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Economy**

**Sustainable Cruise Tourism in Greece:
Challenges and Practical Approaches, a Case
Study of Heraklion Cruise Port**

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ABSTRACT

The cruise industry has experienced significant growth over recent decades, reaching 34.6 million passengers globally in 2024 and reinforcing its role as a major component of international tourism. Within this context, Greece has emerged as a leading cruise destination in the Mediterranean, attracting approximately 7 million cruise passengers annually, while facing increasing environmental and social pressures on coastal destinations.

This thesis examines the sustainability dimensions of cruise tourism in Greece through a qualitative case study of the Port of Heraklion, a medium-sized island port in the Eastern Mediterranean experiencing rapid cruise growth. The analysis is based on secondary source data from port authority reports, academic literature, and policy documents produced at national, European, and international levels.

The findings indicate that cruise tourism contributes significantly to Heraklion's local economy, particularly through passenger expenditure and the port's growing role as a homeport. At the same time, cruise activity is associated with environmental and social challenges, including greenhouse gas emissions, urban congestion, pressure on cultural heritage sites, and risks to sensitive marine ecosystems. The thesis concludes by proposing practical, context-specific approaches to support more sustainable cruise port operations through coordinated stakeholder action.

Key Words: Cruise Tourism, Sustainable Cruise Ports, Port of Heraklion, Blue Economy

ABSTRACT IN GREEK

Η βιομηχανία της κρουαζιέρας έχει παρουσιάσει σημαντική ανάπτυξη τις τελευταίες δεκαετίες, φτάνοντας τους 34,6 εκατομμύρια επιβάτες παγκοσμίως το 2024 και ενισχύοντας τον ρόλο της ως βασικό τμήμα του διεθνούς τουρισμού. Στο πλαίσιο αυτό, η Ελλάδα έχει αναδειχθεί σε έναν από τους κορυφαίους προορισμούς κρουαζιέρας στη Μεσόγειο, προσελκύοντας περίπου 7 εκατομμύρια επιβάτες ετησίως, ενώ παράλληλα αντιμετωπίζει αυξανόμενες περιβαλλοντικές και κοινωνικές πιέσεις στις παράκτιες περιοχές.

Η παρούσα διπλωματική εργασία εξετάζει τις διαστάσεις της βιωσιμότητας της κρουαζιέρας στην Ελλάδα μέσω μιας ποιοτικής μελέτης περίπτωσης του Λιμένα Ηρακλείου, ενός μεσαίου μεγέθους νησιωτικού λιμένα στην Ανατολική Μεσόγειο με ταχεία ανάπτυξη της δραστηριότητας της κρουαζιέρας. Η ανάλυση βασίζεται σε δευτερογενή δεδομένα από εκθέσεις λιμενικών αρχών, ακαδημαϊκή βιβλιογραφία και νομοθετικά έγγραφα σε εθνικό, ευρωπαϊκό και διεθνές επίπεδο.

Τα ευρήματα δείχνουν ότι η κρουαζιέρα συμβάλλει ουσιαστικά στην τοπική οικονομία του Ηρακλείου, κυρίως μέσω της δαπάνης των επιβατών και του ενισχυόμενου ρόλου του λιμένα ως λιμένα αφετηρίας. Παράλληλα, η δραστηριότητα της κρουαζιέρας συνδέεται με περιβαλλοντικές και κοινωνικές προκλήσεις, όπως οι εκπομπές αερίων του θερμοκηπίου, η αστική συμφόρηση, η επιβάρυνση πολιτιστικών μνημείων και οι κίνδυνοι για ευαίσθητα θαλάσσια οικοσυστήματα. Η εργασία καταλήγει προτείνοντας πρακτικές και προσαρμοσμένες στο τοπικό πλαίσιο προσεγγίσεις για την υποστήριξη πιο βιώσιμων λιμενικών λειτουργιών μέσω συντονισμένης δράσης των εμπλεκόμενων φορέων.

Λέξεις κλειδιά: Κρουαζιέρα, Βιώσιμη Ανάπτυξη Λιμένων Κρουαζιέρας, Λιμένας Ηρακλείου, Γαλάζια Οικονομία

1. INTRODUCTION

1.1. BACKGROUND

In recent decades, the cruise industry has shown great growth, while also contributing significantly to the further development of tourism worldwide. As illustrated in Figure 1, the cruise industry has demonstrated remarkable growth over the last 40 years. Data from the Cruise Lines International Association (CLIA) shows passenger volume increasing from 1.9 million in 1985 to 34.6 million in 2024. Despite the significant decrease in passenger volume caused by the COVID-19 pandemic in 2020 and 2021, the sector has rebounded to exceed pre-pandemic levels.

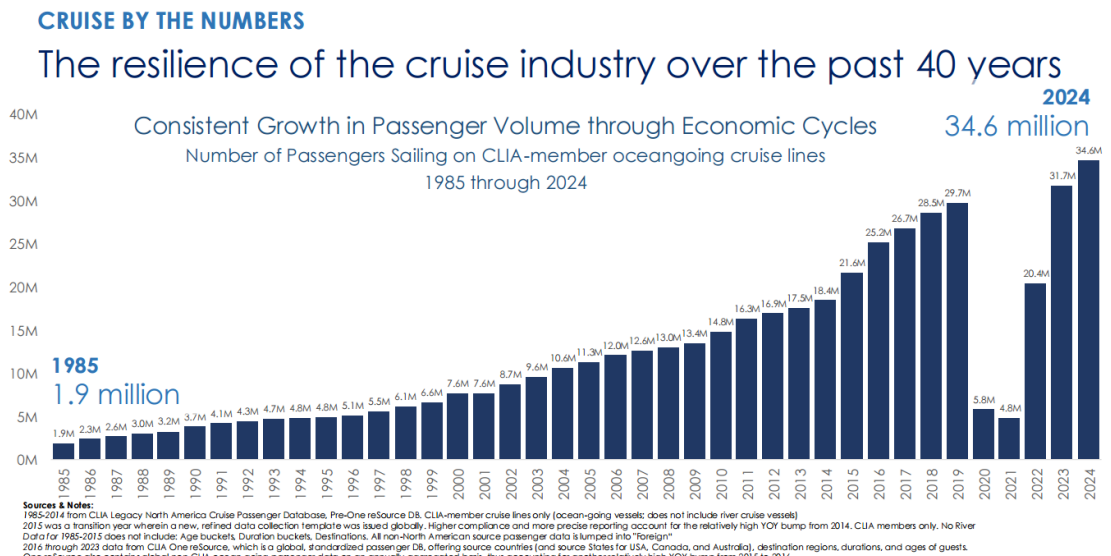


Figure 1. Number of global ocean cruise passengers 1985-2024 (Cruise Lines International Association, 2025)

In the coming years, passenger traffic on cruises is projected to increase at a steady pace. As illustrated in Figure 2, passenger volume is expected to grow from 34.6 million in 2024 to approximately 42 million by 2028 (Cruise Lines International Association, 2025).

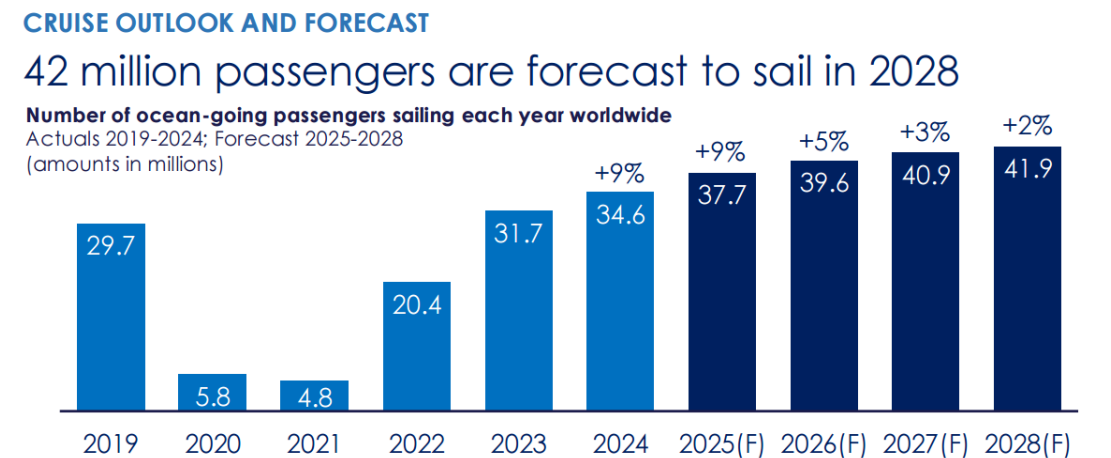


Figure 2. Number of ocean-going passengers sailing each year worldwide, actual 2019-2014, Forecast 2025-2028 (Cruise Lines International Association, 2025)

However, this global expansion is heavily concentrated in specific regions, with the

Mediterranean being a central pillar of the industry. Following the Caribbean, the Mediterranean is the second most popular cruise destination globally, with 5.77 million passengers in 2024 (Cruise Lines International Association, 2025). Within this region, Greece stands out as a crucial nation in the Eastern Mediterranean cruise market. Greece is among the top three tourism destinations cruise in the Mediterranean, while in 2023 Greek ports welcomed 7 million passengers and 5,230 cruise ship calls (Cruise Lines International Association, 2023).

This rapid expansion requires a critical review environmental and social impact of the cruise industry. Research shows that cruise ships significantly harm local air quality. Studies on Greek ports reveal that about 88.5% of emissions, such as nitrogen oxides and sulfur dioxide, occur while ships are docked to power their systems (Maragkogianni & Papaefthimiou, 2015). Beyond air pollution, the sector creates a "pulse" of visitor flows. When thousands of passengers disembark at the same time, it causes severe congestion and strains the infrastructure of historic port cities (International Transport Forum, 2017). Consequently, experts now emphasize that the industry must change to remain valuable for Greece. It must move from simple growth to a model of 'systemic sustainability' that protects the coastal environment (Papathanassis, 2023).

1.2. LITERATURE REVIEW

This section reviews the academic literature on the impacts of cruise tourism, which establishes the framework for analyzing the challenges and opportunities for sustainable practices in Greece. Due to the rapid expansion of the sector, a significant body of research has emerged to assess its complex effects.

The work of Papathanassis (2023) frames the modern discourse surrounding the industry, highlighting the public debate that casts cruise tourism as a key example of unsustainable growth and environmental pollution. The study argues that this common narrative often oversimplifies the issue by focusing narrowly on ship-bound emissions and waste, thereby overlooking the interconnected economic and socio-cultural dimensions that demand a more holistic and systemic analysis.

Research by Brida and Zapata-Aguirre (2010) provides a detailed account of the specific environmental and economic impacts. They describe large cruise ships as 'floating cities' that produce immense volumes of waste, including blackwater, graywater, and solid waste, which pose a significant threat to marine ecosystems. While their work acknowledges the industry's potential for direct and indirect economic benefits, it emphasizes the substantial environmental costs that destinations must manage.

Focusing on the Greek context, the study by the International Transport Forum (2017) on the port of Piraeus reveals a critical challenge: a disconnect between high passenger numbers and the limited economic benefits spilling over into the local city. The report identifies tangible negative impacts on the urban environment, including significant air emissions from ships and traffic congestion, which strain local infrastructure and affect residents' quality of life.

Finally, the study by Dimitrovski et al. (2021) underscores the need for a multi-stakeholder approach to resolve these issues, arguing that sustainable coastal and

marine tourism planning requires balancing economic, environmental, and societal aspects through collaborative management. This body of literature collectively highlights the complex challenges and establishes the need for the practical, integrated solutions that this thesis aims to explore.

1.3. PURPOSE AND STRUCTURE

The purpose of this thesis is to examine the environmental, social, and economic impacts of the cruise industry on the Port of Heraklion. As the port experiences record-breaking growth, reaching over 550,000 passengers by 2025, it faces a critical need to balance this economic success with the preservation of Crete's natural and social environment. This research aims to identify the current barriers to sustainability and propose practical, actionable strategies that can help Heraklion transition into a "green and smart" maritime hub.

To address these objectives, the thesis is structured into six main chapters, each contributing to a coherent analytical framework.

- Chapter 1 introduces the background of cruise tourism development, reviews the relevant academic literature, and defines the purpose and scope of the study.
- Chapter 2 examines the concept of sustainability and its three core pillars—economic, social, and environmental—with a particular focus on their application within the global cruise industry and international best practices.
- Chapter 3 analyzes the cruise industry in Greece, outlining its historical evolution, economic and social significance, environmental footprint, and the international, European, and national legal frameworks governing cruise activities.
- Chapter 4 presents the case study of the Port of Heraklion. This chapter describes the port's characteristics and infrastructure, analyzes cruise traffic trends, and evaluates the environmental, social, and economic impacts of cruise tourism, as well as the sustainability initiatives already implemented by the port authority.
- Chapter 5 builds on the findings of the case study to identify the key challenges limiting the adoption of sustainable practices and proposes a set of strategic and practical approaches aimed at enhancing sustainable cruise development in Heraklion.
- Finally, Chapter 6 summarizes the main findings of the thesis, reflects on their broader implications for sustainable cruise tourism in Greece, and presents concluding remarks and directions for future research.

2. SUSTAINABILITY IN CRUISE TOURISM

2.1. PILLARS OF SUSTAINABILITY

According to the World Wide Fund for Nature (WWF), a Sustainable Blue Economy must respect ecosystem integrity. The only secure pathway to long-term prosperity is through the development of a circular economy (WWF, 2015).

The sustainable blue economy seeks to promote economic growth, social inclusion, and the preservation of livelihoods while ensuring the environmental sustainability of the oceans and coastal areas. In the context of the cruise industry, this approach requires integrating the following three pillars:

- **Economic Pillar:** A sustainable blue economy focuses on long-term profitability that is achieved without environmental harm, encouraging investment in green technologies and infrastructure that support lasting growth rather than short-term gains. It emphasizes shifting from a volume-based model to one that values the quality of economic contributions, ensuring that host destinations receive a fair share of the revenue generated by maritime activities.
- **Social Pillar:** Social sustainability requires that the benefits of the blue economy be equitably distributed, creating stable employment and improving the quality of life for local communities rather than just generating profits for external corporations. It also prioritizes the preservation of local cultural heritage and social cohesion, ensuring that tourism development respects the rights and daily lives of the residents in port cities.
- **Environmental Pillar:** This pillar entails minimizing the industry's ecological footprint through strict adherence to regulations on waste management, emission reductions, and the protection of marine biodiversity. It focuses on maintaining the health of ocean ecosystems, such as coral reefs and coastal waters, which are not only vital for the planet but are also the essential natural assets upon which the cruise industry depends.



Figure 3. Blue Sustainable Economy Model, Source: (WWF, 2015)

2.2. ENVIRONMENTAL SUSTAINABILITY IN THE CRUISE INDUSTRY

Although cruise ships comprise less than one percent of the global maritime fleet, the cruise industry has positioned itself at the forefront of developing innovative technologies and practices to protect the environment. According to the Cruise Lines International Association, operators are actively pursuing net zero greenhouse gas emissions by 2050, a target that is consistent with the 2023 strategy of the International Maritime Organization regarding the reduction of emissions from ships. Furthermore, the industry is aligning its operations with globally recognized environmental and social standards, including the United Nations Sustainable Development Goals, specifically focusing on climate action, sustainable cities and communities, good health and well-being, life on land and life below water (Cruise Lines International Association, 2026).

To achieve this net zero goal, the global fleet is undergoing a significant technological transformation, particularly concerning fuel flexibility and energy sources. The next table shows compiled statistics representing the worldwide oceangoing membership of the Cruise Lines International Association, as per August 2025. Specifically, it details the volume of vessels outfitted with particular environmental technologies, their respective passenger volumes and the proportional share these metrics hold within the total global fleet (Cruise Lines International Association, 2025).

Investments, Commitments and Practices	Ships Reporting (310 Total Fleet)	Aggregate % of Reporting Ships	Capacity Lower Berth Double Occupancy (637,847)	Aggregate % of Reporting Capacity
Oceangoing Ships Reporting	284	91.6%	633,293	99.3%
New Ships On Order (for 2025 ETP, through 2036 delivery year) 55 CLIA ships on orderbook reported into ETP out of 60 for delivery from 2025 through 2036	55	-	186,850	-
Ships (planned to be) removed from the fleet between 1 January and 31 December of Measure Year	1	-	458	-
Average age of fleet as of 1 January of Measure Year	15.2	-	-	-
<u>Liquefied Natural Gas (LNG)</u>				
Ships capable of using LNG as primary fuel for propulsion	19	6.7%	80,016	12.6%
New build ships committed to use LNG	25	-	115,748	-

as primary fuel for propulsion				
<u>Shore Side Electricity (SSE)</u>				
Ships fitted with Shore Side Electricity (SSE) systems	166	58.5%	414,297	65.4%
Ships planned to be retrofitted with SSE systems	59	20.8%	100,486	15.9%
New build ships committed to be fitted with SSE systems	48	-	169,18	-
<u>Additional Air Pollution & Energy Efficiency Technologies</u>				
Ships fitted with particulate filters	37	13.0%	90,734	14.3%
Ships fitted with Selective Catalytic Reduction (SCR) Systems	81	28.5%	141,302	22.3%
Ships capable of complying with NOx Tier III limits	85	29.9%	167,103	26.4%
Ships that have air lubrication systems fitted	33	11.6%	120,988	19.1%
<u>Exhaust Gas Cleaning Systems (EGCS)</u>				
Ships fitted with exhaust gas cleaning systems (EGCS)	167	58.8%	479,447	75.7%
New build ships committed to be fitted with EGCS	4	-	14,800	-
<u>Waste Water</u>				
Ships that have an advanced waste water treatment system on board, approved, used and capable of meeting or exceeding IMO MARPOL Annex IV discharge norms	234	82.4%	540,985	85.4%
New build ships that will have an advanced waste water treatment system on board, approved and capable of meeting or	39	-	144,502	-

exceeding IMO MARPOL Annex IV discharge norms.				
Ships that have a waste water treatment system on board, approved and capable of meeting the discharge standards of the IMO MARPOL Annex IV Baltic Sea Special Area	106	37.3%	219,542	34.7%
<u>Other Technologies</u>				
Ships with a Biofouling Management Plan	268	94.4%	628,354	99.2%
Ships fitted with Water Fuel Emulsion (WFE) technology/treatments	44	15.5%	102,088	16.1%
Vessels fitted with bulbous bow	249	87.7%	584,849	92.4%
Vessels that can produce freshwater onboard	279	98.2%	632,733	99.9%
Vessels that can produce 100% of freshwater onboard	198	69.7%	514,281	81.2%

Table 1. Environmental Technologies and Practices data across CLIA's global oceangoing cruise line membership (Cruise Lines International Association, 2025)

The latest data indicates a steady transition toward lower emission fuels. Currently, 19 ships are capable of using Liquefied Natural Gas as their primary fuel for propulsion, with an additional 25 new build ships committed to this technology. Significant investments are also being made to reduce air pollution while vessels are at berth and at sea. A critical component of this strategy is the implementation of shore side electricity systems, which allow cruise ships to switch off their engines and connect to the local power grid, resulting in a substantial reduction of local emissions. Currently, 166 ships are fitted with shore side electricity capabilities, representing 65.4 percent of the total reporting passenger capacity, with dozens more planned for retrofitting. For emissions at sea, 167 ships, which account for over 75 percent of the global passenger capacity, are equipped with exhaust gas cleaning systems. Additionally, vessels are increasingly being fitted with selective catalytic reduction systems and particulate filters to ensure compliance with strict international air quality limits (Cruise Lines International Association, 2025).

Environmental sustainability in the cruise sector also heavily emphasizes advanced water management and waste reduction. Cruise operators globally employ advanced onboard systems that often surpass shoreside and international standards. According to CLIA's data 234 ships, representing over 85 percent of the reporting capacity, feature

advanced wastewater treatment systems that meet or exceed the strict discharge norms of the International Maritime Organization. Water conservation is further supported by the fact that 279 vessels can produce freshwater onboard, with 198 of these capable of independently generating 100 percent of their freshwater needs. To protect marine biodiversity, 268 ships operate with a dedicated biofouling management plan (Cruise Lines International Association, 2025).

2.3. APPLICATIONS AND BEST PRACTICES OF SUSTAINABLE CRUISES INTERNATIONALLY

The growing pressure from regulations and increasing eco-awareness among passengers has pushed the international cruise industry to adopt a wide range of sustainable practices. This shift is not limited to cruise lines alone but also involves proactive environmental management by port authorities. Best practices now often involve a systemic and holistic approach that addresses the multi-dimensionality of sustainability. A key application of this is the rise of cruise eco-tourism, where passengers are sometimes engaged in conservation efforts like "environmental citizen science," transforming the cruise from a simple holiday into an educational and beneficial experience for the destination. This move towards more responsible tourism is a direct response to the need to balance the industry's growth with its environmental and social obligations (Papathanassis, 2023).

Internationally, major ports are implementing concrete measures to mitigate the environmental impact of cruise tourism. The Port of Barcelona, for example, in 2022 was faced with 18,277kg of Sulphur dioxide due to emissions from the cruise ships. (Transport and Environment, 2023). To address these challenges, the Port of Barcelona implemented a comprehensive Air Quality Improvement Plan aimed at protecting public health and reducing atmospheric pollutants within the port environment. According to the official strategy, this plan establishes distinct areas of action to systematically reduce harmful emissions from port activities (Port of Barcelona, 2026). In Northern Europe, the Port of Stockholm has developed a best-practice model for wastewater management by creating a closed-loop system that allows cruise ships to connect directly to the city's central sewage treatment facility, preventing the discharge of untreated blackwater and graywater into the sensitive Baltic Sea (Ports of Stockholm, 2026).

Beyond environmental pollution, leading international destinations are also developing best practices to manage the severe social impacts of overtourism. In response to overwhelming visitor numbers and damage to its fragile ecosystem, Venice took the drastic step in 2021 of banning large cruise ships from its historic lagoon. This move resulted in an 80% reduction in air pollutants from cruise ships, while an access fee was also introduced for passengers visiting the historical center to help reduce overcrowding (Citta' Di Venezia, 2023). A different, more collaborative approach has been taken by Dubrovnik, a UNESCO World Heritage site. The city signed a Memorandum of Understanding with the Cruise Lines International Association (CLIA) to better manage tourist flows through careful planning and scheduling of cruise ship arrivals, ensuring the protection of its heritage while maintaining a viable tourism industry (Alexandropoulou et al., 2024).

Best practices in sustainable cruising also extend to the active protection of marine biodiversity during port development. A leading example is the Nassau Cruise Port in

the Bahamas, which has established an integrated Environmental Management Plan to minimize adverse impacts on the local marine environment. A key part of this plan involved a proactive coral relocation program, where hundreds of corals were carefully moved from the construction area to a protected site. This measure was taken to safeguard the sensitive marine organisms and ensure that the port's expansion did not come at the cost of the area's natural heritage (Alexandropoulou et al., 2024).

3. THE CRUISE INDUSTRY IN GREECE: CURRENT STATE AND CHALLENGES

3.1. HISTORICAL EVOLUTION AND IMPORTANCE OF CRUISES FOR GREECE

The Greek cruise industry has a long and established history, with its origins tracing back to the 1930s when the first Greek-owned cruise firms began to offer leisure travel services and introduce cruising routes in the Aegean Sea and the broader Mediterranean basin. Early companies like AKTEL and Hellenic Mediterranean Lines (ELMES) were pioneers in developing this form of maritime tourism. For much of its history, the sector's evolution was significantly shaped by national cabotage laws, which were in force from 1920 until they were eventually abolished. These regulations prohibited foreign-flagged cruise companies from embarking and disembarking tourists between Greek ports, which influenced the structure and competitiveness of the industry for decades (Diakomihalis, 2009).

Today, Greece is a major force in the international cruise market. It is accurately described as a "significant participant in the broader East Mediterranean market" and a top-tier global destination, thanks to its extensive and appealing island network. The scale of the industry is demonstrated by its passenger traffic, for the year 2023 the total cruise passenger flow in Greece was 7,003,000 passengers, which equals with approximately 11% of the total European cruise passenger flow of the same year (Cruise Lines International Association, 2023).

To support this massive volume of maritime traffic, Greece relies on a geographically dispersed network of infrastructure. As illustrated in Figure 4, the country's capacity is not limited to a single hub but is distributed across a vast array of island and mainland destinations.



Figure 4. Map of Hellenic Ports Association (ELIME) Members. (Hellenic Ports Association, 2024)

According to the Hellenic Ports Association (ELIME), this network includes the above major Port Authorities and Port Funds (as depicted in the map above) that manage the country's critical maritime gateways. This extensive dispersion allows for a diverse range of cruise itineraries, distributing the economic benefits and the challenges of cruise tourism throughout the entire nation (Hellenic Ports Association, 2024).

3.2. ECONOMIC AND SOCIAL IMPACTS OF CRUISES IN GREECE

The cruise industry is a fundamental pillar of the Greek economy, generating multi-dimensional economic benefits, affecting directly and indirectly major supporting sectors such as shipbuilding, repairs, food supplies, and port services. According to the 2023 report commissioned by the Cruise Lines International Association (CLIA) and conducted by Tourism Economics, the cruise industry's contribution to the Greek economy is substantial. In 2023, the sector generated a total economic output of €2.0 billion, of which €1.1 billion was direct output and €0.9 billion stemmed from indirect and induced effects (Cruise Lines International Association, 2023). In terms of employment, the industry supported a total of 22,600 jobs across the country. This figure includes 2,800 Greek residents directly employed by cruise lines (crew and head office staff) and 19,800 jobs created in the wider economy through supply chain and consumption effects (Cruise Lines International Association, 2023).

In Greece, the total GDP originated by the cruise industry for the year 2023 was almost €973 million, of which €476 million were a result of direct effects and an additional €496 million came from indirect and induced effects. The cruise industry’s impact on the Greek economy came from four key activities: cruise line purchases, ship- and capacity-building, on-shore passenger spending, and the wage-linked spending of crew that reside in Greece (Cruise Lines International Association, 2023), as shown in the following figure.

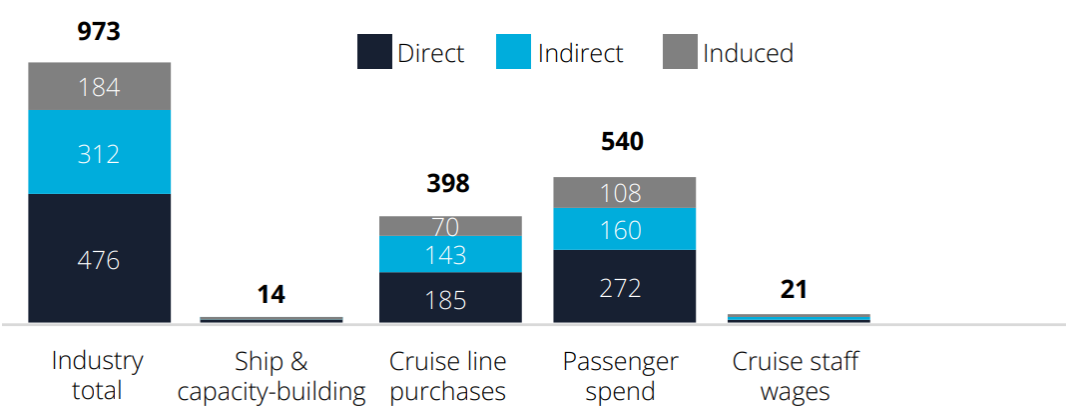


Figure 5. Composition of cruise industry GDP and impact channel in Greece, 2023 (Cruise Lines International Association, 2023).

The passenger spending is the primary driver of this economic footprint, contributing €540 million directly to Greece's GDP and accounting for 55% of the industry's total GDP impact in the country. Cruise line purchases (such as port fees, supplies, and services) contributed an additional €398 million to Greece’s GDP. The ship and capacity building is contributing an additional €14 million to Greece’s GDP.

However, the distribution of benefits varies significantly depending on the port's role, with "home ports" providing significantly greater incremental benefits to the local economy compared to standard transit ports. In the case of Piraeus, despite its status as a major hub handling millions of passengers, the city largely functions as a "place of transit" rather than a destination for overnight stays. It has been observed that despite the numerous arrivals, only a few of the visitors (40%) spend the night in Piraeus (compared to the average overnight stay in the country). Most of them choose to spend the night in other areas of Attica, leaving Piraeus with only environmental damage caused by visitors (Anastasopoulos, et al., 2024).

On a social level, the rapid expansion of cruise tourism in Greece has introduced significant challenges alongside economic gains. There are various negative impacts from cruise shipping for local residents, most importantly air emissions and traffic congestion. For example, in the port of Piraeus cruise ships contribute to the often heavy congestion on Piraeus's main road. Because Piraeus is mostly is a transit port, most of cruise passengers get off the ship for a few hours during the day, disembarking the ship in the morning and returning at the end of the afternoon. This means that cruise passengers are using the Piraeus transport network at times when local commuter traffic is also heavy (International Transport Forum [ITF], 2017).

3.3. ENVIRONMENTAL FOOTPRINT OF CRUISES IN GREECE

The environmental footprint of cruise tourism in Greece is an important issue, as cruise ships in Greece significantly impact the environment through air pollution, water pollution from sewage and scrubber washwater and solid waste. While there are not yet publicly available specific quantified data of the overall environmental impact of cruise ships in Greek ports as a total, there has been a study from Maragkogianni et al, that evaluates the air emissions caused by cruise ships in the five busiest Greek ports (i.e. Piraeus, Santorini, Mykonos, Corfu and Katakolo) for the year 2013. The study evaluated, among others, the emissions values (i.e. NO_x, SO₂ and PM_{2.5}), the emissions from all studied ports under different operational modes and the seasonal distribution of ship emissions (Maragkogianni, 2015).

As shown in the next figure, representing the emissions values (i.e. NO_x, SO₂ and PM_{2.5}) for the studied Greek port, the Port of Piraeus records the highest total emissions at 927 tons, representing one third of the overall pollution. Santorini ranks second with 619 tons, accounting for 23 percent of the total amount. In contrast, Mykonos and Corfu demonstrate very similar pollution levels, emitting 475 and 467 tons of pollutants respectively (Maragkogianni, 2015).

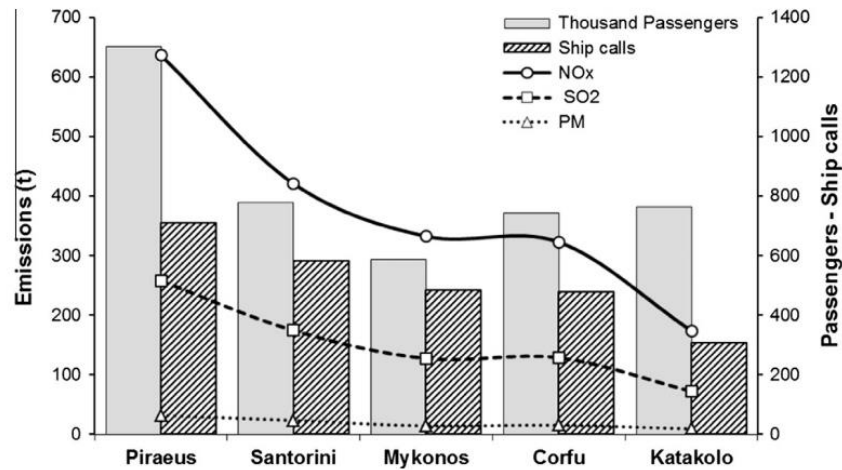


Figure 6. Total amount of emissions in the studied Greek ports (Maragkogianni,2015)

The vast majority of the air pollution generated within port limits occurs while ships are docked. Data summarizing the emissions under different operational modes reveals a big difference between maneuvering and hoteling activities. While maneuvering accounted for an estimated 316 tons of emissions across the studied ports, hoteling generated a massive 2,426 tons of air pollutants, corresponding to 88.5 percent of the total in port emissions. This severe imbalance is due to the fact that hoteling times for cruise ships are extended, and vessels must continuously operate their auxiliary engines at high loads to meet the electricity demands of the ship throughout their entire stay at berth (Maragkogianni, 2015). Next Figure shows the emissions under different operational modes for all the ports under study.

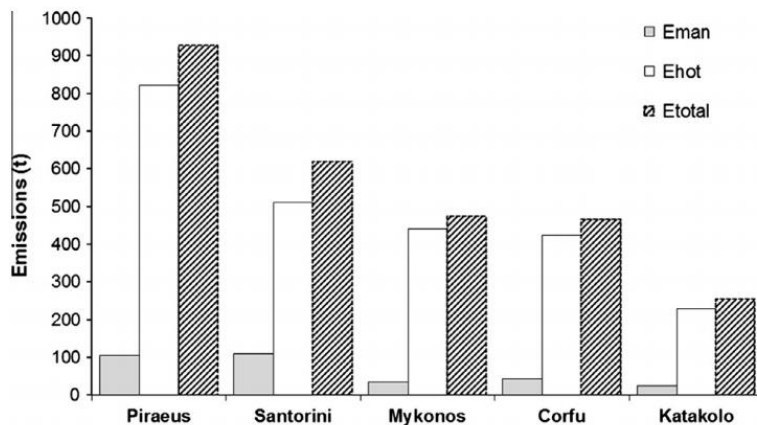


Figure 7. Distribution of emissions according to maneuvering and hoteling activity (Maragkogianni, 2015)

Furthermore, the environmental pressure of cruise shipping is not distributed evenly throughout the year. The seasonal distribution of ship emissions demonstrates a massive peak during the summer period, which accounts for 58.5 percent of the total annual emissions, compared to a mere 0.9 percent during the winter. Interestingly, during the autumn months, emissions remain exceptionally high. Although cruise ships operate their auxiliary engines at slightly lower loads due to reduced air conditioning needs, the sheer volume of ship calls maintains its summer momentum, effectively prolonging the touristic season. For example, in Piraeus, the seasonal distribution of emissions was 50.4 percent in summer, 29.8 percent in autumn, 17.9 percent in spring, and 1.9 percent in winter (Maragkogianni, 2015).

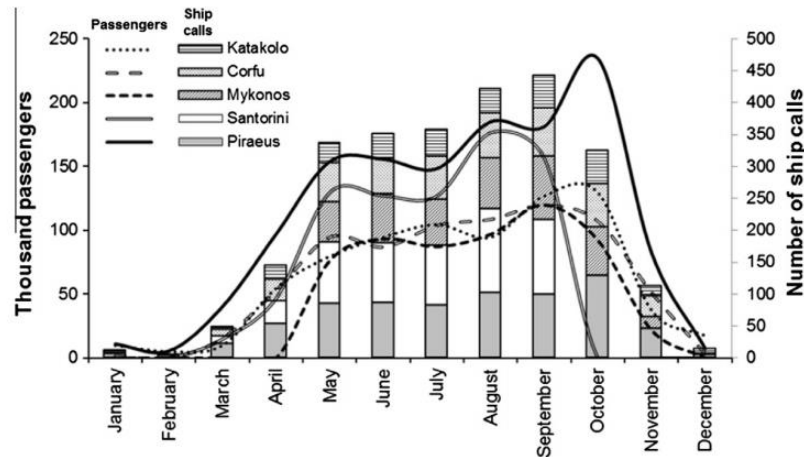


Figure 8. Seasonal distribution of emissions for the studied ports

This pattern of seasonal variation is critical for urban air quality planning. During the summer, the increase in port presence of cruise ships inevitably leads to increased shore-side demand for relevant services, traffic, and congestion. The exhaust emissions from various shore-side vehicles operating in and around the ports, such as supply trucks, tourist buses, and private cars, are added directly to the ship emissions (Maragkogianni, 2015).

3.4. LEGAL AND REGULATORY FRAMEWORK

The regulatory framework referring to cruise tourism in Greece operates on three levels: international maritime law, European Union legislation, and national Greek regulations. Together, these frameworks define the environmental standards and operational requirements for Greek Cruise ports, such as Heraklion.

3.4.1 INTERNATIONAL MARITIME ORGANIZATION

At the international level, Greece adheres to the full body of International Maritime Organization. Most notably, the International Convention for the Prevention of Pollution from Ships (MARPOL), which is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes (International Maritime Organization, 2026). The specific MARPOL Annexes that regulate oil pollution, sewage discharge, waste management, and air emissions are detailed as follows (International Maritime Organization, 2026):

- **Annex I (Oil Pollution):** Mandates strict controls on the discharge of oil and oily water. For cruise ships, this requires the use of oil filtering equipment (separators) that ensure any discharge into the sea has an oil content not exceeding 15 parts per million (ppm). Furthermore, in "Special Areas" like the Mediterranean Sea, discharge is virtually prohibited.
- **Annex IV (Sewage):** Governs the discharge of sewage into the sea. It prohibits the discharge of untreated sewage within 12 nautical miles of land. Cruise ships are required to operate approved sewage treatment plants (STPs) on board, or they must retain sewage in holding tanks until it can be discharged at an onshore Port Reception Facility (PRF).
- **Annex V (Garbage):** Strictly bans the disposal of plastics anywhere in the ocean. It also regulates the disposal of other garbage types, such as food waste, which can only be discharged under specific conditions (e.g., ground down and

more than 12 nautical miles from land, or 3 miles if treated).

- **Annex VI (Air Pollution):** Sets limits on sulfur oxide (SO_x) and nitrogen oxide (NO_x) emissions from ship exhausts. A critical regulation for Greece is the Global Sulphur Cap (2020), which limits fuel sulfur content to 0.50% mass by mass (m/m).

3.4.2 EUROPEAN UNION

The European Union framework plays an important role in shaping the environmental and operational obligations for Greek cruise ports. Current policy directions emphasize the simultaneous need for sustainability, security, and global competitiveness, as officially outlined in the comprehensive EU Ports Strategy adopted by the European Commission in March 2026. This newly adopted framework recognizes ports as multi functional industrial hubs and aims to accelerate their energy transition, improve infrastructure resilience, and strengthen environmental protections to help achieve regional climate neutrality by 2050. Specifically, the strategy advances the green transformation by promoting the upcoming Electrification Action Plan, which supports extensive port electrification, improved grid access, and the deployment of clean energy. Furthermore, the framework aligns with broader initiatives targeting emissions reduction by accelerating the permit granting procedures for strategic environmental port projects and establishing guidelines for the safe handling of alternative fuels. Ultimately, these targeted investments and long term decarbonization measures ensure that Greek ports modernize their operations while sustaining territorial cohesion and supporting quality jobs in the maritime sector (European Commission, 2026).

3.4.3 GREEK LEGISLATION

At the national level, the most significant recent legislation is Article 27 of Law 5162/2024, which establishes a mandatory "Cruise Fee", which got into implementation in the 2025 tourist season. This regulation imposes a levy on every passenger disembarking at a Greek port from a professional cruise vessel (Greek Republic, 2024).

The policy introduces a differentiated pricing model based on the season and the destination. It specifically targets the high-demand islands of Mykonos and Santorini, aiming to act as a mechanism to mitigate over tourism during peak months. The specific fee structure is detailed in Table 3 below.

	Mykonos & Santorini	Other Greek Ports
1 June - 30 September	20 euro/ per passenger	5 euro/ per passenger
1 April - 31 May & 1 October - 31 October	12 euro/ per passenger	3 euro/ per passenger
1 November - 31 March	4 euro/ per passenger	1 euro/ per passenger

Table 2. Greek Port's fee for Cruise Passengers (Greek Republic, 2024)

Beyond managing traffic flows through pricing, the law aims to utilize these revenues to for the construction and improvement of infrastructure and general public works, as well as for the enhancement of the country's tourism sector. According to Paragraph 4 of the Article, the collected funds are distributed equally (33% each) among three stakeholders (Greek Republic, 2024):

1. **Local Municipalities (via Ministry of the Interior):** One-third is allocated to

the municipalities where the disembarkation ports are located, specifically for improving local tourism products and infrastructure.

2. **Port Infrastructure (via Ministry of Maritime Affairs):** One-third is directed in the Public Investment Budget of the Ministry of Maritime Affairs and Insular Policy for works.
3. **Tourism Policy (via Ministry of Tourism):** The final third supports the regular budget of the Ministry of Tourism for broader promotional and strategic activities.

Additionally, Greece has launched institutional mechanisms strengthening governance in cruise tourism. Greece's Tourism Ministry had signed a Memorandum of Cooperation with UN Tourism in order to create the Observatory for Coastal and Marine Tourism, tasked with collecting environmental, social, and economic data to guide evidence-based policy and sustainability planning. Countries participating in the network include Italy, Israel, Malta, Montenegro, Spain, Morocco, Croatia, Egypt, Algeria, Cyprus, Albania, and Lebanon, with Bulgaria, Portugal, and Romania taking part as observers (Greek Travel Pages, 2024).

Parallel to this, the Cruise Lines International Association (CLIA) has proposed the development of a National Cruise Development Plan, emphasizing coordinated long-term planning for port infrastructure, destination management, and environmental improvements, financed through revenues from the cruise levy. This plan—expected to be co-developed by the Greek State and the cruise industry—aims to ensure that Greek ports evolve in line with sustainability priorities and changing patterns of cruise demand (Greek Travel Pages, 2025).

4. THE CASE STUDY OF HERAKLION CRUISE PORT

4.1. METHODOLOGICAL APPROACH OF THE CASE STUDY

This chapter adopts a qualitative case study research approach to examine the sustainability challenges and practices of the Port of Heraklion as a representative medium-sized cruise destination in the Eastern Mediterranean.

The analysis is primarily based on secondary data sources, including official statistics from national and international port organizations, reports from the Heraklion Port Authority, academic studies, and policy documents produced by European and international maritime institutions. Quantitative indicators, such as cruise passenger traffic, economic contribution, and estimated emissions, are combined with qualitative evidence drawn from sustainability reports, environmental monitoring studies, and existing impact assessments. This approach allows quantitative indicators to be used descriptively in support of the qualitative analysis, enabling a comprehensive evaluation of cruise tourism impacts.

Heraklion was selected as a case study due to its rapid growth in cruise traffic, its dual function as a transit and homeport, and its geographical and infrastructural constraints as an island port located adjacent to an urban center. These characteristics make it a relevant and illustrative example for assessing the practical challenges of implementing sustainable cruise port strategies in island destinations.

This methodological approach has certain limitations. The reliance on secondary data means that stakeholder perceptions, such as those of local residents, port workers, or cruise operators, are not captured directly. In addition, focusing on a single case study limits the direct generalizability of the findings. Nevertheless, the Port of Heraklion can be considered representative of a broader category of Mediterranean island ports facing similar sustainability pressures, allowing the results to generate insights that may inform policy and planning in comparable cruise destinations. These limitations also point to meaningful directions for future research, including the use of primary data collection methods or comparative multi-port analyses.

4.2. THE HERAKLION CRUISE PORT

Heraklion is the most significant urban center, the capital, and the economic, social, and scientific hub of the island of Crete. With a population reaching 155,700, according to the latest research by World Population, it holds the title of the most populous city in Crete (World Population Review, 2025).

The size and importance of the city are reflected in its port. The new, modern passenger and commercial port is situated at the eastern edge of the city center, east of the famous Venetian harbor.



Figure 9. Heraklion Port Location, (Heraklion Port Authority, 2025)

The Heraklion Port Authority asserts that the port offers superior and competitive services within the cruise market. Regarding infrastructure, piers II, III, and IV-V are capable of simultaneously berthing up to five cruise vessels in full accordance with the safety standards of the ISPS Code. Additionally, the infrastructure of the two passenger terminals is equipped to process a daily volume exceeding 10,000 passengers and crew. To facilitate logistics, there are designated zones specifically arranged for the parking of pre-arranged tour buses, ensuring secure access and boarding for visitors. A crucial development was the 2017 inauguration of the new Cruise Passenger Terminal on pier IV-V; this facility met the requirements of leading cruise companies and established the necessary foundation for Heraklion to operate as a homeport (Heraklion Port Authority, 2025).

Port Specifications (Hellenic Port Association, 2024) :

- **Hours of operation:** 24hours
- **Security Code ISPS:** Yes
- **Waste management solid:** Yes
- **Waste management liquid:** Yes
- **Number of mooring spaces:** II EAST, III WEST, IV-V WEST, IV-V NORTH, IV-V EAST
- **Dock Length:** 200m/147m/331m/290m/250m
- **Max Dock Depth:** 9m/9m/11.5m/12m/10m
- **Max Length of C/S:** No restrictions
- **Port Services:** Tug boats, Pilots, Fresh Water
- **Passenger Terminal Station:** Yes (2)

- **Nearest airport:** 1,5 km
- **Taxi station:** 20m
- **Bust station:** 40m
- **Distance to town center:** 1,2km
- **Other Services:** Free maps, Free application for mobile city guide (iOS-Android), Free internet Wi-Fi, Information Desk, Cafeterias, Shops and Restaurants in Passenger terminal stations, Duty Free Shops, Open-top buses, Travel train, Rent a car, Parking facilities.

4.3 CRUISE INDUSTRY IN HERAKLION

Heraklion port is one of the biggest cruise ports in Greece with hundreds of thousands of Cruise passengers arriving on the port each year. According to data from the Hellenic Ports Association (ELIME), Heraklion ranked 5th among all Greek ports in terms of passenger traffic for 2024 (Hellenic Ports Association, 2010-2024). Additionally, it has established itself as a critical 'homeport' for the region, ranking 3rd in Greece for homeporting operations after Piraeus and Corfu (Hellenic Ports Association, 2025).

In alignment with the global upward trend in the cruise sector over recent decades, the number of cruise passengers arriving in the port per year has been increased, as well. In the following table the data for cruise ships and passengers arrivals on Heraklion port are presented, as are being published by Heraklion Port Authority every year.

YEAR	PASSENGERS	SHIPS (Numbers of Arrival)
2010	305.675	247
2011	224.571	209
2012	215.700	156
2013	270.020	177
2014	242.951	160
2015	219.805	170
2016	238.780	165
2017	181.693	131
2018	297.929	187
2019	307.043	204
2020	19.998	24
2021	119.930	118
2022	304.257	227
2023	382.981	253
2024	518.575	266

Table 3. Heraklion Cruise Port Traffic Data per year (Hellenic Ports Association, 2010-2024)

The two following figures present the Annual evolution of cruise passenger arrivals at the Port of Heraklion (2010–2024) and the Distribution of cruise ship arrivals per year. From the data presented below, it is obvious that the last 15 years there is a constant increase in cruise ships arrivals and passengers in Heraklion port.

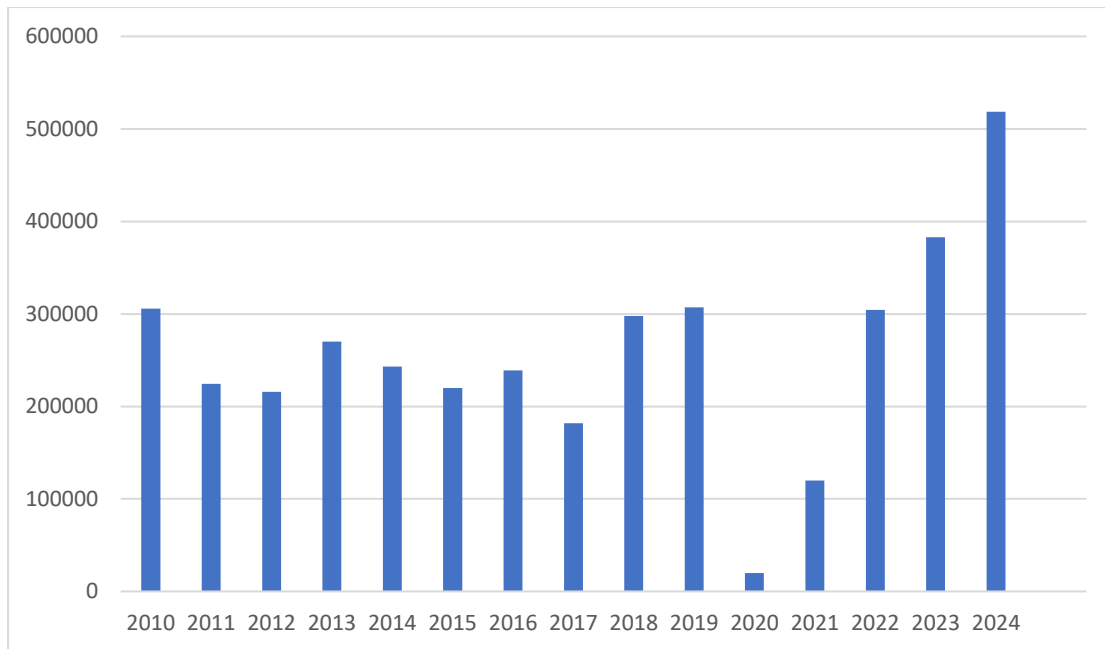


Figure 10. Cruise Passengers in Heraklion Port per Year (Hellenic Ports Association, 2010-2024)

Over the past 15 years, the port has seen a 69.65% increase in passenger volume, growing from 305,675 in 2010 to 518,575 in 2024. This rate is notably higher than the corresponding global growth of 57.22% mentioned in Chapter 1.1, indicating that the port is capturing a growing share of the international market.

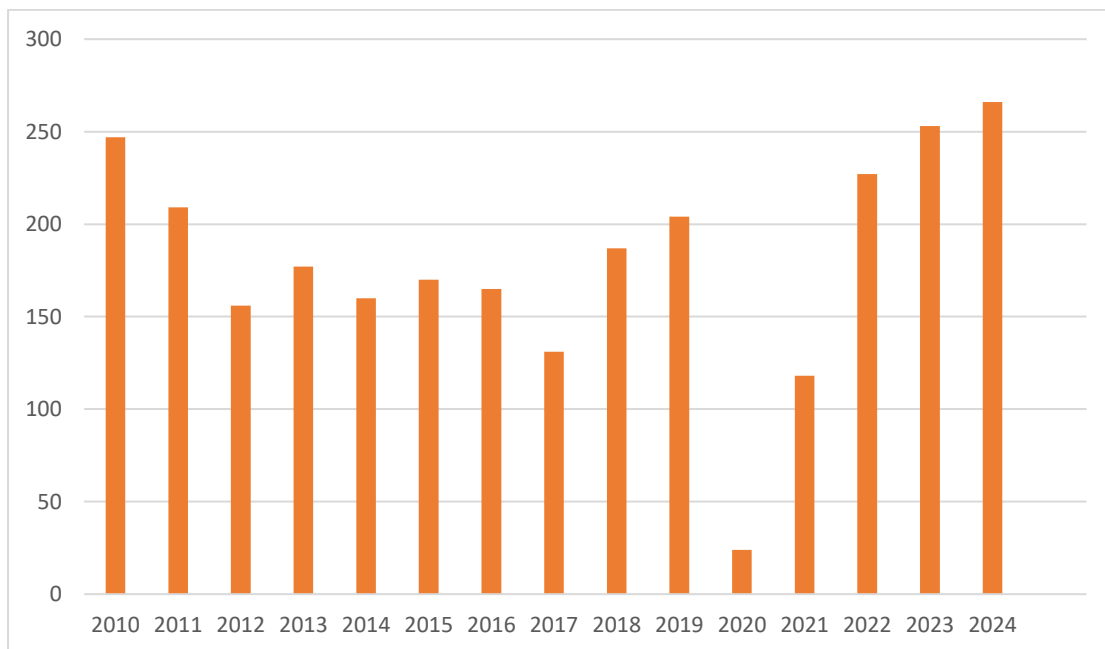


Figure 11. Cruise Ships Arrivals in Heraklion Port per Year (Hellenic Ports Association, 2010-2024)

The increase in the number of vessel arrivals in the last 15 years is equal to 7.69%, rising from 247 ships in 2010 to 266 ships in 2024. This data highlights that while the increase in the number of ship arrivals is not so significant, the number of passengers has increased dramatically. This suggests that the Port of Heraklion is now hosting

much larger cruise vessels with higher passenger capacities compared to 2010.

Regarding the period between 2010 and 2017, the port experienced a general downward trend in ship calls, reaching a low point in 2017 with only 131 ships and roughly 181,000 passengers. This significant decline, particularly the year 2017, was probably driven, as has been stated from press articles of that year, by geopolitical instability in neighboring Turkey, which forced international cruise lines to cancel combined 'joint-stop' itineraries that had previously linked Greek ports like Heraklion with Turkish destinations.

The years 2018 and 2019 saw a sharp rebound, with passenger numbers jumping back to over 300,000. The data shows a near-total collapse in 2020 (19,998 passengers) followed by a partial recovery in 2021. The global pandemic halted all cruise operations. However, Heraklion was one of the first ports in the Mediterranean to restart operations by implementing strict health protocols. Notably, TUI Cruises chose Heraklion as a "homeport" for its Mediterranean restart in late 2020 (Greek Travel Pages, 2020).

The numbers for 2023 and 2024 represent a milestone, with 2024 reaching an all-time high of 518,575 passengers. This growth is the result of several factors: the establishment of Heraklion as a major homeport for lines such as TUI and Celestyal Cruises and the infrastructure enhancements under the port's Master Plan.

Moreover, according to the data published from the Heraklion Port Authority in July 2025 for the first half of the year 2025, there were already 190,606 passengers from cruise ships arrived in Heraklion port, by marking an increase of 14,29% to the same period in 2024 (Heraklion Port Authority, 2025). This upward trend was confirmed by the year-end results. According to Heraklion Port Authority, for the year 2025 the port had handled a total of 536,543 passengers (an increase of 3.46% over 2024), establishing 2025 as a new historic record year for cruise passenger traffic in Heraklion (Heraklion Port Authority, 2025). This growth is largely attributed to the strengthening of the 'shoulder months' (outside the summer peak), with particularly high performance recorded in February, June, and October, reflecting a successful strategy to extend the tourism season and balance visitor flows throughout the year (Heraklion Port Authority, 2025).

4.4 SOCIAL IMPACT

The growth of cruise tourism in Heraklion has a dual effect on the local community, bringing both significant opportunities and specific challenges to the city's social fabric. According to a 2024 study by the University of Piraeus (Pallis & Vaggelas, 2024), cruise activity in Heraklion supports approximately 521 full-time jobs, including 35 direct and 486 indirect full time jobs, providing stable income for many local families. Beyond direct employment, cruise visitors act as "global ambassadors" for Crete; approximately 72% of passengers stated they would recommend Heraklion to others. Furthermore, 29.1% of these tourists plan to return to Heraklion for a longer land-based vacation in the future, which helps the long-term growth of local hotels.

However, the high volume of arrivals also puts pressure on the city's infrastructure and the quality of life for residents. For example, the year 2024 was a record visitation year for the Palace of Knossos with over 1 million visitors, which is partially attributed to

the surge of cruise passenger ships the same year (Zorbas, 2025). This rapid increase in visitors can cause congestion, which can make the experience less enjoyable for visitors (Pallis & Vaggelas, 2024).

The day-to-day life of Heraklion's residents is directly affected by the sudden influx of thousands of tourists into the city center, which often leads to increased noise and competition for the use of public parks, cafes, and local transportation. There is also a noted deficiency in the availability of tourist information points and clear signage (Pallis & Vaggelas, 2024), which can possibly create confusion on the travelers and congestion.

4.5 ECONOMIC IMPACT

The cruise industry is a major driver of the local economy in Heraklion, providing significant financial benefits to businesses, the port, and the labor market. The total annual economic contribution of cruise tourism to Heraklion and the surrounding region for the period May 2023 to May 2024 was estimated at €60.2 million (Pallis & Vaggelas, 2024). This figure includes €36.05 million in direct spending from passengers, crew, and cruise lines, alongside €24.43 million in indirect benefits that flow through the local supply chain (Pallis & Vaggelas, 2024). The financial impact of the cruise sector is largely driven by individual spending habits during port calls. The average cruise traveler spends €45.2 while in the city, a figure that rises to a total average of €47.1 when including those who utilize Heraklion as a homeport (Pallis & Vaggelas, 2024). A detailed breakdown of this contribution for the period May 2023 to May 2024, as illustrated in the figure below, shows that the local commercial market is the primary beneficiary.

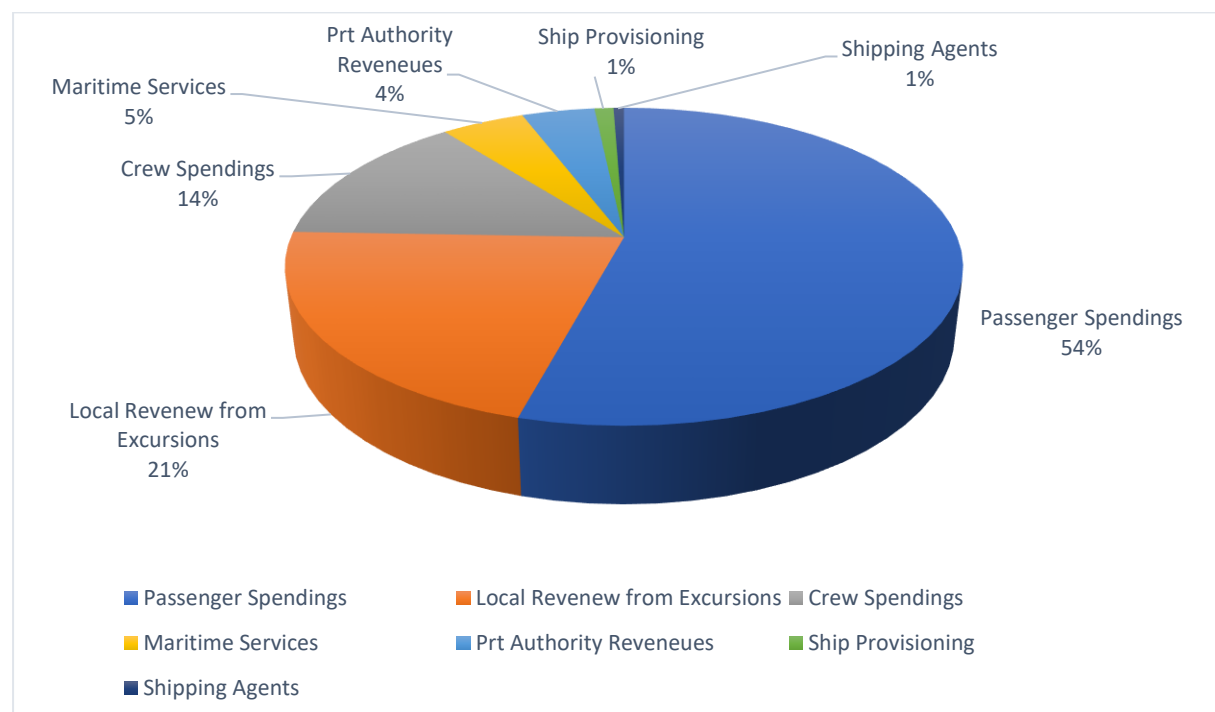


Figure 12. Distribution of Total Financial Contribution in Heraklion Port (%) (Pallis & Vaggelas, 2024).

The majority of the total economic impact (54.8%) is derived from passenger spending (shops, dining, transportation). This is followed significantly by local revenue from

excursions (21.6%), highlighting the vital role of organized tours and cultural sites in capturing value from visitors. Almost half of the cruise passengers visiting Heraklion port (47%) participated in organized excursions, generating an added value of approximately €7,678,732 for the local economy a participation rate that is considered comparable to other international cruise destinations. Crew spending also represents a substantial portion of the economy (14.0%), demonstrating that ship employees are key consumers during port calls. Although only 20% typically go ashore, they are high-value spenders who contribute an average of €182.95 per person to the local economy, primarily through retail purchases. The remaining economic benefits are distributed among operational sectors: maritime services (4.8%), port authority revenues (4.2%), ship provisioning (1.1%), and shipping agents (0.6%). This distribution underscores that while port fees are necessary, the broader "shore-side" ecosystem, such as shops, tour operators, and local services, gains the most from cruise traffic (Pallis & Vaggelas, 2024).

Furthermore, the homeporting strategy provides a clear economic advantage, as passengers who begin or end their journey in Heraklion have a higher economic footprint, spending an average of €53.1 on local services such as hotels and dining before their departure. This spending is expressed in benefits for local community up to €3,464,054 for the period May 2023 to May 2024 (Pallis & Vaggelas, 2024).

4.6 ENVIRONMENTAL IMPACT

As more cruise ships visit the Port of Heraklion, the impact on the local environment is becoming more obvious. While these ships bring many financial and social benefits to the city, they also create pollution.

4.6.1 AIR POLLUTION

One of the most immediate impacts on Heraklion is the decline in local air quality caused by ship emissions. While docked at the pier, cruise ships must keep their engines running to provide electricity for thousands of passengers, a process known as the "hotel load." In Heraklion, these ships are estimated to produce 30,537 tons of CO₂ annually (data of 2024) while at berth, which adds a heavy burden to the city's greenhouse gas footprint (Vourdoubas, 2025). A specific study conducted in Heraklion during 2018 analyzed the impact of maritime operations on the city's air quality by comparing periods of high and low port activity. The findings confirm that shipping and port operations are directly linked to the degradation of local air quality across both seasons, though the impact is significantly more pronounced during the high-traffic season. Specifically, while ozone levels remained largely stable due to broader atmospheric circulation patterns over the Eastern Mediterranean, concentrations of other gases and Particulate Matter (PM) increased notably during peak periods. Meteorological factors also played a critical role; wind speed was found to be significantly anti-correlated with gaseous pollutants, meaning stronger winds helped disperse pollution. Furthermore, the ratio of fine particles (PM_{2.5}/PM₁₀) increased during the high-activity season, serving as a clear indicator of the anthropogenic impact of shipping. Ultimately, this analysis underscores the critical influence of port activities on coastal air quality, highlighting the urgent need for sustainable development strategies aligned with the Paris Agreement and climate risk management (Logothetis et al., 2021).

4.6.2 SOLID WASTE AND SEWAGE WATER

The management of solid waste and wastewater is another major environmental challenge for the Heraklion Port. With the cruise passenger volume rapidly increasing, reaching approximately 500,000 passengers in 2025, the volume of garbage produced by cruise ships is huge. For example, it is estimated that a single large ship can generate roughly 50 tons of waste in just one week (Nansen, 2025). When this waste is offloaded, it places a massive strain on Heraklion's local disposal systems. Furthermore, the discharge of "grey water" from sinks and "black water" from toilets can lead to a problem called eutrophication. This occurs when nutrients such as nitrogen and phosphorous are discharged from the sewage treatment plants. This results in a buildup of algae which blocks light from the marine environment and affecting their ability to grow. These effects can potentially be a threat to maritime navigation and safety as well as to human health (Bailey, 2024).

4.6.3 NOISE AND LIGHT POLLUTION

Beyond chemical pollution, the physical presence of these massive vessels creates significant noise and light pollution. While noise pollution is often a concern in port cities, a study in Heraklion found that some residents have stated the sounds of the harbor (audio announcement of ships arrivals and ships departures) as pleasant (Vogiatzis et al., 2014). This is largely because the port's cruise terminals are located in areas with lower residential density. However, the constant sounds of ship engines and heavy ventilation systems creates noise pollution, which can have significant impacts in animal life by causing stress, by unbalancing predator-prey interaction, and by interfering with sound-based orientation and communication, especially in reproductive contexts (Peng, 2015). Moreover, the bright 24/7 lighting on cruise ships can disrupt the natural environment and interfere with bird population, by causing bird collisions or exhaustion through endless circling (Burt, 2023).

4.6.4 EFFECT ON SEABED

Finally, the physical movement of cruise ships affects the seabed. As they enter or leave the harbour, their powerful propellers kick up sand and mud from the bottom. This makes the water cloudy, a condition known as turbidity, which blocks the sunlight needed by *Posidonia oceanica* (seagrass) (Boudouresque, 2009). This seagrass is a highly significant ecosystem for the Mediterranean from biological, ecological, and economic perspectives (Region of Crete, 2026). Moreover, it has been noted that the parts of the ports which are used for Passenger and Cruise ships are mainly rough and poor in organic content and nutrients due to the strong hydrodynamic movements caused by the turbines and propellers of the large passenger cruise ships (Chatzinikolaou, 2016).

4.7 CURRENT SUSTAINABILITY INITIATIVES IN HERAKLION CRUISE PORT

While the environmental challenges facing the Port of Heraklion are significant, the Port Authority has already begun researching and implementing several advanced measures to reduce its footprint. These strategies are part of a broader goal to transform Heraklion into a "green and smart" maritime hub.

4.7.1 MANAGEMENT SYSTEMS

- Integrated Quality, Environmental & Energy Management System

Heraklion Port applies an Integrated Quality, Environmental & Energy Management System in accordance with the requirements of ISO 9001:2015 (Quality Management System requirements) and ISO 14001:2015 (Environmental Management System requirements). According to Heraklion Port Authority's statements, port's priority is the continuous improvement of the quality of port's services, while enhancing the environmental & energy performance. Towards this target, the Heraklion Port Authority sets quality, environmental and energy goals that are under continuous review. The performance of those goals are shared to all stakeholders, by issuing a sustainability report biannually (Heraklion Port Authority, 2024).

- **Waste Management System**

The Heraklion Port Authority aims to improve its waste management, by focusing on prevention of waste production, where doable. For example, the paper consumption is been minimized and long lasting LED bulbs are being used. Moreover, the categories of waste produced within the Port's facilities are reported in detail in the Electronic Waste Registry (Heraklion Port Authority, 2024). As of March 2026, Heraklion Port Authority S.A. signed a new contract for the provision of solid ship waste management services, in cooperation with a private company. Through this new collaboration, the Port's capacity to manage ship-generated waste efficiently is being enhanced by new equipment, procedures and operational organisation (Heraklion Port Authority, 2026).

- **Water Management System**

The Heraklion Port Authority ensures water wasting is eliminated by using taps with new technology filters and air infusion system and double-flow toilet flushes. Moreover, rational water consumption and avoidance is ensured, at the water services provided by Heraklion Port Authority to ported vessels. By using the above measures, it has been recorded that the water savings have been reduced by -71.5% from 2021 to 2023 (Heraklion Port Authority, 2024).



Figure 13. Sea Water Quality monitor points (Heraklion's Port Authority, 2024).

- **Marine Pollution Management**

The Heraklion Port authority organizes readiness exercises for marine pollution

scenarios, aiming to test and improve the readiness of the staff and the authorities in case of an oil spill. Moreover, in the last biannually Sustainability Report the Heraklion Port Authority states that there were not major oil spills recorded in 2022-2023 period (Heraklion Port Authority, 2024).

4.7.2 “ELECTRIPORT” RESEARCH PROJECT

One of the most important steps taken is the "Electriport" project, which is an EU funded research Project that addresses the issue of air pollution while ships are docked. This initiative focuses on "Cold Ironing," a technology that allows cruise ships to plug into the city's electrical grid and turn off their diesel engines while at berth. By providing shore-side power, the port can drastically reduce the amount of CO₂ and sulfur released into the air near the city center (Hellenic Ports Association, 2021). This initiative is particularly important for the berth of cruise ships, as they can be considered one of the most pollutant ships while hoteling in ports, as they need to provide services for a large amount of people. Notably, it has been estimated that emissions during the hoteling represent the 85% of the total emissions while cruise ships are in port, while emissions related to manoeuvring represent 12% (Bianco & Rosa, 2024).

The port aims to be the first Greek Port that will apply fully integrated electrification services for any ship type approaching alongside. Electiport Project provides all the detailed studies that are needed for “cold ironing” to become eligible for funding timely and effectively. The studies do not only focus on the technical options, but they also investigate the economic and financial aspects. This project is expected to contribute to the development of “know-how”, the implementation of environmental policies, the reduction of CO₂ emissions in the port and consequently in the neighboring Port–City of Heraklion (Electriport, 2026). Especially, it is estimated that CO₂ emissions of the ported ships will be reduced by more than 80% until 2028 (Heraklion Port Authority, 2024).

4.7.3 “HUPPINESS” RESEARCH PROJECT

To support this massive need for clean energy, the port is also working on the "Huppiness" project, which contributes to increased safe maritime access by improving basic port infrastructure and to increased environmental benefits by using wave energy generation on the windward breakwater (Huppines, 2026).

According to the project's official website, the project involves the studies of the upgrading and extension of the existing windward breakwater, as well as the installation of a wave energy generation system at Heraklion port. In summary, the project will provide all required documentation, studies and designs, Cost-Benefit Analysis, and tender documents for future works that will enhance the security of the port and improve its environmental profile (Huppines, 2026).

4.7.4 “ECOPORTS” CERTIFICATION

Heraklion Port also operates under the "EcoPorts" certification, which is the main environmental standard for European ports. EcoPorts focuses on voluntary self-regulation to show the sector's capability in managing its environmental responsibilities. The goal of this initiative is to increase awareness of environmental challenges, to assist in regulatory compliance, and to uphold high standards of environmental management, as highlighted in the 2025 Port Strategic Review- ESPO

Environmental Report 2025 (ESPO, 2025).

4.7.5 "BLUE PORTS" PROJECT

The Heraklion port is also working on the "human" side of sustainability as active partner for the "BLUE PORTS" project. This initiative aims to strengthen the green skills and competencies of the employees within the port ecosystem, by delivering a mutually acknowledged training and certification scheme. The training methodology focuses on green technology solutions, the integration of eco-friendly products and services, in order to reduce the environmental footprint of port activities and drive their transition to a green model, as described on the BLUE PORTS official website (Blue Ports EU, 2026).

4.7.6 HERAKLION PORT LOCAL MARKET

Besides the environmental measures taken by the Port, another initiative has been implemented aiming to enhance the local economy of Heraklion, the adoption of a local market in the port's premises. The "Heraklion Port Local Market" is a compact marketplace located within the Heraklion port, designed to offer local goods and products to cruise passengers. This small market acts as a hub and sales point for regional products, highlighting the area's gastronomy and culinary traditions while enhancing the brand identity of "Heraklion Flavors," which allows international visitors to discover local products and desire to have them in their own countries. (Heraklion Port Authority, 2024).

5. STRATEGIC AND PRACTICAL APPROACHES FOR SUSTAINABLE CRUISE DEVELOPMENT IN HERAKLION

Building on the findings of the case study analysis presented in Chapter 4, this chapter examines the key challenges limiting the adoption of sustainable cruise practices in Heraklion and proposes a set of strategic and practical approaches aimed at supporting the transition toward more sustainable cruise port operations.

5.1 KEY CHALLENGES IN ADOPTING SUSTAINABLE PRACTICES

Even though the Port of Heraklion has started several green projects, there are still major hurdles that make it difficult to become fully sustainable.

5.1.1 HIGH COST

The biggest challenge is the extremely high cost of the transition. Installing the massive electrical infrastructure needed for shore power requires millions of euros in investment. For a medium sized port like Heraklion, finding the budget for these upgrades is a slow process, and there is often a financial risk associated with the slow return on investment. These financial barriers are consistently highlighted by the European Sea Ports Organisation as the primary obstacles for the green transition of the maritime sector (European Sea Ports Organization, 2023).

5.1.2 LOCAL ELECTRICITY GRID

A second critical challenge concerns the capacity of the local electricity grid on the island of Crete. As of 2025, the Crete-Attica high-voltage direct current (HVDC) interconnection, a transmission infrastructure with a total capacity of 1,000 MW, became operational and effectively ended the island's long-standing electrical isolation (Independent Power Transmission Operator, 2025). However, despite this major upgrade at the transmission level, the provision of shore-side electricity to cruise vessels remains constrained by local factors. A single berthed large cruise ship is likely to draw at least 5MW, perhaps approaching 10MW (Lloyd's Register, 2023), depending on vessel size and hotel load, creating highly concentrated demand at the port interface. Meeting such demand necessitates targeted investments in local distribution networks, dedicated port-side substations, frequency conversion equipment, and smart grid or load-management solutions to prevent congestion and ensure operational reliability. As emphasized in the EMSA Guidance on Shore-Side Electricity, the feasibility of onshore power supply does not depend solely on national or regional generation and transmission capacity, but critically on the strength and configuration of local distribution networks, port-level substations, and the availability of redundancy and demand-management measures, particularly in island and peripheral regions (European Maritime Safety Agency, 2023).

5.1.3 SPATIAL LIMITATIONS

Finally, the Port of Heraklion faces pronounced spatial constraints that directly affect the feasibility of deploying next-generation energy infrastructure. The port is physically embedded within the historic Venetian harbour and operates in immediate adjacency to the dense urban fabric of Heraklion, as well as protected cultural and archaeological assets, including the Venetian walls and the Koules Fortress. According to the Heraklion Port Authority, the port's location within the old Venetian port and its invaluable cultural heritage makes it inextricably linked to the urban structure and landscape of the city, thereby inherently limiting options for large-scale physical

expansion (Heraklion Port Authority, 2024).

These spatial limitations severely restrict the availability of land for space-intensive installations such as battery energy storage systems, hydrogen production and storage facilities, or alternative fuel bunkering stations, all of which require substantial footprints and safety buffer zones. Based on the planning considerations outlined in the EMSA Guidance on Shore-Side Electricity, historic and urban ports may face structural constraints compared to purpose-built industrial ports, as limited space and coexistence with urban functions can restrict the deployment of energy infrastructure requiring substations, safety distances, and auxiliary systems (European Maritime Safety Agency, 2023).

In the case of Heraklion, spatial and locational constraints are documented in technical energy system studies that explicitly use the port as a case study. Nikologiannis et al. (2024) select the Port of Heraklion on the basis of its limited available installation area and its close proximity to the city center, which impose constraints on the deployment of renewable energy systems within the port (Nikologiannis et al., 2024). In parallel, urban and coastal planning research focusing on Heraklion highlights that port and coastal development interventions are subject to strict cultural-heritage protection requirements, particularly related to the preservation of the Venetian walls and historic waterfront (Rempis et al., 2017).

5.2 NEW PRACTICAL APPROACHES AND STRATEGIES FOR HERAKLION

To overcome these challenges, Heraklion can implement successful strategies used in other major ports. Taken together, these measures illustrate how a combination of economic incentives, operational optimization, environmental protection, and digital coordination can support the gradual transition of the Port of Heraklion toward more sustainable cruise operations, without exceeding the port's structural and spatial constraints.

5.2.1 ENVIRONMENTAL SHIP INDEX (ESI)

One effective idea is the Environmental Ship Index (ESI) Incentive. In 2011, the International Association of Ports and Harbors (IAPH) established the Environmental Ship Index (ESI), as a means of motivating ships to use cleaner engines and fuels through preferential treatment, such as discounts on port dues, bonuses, or other benefits commensurate with a specified level of cleanliness (International Association of Ports and Harbors, 2026). By rewarding "green ships" with lower costs, Heraklion could encourage cruise lines to send their newest and cleanest vessels to Crete. Numerous ports have already adopted the ESI, such as the Port of Barcelona and Port of Amsterdam (International Association of Ports and Harbors, 2026).

5.2.2 "JUST-IN-TIME" ARRIVAL

Another smart strategy is the use of "Just-in-Time" (JIT) Arrivals. Currently, many ships speed across the sea only to wait outside the harbor for their turn to dock, which wastes a lot of fuel. According to (International Maritime Organization, 2020), the concept of JIT Arrival of ships allows the ship to adjust and optimize its speed during the voyage and has been identified as a feasible opportunity to reduce GHG emissions from ships. Therefore, by using digital tracking and better communication, the Port of Heraklion could tell ships exactly when to arrive so they can sail at slower, more

efficient speeds.

5.2.3 SMALL-SCALE MICROGRID

At the port-operations level, the deployment of a localized smart energy system, such as a small-scale port microgrid, represents another practical approach. This transition to solar power is highly viable given that Heraklion possesses an exceptionally high solar potential, recording approximately 2700 hours of annual average sunshine (Current Results, 2026). Installing photovoltaic panels on terminal buildings and warehouses could allow the Port of Heraklion to partially meet its own electricity demand for administrative buildings and light electric vehicles, reducing dependence on the local grid and lowering indirect emissions. This concept aligns with recommendations promoted by the European Sea Ports Organisation, within the EcoPorts framework, which encourages ports to act as local energy hubs (ESPO, 2025).

5.2.4 ELECTRIC BUSES

The mitigation of transport-related environmental impacts associated with cruise passenger movements can be supported through the use of electric shuttle buses, as demonstrated in selected cruise destinations. A documented example is the Port of Barcelona, where MSC Cruises has introduced electric buses for shore excursions and passenger transfers as part of its wider sustainability strategy. According to Seatrade Cruise News, the use of electric tour buses in Barcelona has been implemented to reduce local air pollutant emissions and noise levels associated with cruise passenger transportation within the city (Seatrade Cruise News, 2022). Drawing on this example, the adoption of electric shuttle services for cruise passenger transport in Heraklion could be explored as a practical measure to reduce transport-related emissions linked to port calls, while remaining compatible with urban mobility and destination management objectives.

5.2.5 ADVANCED MOORING SYSTEM

Furthermore, the protection of the underwater environment represents a vital strategic priority that requires immediate practical solutions outside the main docking infrastructure. As cruise vessels approach coastal areas or wait for clearance to enter the port, their massive conventional anchors and the sweeping motion of their heavy anchor chains across the seabed pose a direct and severe threat to the highly sensitive *Posidonia oceanica* seagrass meadows (Randone, M., et al., 2025). To counter this, the Port of Heraklion could implement Advanced Mooring Systems utilizing a combination of helical screw anchors and submerged flotation buoys. Unlike traditional gravity blocks that crush the seabed, helical anchors are hydraulically screwed directly into the sediment, providing immense holding capacity for large vessels while minimizing the initial installation footprint. Concurrently, the submerged buoys elevate the heavy mooring cables entirely into the water column, as shown in the next figure. By deploying these advanced helical mooring configurations in the designated coastal waiting areas outside the Heraklion breakwater, the port could completely eliminate bottom abrasion and strictly comply with European marine biodiversity protection objectives (Ocean Conservation Trust, 2026).

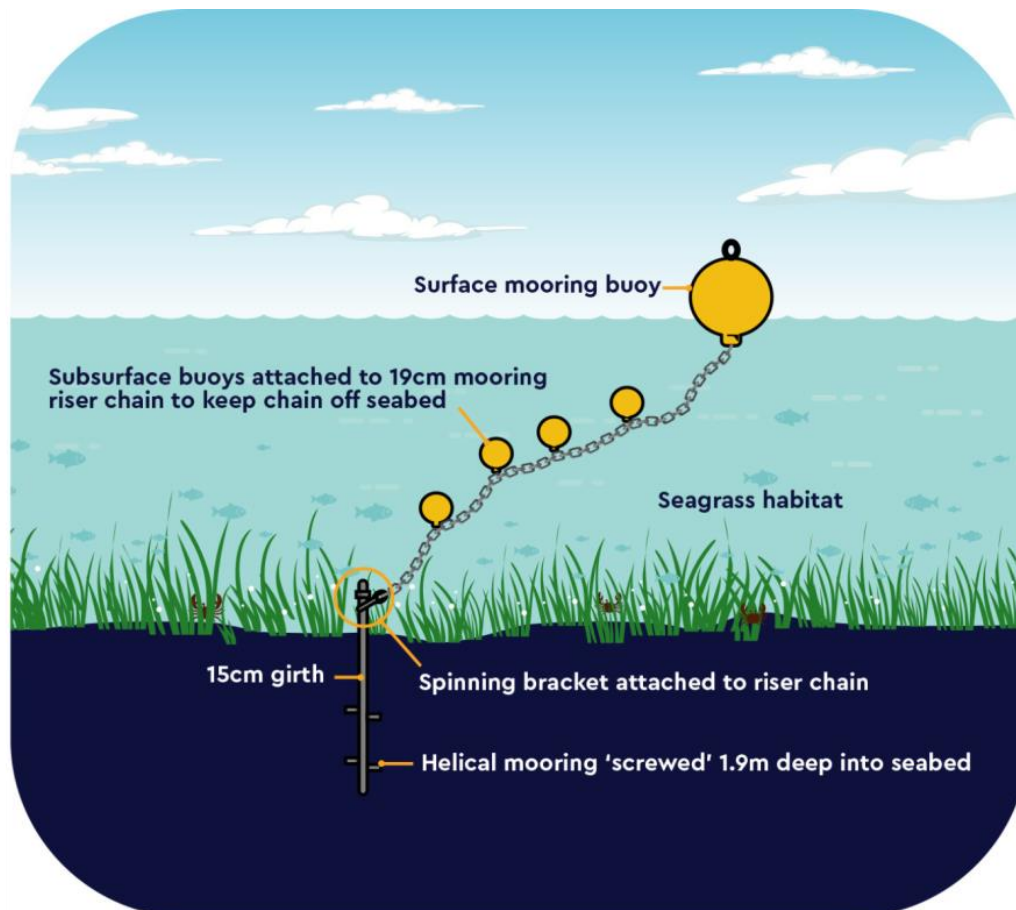


Figure 14. Representation of the Advanced Mooring System (Ocean Conservation Trust, 2026)

5.2.6 DIGITAL FLOW MANAGEMENT SYSTEM

Finally, the severe social impacts of cruise tourism, particularly urban congestion, must be addressed through the strategic implementation of a comprehensive flow management and mobility system. According to the joint Working Group on Cruises and Port Cities established by MedCruise and the Association Internationale des Villes et Ports, prioritizing passenger flow management is an essential pillar for the sustainable growth of cruise destinations (MedCruise, 2025). In Heraklion, a centralized digital platform coordinating ship disembarkation schedules with excursion planning could actively stagger visitor flows to sites such as Knossos, reducing peak time pressure on urban infrastructure and heritage assets. By leveraging these advanced digital information and communication technologies, the destination can optimize shore excursion schedules, ensuring a balanced and sustainable experience that protects the daily lives of local residents while maintaining the high quality of the tourism product.

5.2.7 CREW-ORIENTED SERVICES

Furthermore, expanding the economic benefits of cruise tourism requires a targeted strategy focused specifically on ship personnel. As established in the economic analysis of Chapter 4.5, the cruise sector acts as a massive driver for the local economy of Heraklion, with ship employees representing the 14.0 percent of the total local economic contribution (Pallis and Vaggelas, 2024). To maximize the potential of these high value spenders, the strategic action plan recently published by MedCruise emphasizes the necessity of investing in dedicated crew oriented services. The

framework identifies crew members not only as active consumers but also as powerful global influencers for the destination. By developing specialized resting areas within the port, negotiating targeted retail discounts, ensuring seamless access to urban amenities, and providing high capacity digital connectivity, the Port of Heraklion can build long term loyalty among maritime professionals (Bras, 2025).

6. CONCLUSIONS

The conclusions presented in this chapter are derived from a qualitative case study analysis and should be interpreted within the context-specific scope of the Port of Heraklion. The aim of this thesis was to examine the sustainability challenges and opportunities associated with cruise tourism in Greece through an in-depth case study of the Port of Heraklion. The analysis demonstrates that cruise tourism constitutes a vital economic activity for both Greece and the local economy of Crete, generating significant income, employment, and international visibility. At the same time, the findings indicate that the continued growth of cruise traffic, if not effectively managed, intensifies environmental pressures and social impacts on host destinations.

The case study of Heraklion highlights this dual reality. On one hand, the port has experienced rapid growth, evolving into an important homeport and transit hub and delivering substantial economic benefits to local businesses, tour operators, and the broader regional economy. On the other hand, cruise activity contributes to increased greenhouse gas emissions during ship hoteling, congestion in the urban environment, pressure on cultural heritage sites, and risks to marine ecosystems such as *Posidonia oceanica* seagrass meadows.

The research indicates that the transition toward sustainable cruise port operations is constrained by a combination of structural factors, particularly in medium-sized island ports. High capital investment requirements for port electrification, limited local grid capacity and spatial restrictions within the urban fabric collectively hinder the rapid adoption of green technologies. Nevertheless, the Port of Heraklion has already taken important steps toward sustainability through initiatives such as the Electriport and Huppiness projects, environmental management systems, and participation in European sustainability networks.

Building on international best practices and the specific characteristics of Heraklion, the thesis proposes a set of realistic and context appropriate strategies. These include economic incentives for cleaner vessels through the Environmental Ship Index, operational efficiency improvements via Just in Time arrivals, localized energy management through a small scale port microgrid, low emission mobility solutions for passenger transfers, the protection of sensitive marine habitats utilizing Advanced Mooring Systems, the mitigation of urban congestion via digital flow management platforms, and the expansion of local economic benefits through targeted crew oriented services. Rather than isolated measures, these actions should be viewed as components of an integrated sustainability framework aimed at balancing environmental protection, operational optimization, and socio economic growth.

In conclusion, the findings indicate that Heraklion demonstrates the potential to align cruise tourism growth with sustainability objectives within its specific urban and environmental context. Achieving this balance requires coordinated action among port authorities, local and national governments, cruise operators, energy providers, and the local community. By adopting an integrated, multi-stakeholder approach, cruise destinations such as Heraklion can enhance their long-term economic viability while safeguarding environmental resources and preserving social cohesion.

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