CO_{2eq.} emissions [Tons per year]
- Engine performance (Efficiency, maintenance requirements)
- Validation by a specialist company in maritime engineering and environmental solutions for B15 use, based on engine technical features (brands, models, power, and other specifications).

B. After implementation

- Reduction of fuel consumption (Biofuel B15 vs. marine diesel B0) [Liters/year]
- Reduction of CO_{2eq.} emissions [Tons per year]
- Potential scalability analysis for other port vessels.

5. ECONOMIC AND ENVIRONMENTAL ANALYSIS (*IF THE INFORMATION IS ACCESSIBLE*)

A. Initial investment required

The initial investment required for the introduction of biofuels in port operating vessels depends primarily on the compatibility assessment and potential retrofitting costs. For new vessels, a detailed technical analysis is essential to ensure the engine's suitability for biofuel use. For existing vessels, modifications may be required to adapt the fuel properties, although many modern engines can already run on blends such as B15 without modification. In the pilot case of the *Triângulo* boat, no engine modifications were required, however, increased wear on fuel filters was observed, necessitating more frequent replacement than usual. This highlights the importance of ongoing monitoring and minor adjustments to optimize long-term operational efficiency and cost effectiveness.

B. Key savings or economic impact

- Fuel Cost Stability and Immediate Savings:

The pilot test was conducted in partnership with PRIO, a biofuel producer operating within the Port of Aveiro, under a formal proof-of-concept agreement. As part of this collaboration, PRIO applied a discount to the B15 biofuel, ensuring that its price remained at the same level as conventional marine gas oil (B0). This allowed the Port of Aveiro to transition to biofuels without incurring additional fuel costs. While the market price of B15 is generally higher than B0, future tests on additional pilot boats will provide a more accurate assessment of the long-term economic impact, taking into account fuel price fluctuations and consumption reductions.

- **Avoidance of High Capital Investments in Electrification or New Vessel Purchases:**

Unlike full electrification or the replacement of vessels with new sustainable-energy-powered alternatives, the adoption of biofuels does not require large capital investments. Many existing engines can run on B15 without modification, allowing for a cost-effective transition. By leveraging biofuels, ports can achieve significant carbon reductions while maintaining financial flexibility, directing resources toward other sustainability initiatives without the burden of acquiring new fleets or investing in extensive charging infrastructure.

- **Operational Continuity with Minimal Disruptions:**

The introduction of B15 in the pilot boat *Triângulo* demonstrated that biofuel adoption can be seamlessly integrated into existing operations. The only notable adjustment was an increased frequency of fuel filter replacements, which is manageable within routine maintenance schedules. This ensures that vessels remain fully operational with no downtime, maintaining efficiency and reliability. As the use of biofuels becomes more widespread, further optimizations can enhance maintenance strategies, increase asset longevity and maintain high levels of service availability.

c. Contribution to environmental goals

The use of biofuels significantly contributes to environmental goals by directly reducing greenhouse gas (GHG) emissions from port vessel operations. A B15 blend achieves a 15% reduction in GHG emissions, while B100 offers an 88% reduction, making biofuels a valuable tool in the decarbonization of ports.

The direct environmental contribution of this use case is therefore the reduction of GHG emissions, measured in CO_{2eq.}. Regarding the KPIs described above, the fuel consumption of the *Triângulo* in 2024 was 1200 L/year, which means a saving of 0.5 tCO_{2eq.}. In addition, the average fuel consumption with B0 was 8.20 L/h and, after the implementation it was reduced to 7.20 L/h, resulting in an additional saving and CO_{2eq} emission reduction.

Taking into account the fuel consumption of all pilot boats and tugs in 2024, which was 259,582 litres, the GHG emissions were calculated as 695.68 tCO_{2eq.}. If B15 had been used by all the vessels, a saving of 103.83 tCO_{2eq} would have been achieved. Using B100 means a saving of 695.484 tCO_{2eq.}

The pilot test confirmed that B15 is a viable and effective solution that requires only minor operational adjustments, such as more frequent fuel filter maintenance, and does not imply any engine retrofitting. Given the financial and infrastructural constraints of many Small and Medium-Sized Ports (SMPs), scaling up biofuel adoption across European ports could provide a cost-effective and accessible pathway to achieving sustainability goals. Furthermore, the successful implementation of biofuels reinforces the need for stronger policy support at the EU level, encouraging regulatory frameworks and incentives for sustainable fuels.

- Direct reduction in CO₂ emissions from port vessel operations.
- Demonstration of biofuel viability for broader maritime use.
- Encouragement of policy support for sustainable fuels in EU ports.

6. CONCLUSIONS

A. Success of the green practices

This use case demonstrates the success of using B15 in the pilot boat without engine modifications, ensuring safe operation while achieving a reduction in greenhouse gas emissions, helping the Port of Aveiro to further its decarbonisation process and sustainability goals.

It has been clearly demonstrated that this blend (B15) can be used without restriction in other harbour craft, including tugs, so there is great potential for its use to be extended.

Collaboration with other ports, following the example of the Port of Aveiro, will make it possible to expand the use of biofuels in ports:

- The **pilot boat biofuel test** demonstrated safe operation without modifications.
- **Emissions reductions achieved**, contributing to sustainability goals.
- **Expansion potential** identified for tugboats and additional port vessels.
- **Stronger collaboration** established between northern Portuguese ports.

B. Lessons learned:

The implementation of this pilot project has provided some important lessons, highlighting the importance of raising awareness among those involved in the use case, from the board to those using new fuels. The main resistance to change comes from the boat captains.

Another challenge was how to supply the pilot boat outside the normal supply circuit, where the biofuel is not available.

Partnering with local suppliers is fundamental to the success of this use case and ensuring its continuity over time.

- **Challenges faced:** Ensuring consistent biofuel supply, addressing potential cost fluctuations.
- **Solutions found:** Developing partnerships with local biofuel producers.
- **Training needs:** Awareness programs for port operators on biofuel handling and sustainability benefits.

C. Next steps

Based on the results obtained with the implementation of the use of biofuel instead of marine gas oil in one of the pilot boats of the Port of Aveiro, the *Triângulo*, it is demonstrated that this type of fuel can help ports in their decarbonisation process, as a transitional fuel when other green solutions are not feasible, or even as a definitive fuel in higher blends than B15.

As mentioned above, APA intends to extend its use to the other two pilot vessels in the near future, and also to introduce this green practice to other vessels used in port operations, both in the tugboat operation in the Port of Aveiro and in other Portuguese ports, for wider adoption.

Regarding the retrofitting needs for the use of other biofuel blends higher than 15%, and in order to encourage companies to switch to other advanced fuels, a political commitment with the maritime authorities will be needed to raise awareness and provide funds not only to public administrations but also to private ones.

Concluding:

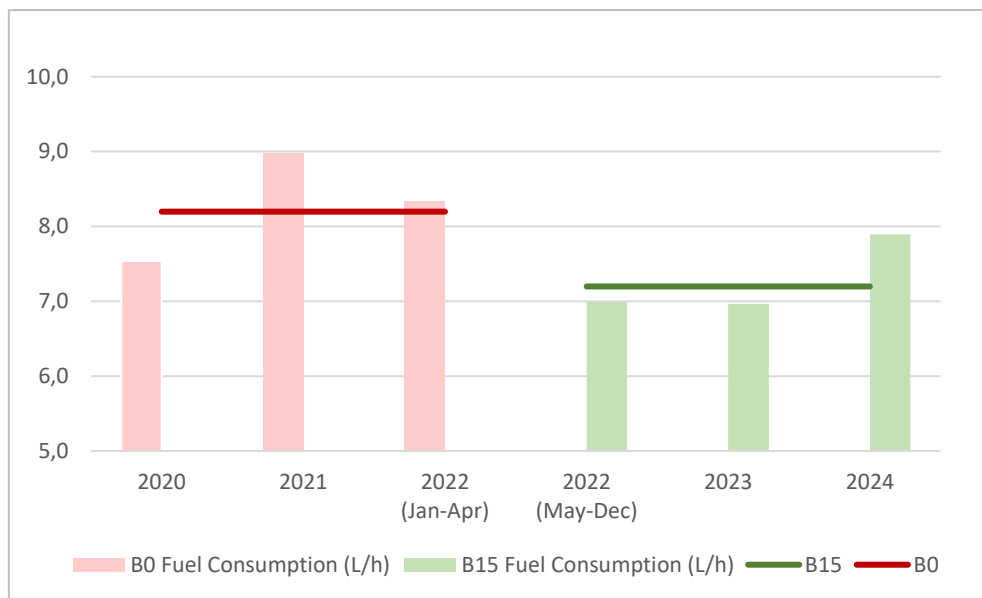
- **Expanding the use of biofuels** beyond pilot boats to other port vessels.
- **Strengthening collaboration** with additional ports for larger-scale adoption.
- **Policy engagement** with maritime authorities to encourage incentives for biofuel transition.

7. ANNEXES

D. Include relevant supporting materials

Table 1 - Average fuel consumption 2020-2024

	2020	2021	2022 (Jan-Apr)	2022 (May-Dec)	2023	2024
Fuel (L)	5,910	5,800	800	2,000	1,400	1,200
"Triângulo" Manoeuvring Time	784	646	96	286	201	152
B0 Fuel Consumption (L/h)	7.54	8.98	8.33	-	-	-
B15 Fuel Consumption (L/h)	-	-	-	6.99	6.97	7.89
Average fuel consumption (B0)	8.20					
Average fuel consumption (B15)				7.20		



Graph 1 - Fuel Consumption 2020-2024

Table 2 - Emission factors

Fuel	tCO ₂ /l	Fuel	tCO ₂ /l
Marine Gas Oil (B0)	0.00268	Eco diesel/Eco Bunker (B15)	0.00228
Eco Diesel (B7)	0.00246	UCOME (B100)	0.00033

Source: Directive (UE)2018/2001 (RED II)

Table 3 - Estimated GHG emission (tCO₂eq.)

Vessel Name	Type of vessel	Type of fuel	Fuel Consumption 2024 (lts)	GHG emission (tCO ₂ eq.), in 2024				
				Real	Using B15 (estimated)	Using B15 savings	Using B100 (estimated)	Using B100 savings
Triângulo	Pilot Boat	B15	1,200	2.74	2.74	0.48	0.00	3.22
Mó do Meio	Pilot Boat	B0	18,400	49.31	41.95	7.36	0.01	49.30
Espinheiro	Pilot Boat	B0	24,982	66.95	56.96	9.99	0.02	66.93
Castelo de Leiria	Tugboat	B0	85,000	227.80	193.80	34.00	0.06	227.74
Castelo de Viana	Tugboat	B0	95,000	254.60	216.60	38.00	0.07	254.53
Salinas de Aveiro	Tugboat	B0	35,000	93.80	79.80	14.00	0.03	93.77
Total			259,582	695.68	591.85	103.83	0.20	695.48

Photos or diagrams of the implemented system

Table 4 - Pilot Boats of the Port of Aveiro

Pilot Boats		Engines
Triângulo		2 x VOLVO PENTA TAMD31P-A 150HP- 3900 RPM
Mó do Meio		2 x YANMAR 6LYA-STE 350 HP- 3300 RPM
Espinheiro		2 x VOLVO PENTA D9-425 425 HP- 2200 RPM