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GREENPORT Alliances
Work Package 4, Deliverable 4.2
VET Modules and supporting learning material

September 2025

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Sustainable Maritime Operations and Green Ports

VET Modules

&

Supporting Learning Material

September 2025

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INTRODUCTION

Executive Summary

The maritime sector is evolving to respond to the urgent need for environmental sustainability, regulatory change, and technological advancements. Within this context, port services, although often operating outside the scope of international conventions and European regulation, play a crucial role in supporting the broader decarbonization goals of the shipping industry. The Sustainable Maritime Operations and Green Port Technologies course has been designed to equip pilots and tug-masters with the knowledge, tools, and practical strategies needed to contribute meaningfully to emission reduction efforts while maintaining the highest standards of navigational safety. Through a blend of theoretical sessions, case-based learning, and immersive simulation, the course encourages a shared understanding of sustainable operations and empowers participants to lead change within their ports and professional communities.

The course provides participants with practical tools and behaviors to enhance fuel efficiency and operational performance. Participants will learn how small operational changes and behaviors can impact emissions and cost savings. The course presents aspects of sustainable maritime innovations such as hybrid tugboats, biofuels, and data-driven navigation. Through interactive simulations, participants apply their skills in realistic maritime port operations scenarios. Graduates should gain a solid understanding of sustainability regulations, enhanced decision-making capabilities, and the confidence to contribute to cleaner, more efficient port operations. Upon completion of the course and final evaluation, participants will receive a Certificate of Participation, developed as a key output of the GREENPORT Project for maritime professionals' vocational education and training (VET). The course is designed to be delivered over 2 days (8.5 hours), using a blended learning approach with a minimum of 40% face-to-face instruction, including simulator-based exercises and final assessment. This textbook compiles eight comprehensive modules on sustainable maritime operations and green port strategies. Designed for Vocational Education and Training institutions, the material covers key topics such as environmental regulations, energy efficiency, emission reduction theory and regulations, industry ecosystem and technological landscape, operational strategies for energy saving, communication and stakeholder engagement, digitalization in ports, and technological innovation for emission reduction. Each chapter corresponds to a thematic focus and aims to equip professionals, such as pilots and tug masters, with the knowledge, tools, and practical strategies needed to contribute meaningfully to emission reduction efforts while maintaining the highest standards of navigational safety.

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VET Learning Content (Course Catalog)

Course Name: Sustainable Maritime Operations and Green Port Technologies				Degree: VET Undergraduate/Graduate		
Code	**Year/Semester**	**Local Credits**	**ECTS Credits**	**Course Implementation, Hours**		
				Course	**Tutorial**	**Simulator Laboratory**
GRNPRT02	/	1	/	4	6	4.5

Department	Vocational Education and Training			
Instructors	…………………..			
Contact Information	…………………….			
Office Hours	………………………….			
Web page	https://greenportalliance.eu			
Course Type	Blended Learning (Online and Classroom)	**Course Language**	English	
Course Prerequisites	N/A			
Course Category by Content (%)	**Basic Sciences**	**Engineering Science**	**Engineering Design**	**Humanities Social Sciences**
	20	50	-	30
Course Description	**Preamble** The maritime sector is evolving to respond to the urgent need for environmental sustainability, regulatory change, and technological advancements. Within this context, port services, although often operating outside the scope of international conventions and European regulation, play a crucial role in supporting the broader decarbonisation goals of the shipping industry. **Sustainable Maritime Operations and Green Port Technologies** course has been designed to equip pilots and tug masters with the knowledge, tools, and practical strategies needed to contribute meaningfully to emission reduction efforts while maintaining the highest standards of navigational safety. Through a blend of theoretical sessions, case-based learning, and immersive simulation, the course encourages a shared understanding of sustainable operations and empowers participants to lead change within their ports and professional communities. The course provides participants with practical tools and behaviours to enhance fuel efficiency and operational performance. Participants will learn how small operational changes and behaviours can impact emissions and cost savings. The course presents aspects of sustainable maritime innovations such as hybrid tugboats, biofuels, and data-driven navigation. Through interactive simulations, participants apply their skills in realistic maritime port operations scenarios. Graduates should gain a solid understanding of sustainability regulations, enhanced decision-making capabilities, and the confidence to contribute to cleaner, more efficient port operations.			

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	Upon completion of the course and final evaluation, participants will receive a Certificate of Participation. This is developed as a key output of the GREENPORT Project for maritime professionals' vocational education and training (VET). **The course is designed to be delivered over 2 days (8.5 hours), using a blended learning approach with a minimum of 40% face-to-face instruction, including simulator-based exercises and final assessment.**
Course Objectives	**General Objectives** Increase awareness and behavioural change by accumulating knowledge, tools, and practical strategies needed to contribute to emission reduction efforts while maintaining the highest standards of navigational safety. **The GREENPORT Learning methodology for VET** - Blended learning includes face-to-face sessions and group work, with at least 40% of the training conducted in person through simulator-based activities. - Participants engage with emissions dashboards, sensors, and AI-based tools to optimise fuel use and reduce emissions. - Industry-based case studies from green port operations ensure that training reflects current challenges and innovations - Group tasks and role-play scenarios encourage teamwork, communication, and shared problem-solving - Simulator-based exercises help learners develop decision-making skills and promote eco-efficient practices - Continuous evaluation, real-time feedback, and end-of-day reflections help reinforce learning and support behavioural change **Specific Objectives** 1. To define key concepts related to sustainability in the maritime sector, including international and regional regulations. 2. To identify operational behaviours that influence fuel consumption and emissions levels. 3. To describe the impact of various navigation and port practices on environmental performance. 4. To apply energy-saving techniques for optimizing tugboat and pilot vessel operations for sustainability 5. To analyse emissions data provided by digital tools and instruments to make decisions and propose operational improvements 6. To fundament operational decisions during role-play scenarios based on environmental and efficiency criteria. 7. To implement best practices for eco-friendly port logistics and fuel and energy saving management.
Course Learning Outcomes	1. Understand sustainability concepts, the principles of sustainable maritime operations and environmental regulations (Green Deal, Fit for 55, FuelEU, EU ETS/IMO NZF). 2. Understand outcomes of the best practices by analysing real-world examples of sustainable operations (e.g., alternative fuel, hybrid tugboats, onshore power supply) and assessing their applicability within local ports' operational environment. 3. Enhance knowledge on emissions monitoring and stay updated with digital tools and techniques while observing the evolution of emissions levels and fuel use. 4. Apply operational strategies, including Eco Speed Steaming, scheduling with tidal windows, real time fuel consumption visualization. 5. Use energy saving techniques, identify and implement fuel-efficiency practices.

	6. Change of operational behaviour by using data-driven feedback, making informed decisions that will contribute to cleaner seas, green port operations, and eco-friendly logistics. 7. Get practical experience with eco-navigation using simulators to understand the impact of operational choices on fuel consumption. 8. Practice teamwork, decision-making, and fuel-saving strategies in a simulated environment.
Instructional Methods and Techniques	Lectures, real-world case studies, group activities, simulator-based exercises
Tutorial Place (classroom, simulator)	Classroom (physical or virtual)
Learning Resources (Textbook, PPT, video)	Textbook (handouts), PPT presentations, animated videos, seminar & simulator exercises
Other References	1) 2023 IMO Strategy on Reduction of GHG Emissions from Ships. https://www.imo.org/en/OurWork/Environment/Pages/2023-IMO-Strategy-on-Reduction-of-GHG-Emissions-from-Ships.aspx 2) Anindita, P., & Sari, A. P. (2022). Green Port Strategies in Developed Coastal Countries. https://ijred.cbiore.id/index.php/ijred/article/view/46539 3) BALAMAN, Dilek; ÖZDEMİR, Ünal; Yazir, Devran. Investigating the Factors Affecting Ship Fuel Consumption Using Quantitative Methods. https://ssrn.com/abstract=4876934 4) Barata, Ricardo; Cruz, Maria; Macedo, Joaquim; Coelho, Margarida. (2025). Improving Transport Performance and Decarbonization Potential in Small-Medium Ports. https://doi.org/10.1007/978-3-031-89444-2_30 5) Barbosa, S.; Cruz, M.M.; Coelho, M.C. (2025). Green Mobility for Small-Medium Size Ports: A GHG Emissions Web Calculator. https://doi.org/10.1007/978-3-031-89444-2_69 6) Bouman, E. A.; Lindstad, E.; Rialland, A. I.; Strømman, A. H. (2017). State-of-the-art technologies... https://doi.org/10.1016/j.trd.2017.03.008 7) ClassNK. (2022). Alternative Fuels Insight. https://download.classnk.or.jp/documents/ClassNKAlternativeFuelsInsight_e.pdf 8) Corbett, J. J.; Wang, H.; Winebrake, J. J. (2009). The impact of slow steaming... https://doi.org/10.3141/2100-01 9) DNV. (n.d.). Alternative Fuels Insight (AFI) Platform. https://www.dnv.com/services/alternative-fuels-insights-afi--128171/ 10) Dr. Theo Notteboom; Dr. Athanasios Pallis. Port Economics, Management and Policy - Chapter 8.5... https://porteconomicsmanagement.org/pemp/contents/part8/green-port-governance/ 11) Duru, O., & Yoshida, S. (2023). Management Strategy for Seaports Aspiring to Green Logistical Goals... https://www.researchgate.net/publication/372569976 12) EcoPorts. https://www.ecoports.com/ 13) EPA, Clean Ports Program. https://www.epa.gov/ports-initiative/cleanports 14) European Maritime Safety Agency (EMSA). (2023). Annual Report on Port State Control... https://www.emsa.europa.eu/ 15) GEF-UNDP-IMO GloMEEP Project and IAPH. (2018). Port Emissions Toolkit, Guide No.2. 16) IDENTEC SOLUTIONS. Green Port Initiative Worldwide... https://www.identecsolutions.com/news/green-port-initiative-worldwide-and-how-terminals-contribute

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Homework & Projects	-
Laboratory Work	BRIDGE SIMULATIONS AND CASE STUDIES

Other Activities (Group Discussions, Guest speakers..)	Group Discussions

	Activities	**Quantity**	**Effects on Grading, %**
Assessment Criteria	Attendance [hrs]	**8.5**	**10**
	Midterm	**-**	**-**
	Quiz [MCQ]	**10**	**20**
	Homework	**-**	**-**
	Term Project	**-**	**-**
	Laboratory Work [scenarios]	**1**	**20**
	Practices	**-**	**-**
	Tutorial	**-**	**-**
	Seminar	**-**	**-**
	Presentation	**-**	**-**
	Field Study	**-**	**-**
	Final Exam [MCQ]	**10**	**50**
	TOTAL		
	Effects of Midterm and Activities on Grading, %		**50**
	Effects of Final on Grading, %		**50**
	TOTAL		**100**

No	TOPICS	Learning Outcomes
	Foundations & Practical Aspects	
1	**Day 1/ Session 1** **Introduction to sustainable maritime operations (15 min)** ● Scope of the training programme ● Safety of navigation and ship handling is paramount	1
2	**Day 1/ Session 2** **Fostering understanding of emission reduction theory and regulations (45min)** ● Understanding energy saving and emission reduction principles ● Overview of EU and IMO regulations and their indirect impact on port services and our clients (Green Deal, Fit for 55, FuelEU, EU ETS/IMO NZF) ● Port services not specifically falling within these regulations for the time being ● The need to be proactive, energy saving and emission reduction theories and practices ● Importance of aligning with client expectations and future-proofing operations	1
3	**Day 1/ Session 3** **Industry ecosystem and technological landscape (30min)** ● Port requirements (e.g. Onshore Power Supply - OPS) ● Trends in shipping: Alternative fuel vessels (e.g. LNG, methanol, ammonia) ● Use of ShaPoli systems on client vessels and implications for port services ● Emission monitoring tools and their usability for crews ● Case examples: Different types of tug and pilot boats using cleaner fuels, including HVO ● Challenges for their uptake: Limited availability and high cost of alternative fuels ● Available funding and the cost of going green	2,3
4	**Day 1/ Session 4** **Operational strategies for energy saving and emission reduction (1.5 Hours)** ● Techniques using existing resources	4,5,6

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	● Eco Speed Steaming: Benefits and Implementation ● Scheduling with tidal windows to optimise fuel use ● Real-time fuel consumption visualisation for port service craft ● Encouraging behavioural change through data-driven feedback ● Tug energy saving, before and after a job	
5	**Day 1/ Session 5** **Communication and stakeholder engagement (45 min)** ● Roles of various stakeholders in sustainable port operations ● Behavioural change: The role of training, leadership, and peer influence ● Good planning of effective communication with all players involved ● Eliciting the required information for smooth operations ● Experiential communication exercises ● Clarifying the role of digital aids (e.g. PPU, VR): aids, not solutions (bearing in mind GNSS spoofing, jamming, and cyber threats in navigation)	2,6
6	**Day 1/ Session 6** **Recap and reflections (15 min)** ● Summary of key takeaways ● Open discussion and Q&A	6
	Simulation Exercises	
7	**Day 2/ Session 1** **Simulation exercises: Eco Navigation (4 hours)** ● Joint simulations with tug masters and pilots ● Scenarios: Large vessel approaching port, requiring tug assistance, with tide and wind. The vessel must be swung to face tide and placed safely alongside. ● Focus areas: ○ Port-specific digital modelling ○ Using vessel momentum strategically ○ Prioritising safety in maneuvering ○ Using elements to advantage ○ Monitoring for overuse of tugs and ship's engine by pilot ○ Elements which a tug master can do better to save energy ○ Post-operation pilot and tug master/s debrief. ● Post-simulation debriefs for each scenario.	6,7,8
8	**Day 2/ Session 2** **Final reflections and course wrap-up (30 min)** ● Group discussion on simulation insights ● Consolidation of learning outcomes ● Feedback and next steps	6

ECTS / WORKLOAD TABLE

Activity	**Count**	**Hours**	**Total Workload**
Course	1	4	4
Preparation for the lecture	0	0	0
Homework	0	0	0
Quiz	0	0	0
Presentations/ Seminars Preparation	0	0	0
Midterm(s) (Exam +Preparation)	2	2	4
Group Project	0	0	0
Lab.	2	4.5	9
Field Work	0	0	0
Final Exam (Exam +Preparation)	1	4	4
Total Workload			**21.5**
Course ECTS Credits	**(Total Workload/ 25)**		/

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Course Local Credits	**(Total Workload/ 25)**	**1**

Prepared by	***Date***	***Signature***
Assoc Prof Dr Eng Nicoleta Acomi Senior Lecturer Dr Capt Gheorghe Surugiu Full Prof Marco Ferretti ("Parthenope" University of Naples) Assoc Prof Marcello Risitano ("Parthenope" University of Naples)	31.07.2025	

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Chapter 1: Introduction to sustainable maritime operations

1.1. Scope of the training program

The Sustainable Maritime Operations and Green Port Technologies training program has been designed specifically for pilots, tug masters, and port service operators. Its purpose is to equip participants with the knowledge, tools, and practical strategies needed to reduce emissions and improve operational efficiency while maintaining the highest standards of navigational safety.

As part of the GREENPORT Project, the course provides attendees with a solid understanding of sustainability regulations and enhanced decision-making capabilities, ensuring they are ready to meet the demands of a changing maritime industry.

Through a blended learning approach that combines classroom-based theory, industry case studies, and simulator-based practical exercises, participants will learn how small operational changes and behaviors can impact emissions and cost savings.

1.2. Safety of navigation and ship handling is paramount

In sustainable maritime operations, environmental performance must never come at the expense of safety.

The safe navigation of vessels is the primary responsibility of pilots, tug masters, and port service teams.

Sustainability measures should complement but not conflict with navigational safety. For example:

- Reducing engine RPM when safe to do so can save fuel, but this must be balanced against maintaining full control in challenging conditions.
- Timing arrivals and departures with favorable tides and currents can reduce fuel consumption but should be planned in coordination with other port traffic.
- Efficient tug deployment can minimize idling and fuel use, but safety margins must be preserved for unexpected events.

A sustainable operation is, above all, a safe operation.

1.3. Overview of international regulations for the maritime sector

The maritime industry is undergoing a transition driven by climate change concerns, decarbonization targets, and market expectations. Even though most port service vessels are not yet directly regulated under major EU and IMO climate

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measures, their operations influence a ship's overall environmental footprint during port calls.

Key reasons why sustainability matters for port service providers:

- Small operational decisions (such as approach speeds, tug positioning, or minimizing idle time) can reduce a vessel's fuel use and emissions.
- Shipowners, charterers, and cargo owners must meet ambitious IMO and EU climate targets, and they may prefer low-emission partners.
- Build competitive advantage - service providers who demonstrate eco-efficient operations are more likely to retain and attract clients in a low-carbon market.

- Example: If a tug maintains unnecessarily high engine speed while waiting, fuel is wasted and the ship's total emissions for the port call increase. Reducing such inefficiencies delivers measurable environmental and cost benefits.

1.4. Behavioral change for sustainability – The COM-B Framework

Sustainable operational change requires more than technical solutions — it demands a shift in daily behavior. The COM-B model explains that behavior change happens when three factors come together:

- **Capability** – having the skills and knowledge to operate efficiently.
  Example: Understanding optimal engine settings for different operational phases.
- **Opportunity** – having the tools, systems, and operational conditions to enable eco-friendly choices.
  Example: Access to real-time fuel monitoring dashboards or emissions data.
- **Motivation** – having the drive to act, supported by awareness of environmental impact, client expectations, and competitive advantages.

When capability, opportunity, and motivation align, small operational changes can deliver significant cumulative emissions reductions.

1.5. Looking ahead

This introduction has set the context for why sustainable maritime operations matter for port services, and the critical role behavioral change plays alongside technology and regulation.

In the next session, we will explore energy-saving and emission-reduction principles and provide an overview of EU and IMO regulatory frameworks that, although not directly applied to most port service vessels, are already shaping client expectations and operational standards.

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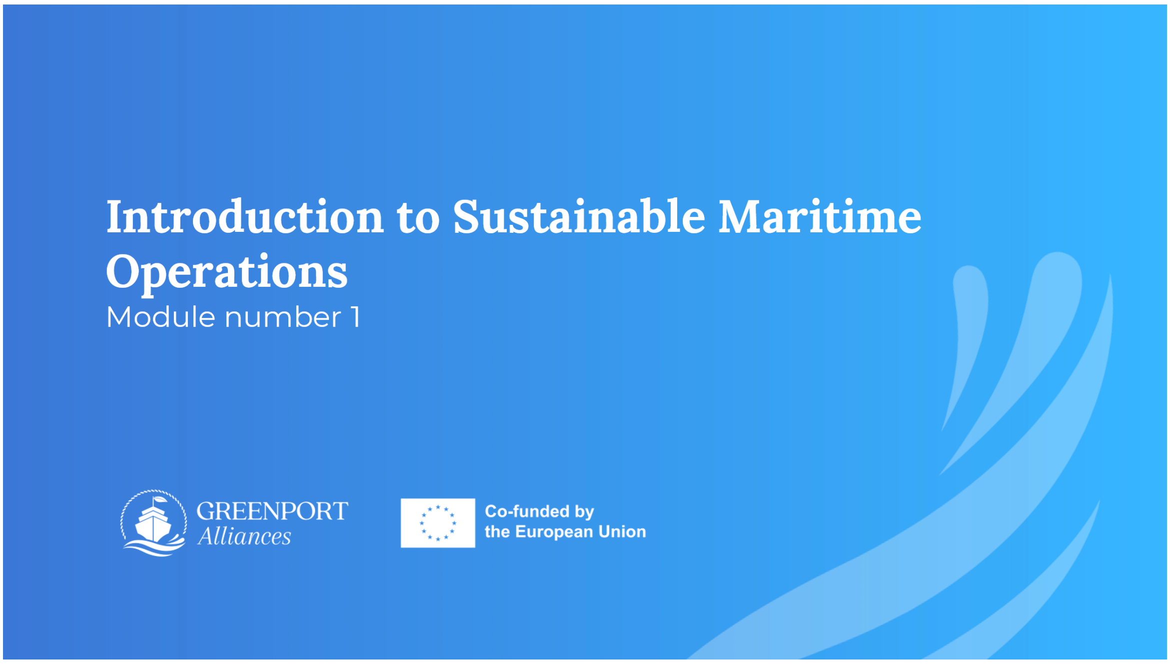
Chapter 1 Supporting material



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Scope of the Training Programme

This 2-day course comprises of 8 course modules designed for: pilots, tug masters, port service operators and for professionals directly influencing port efficiency and environmental impact.

Purpose:
- Equip participants with knowledge, tools, and strategies for greener operations
- Support emission reduction through small but impactful operational changes
- Enhance operational efficiency without sacrificing reliability
- Ensure navigational safety remains the top priority

Approach:
- Classroom theory → foundations of sustainability & regulations
- Case studies → real-world examples of successful practices
- Simulator-based training → hands-on practice of eco-navigation and ship handling

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Safety of navigation and ship handling

In sustainable maritime operations, environmental performance must never come at the expense of safety

Examples:
- Reducing engine RPM when safe to do so can save fuel, but this must be balanced against maintaining full control in challenging conditions.
- Timing arrivals and departures with favourable tides and currents can reduce fuel consumption, but should be planned in coordination with other port traffic.
- Efficient tug deployment can minimise idling and fuel use, but safety margins must be preserved for unexpected events.

A sustainable operation is, above all, a safe operation

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Why sustainability matters

- ❑ Small operational decisions (such as approach speeds, tug positioning, or minimising idle time) can reduce a vessel's fuel use and emissions.
- ❑ Shipowners, charterers, and cargo owners must meet ambitious IMO and EU climate targets, and they may prefer low-emission partners.
- ❑ Service providers who demonstrate eco-efficient operations are more likely to retain and attract clients in a low-carbon market

Benefits

- Reduce emissions through operational choices
- Attract clients aligned with IMO/EU climate goals
- Build competitive advantage

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Behavioural change & COM-B Framework

Sustainable operational change requires more than technical solutions — it demands a shift in daily behaviour

- **Capability** – having the skills and knowledge to operate efficiently. Example: Understanding optimal engine settings for different operational phases.
- **Opportunity** – having the tools, systems, and operational conditions to enable eco-friendly choices. Example: Access to real-time fuel monitoring dashboards or emissions data.
- **Motivation** – having the drive to act, supported by awareness of environmental impact, client expectations, and competitive advantages.

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Looking ahead

In the next session, we will explore:

- Energy-saving and emission-reduction principles
- EU and IMO regulatory frameworks overview
- Examples of sustainable operations (e.g., alternative fuel, hybrid tugboats, onshore power supply)
- digital tools and techniques for observing the evolution of emissions levels and fuel use
- Operational strategies, including Eco Speed Steaming, scheduling with tidal windows, real time fuel consumption visualization
- Eco-navigation using simulators to understand the impact of operational choices on fuel consumption

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Module number 1 | Course Name: Sustainable Maritime Operations and Green Port Technologies

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Chapter 2: Fostering understanding of emission reduction theory and regulations

2.1. Understanding energy saving and emission reduction principles

The maritime industry faces increasing pressure to save energy and reduce greenhouse gas (GHG) emissions and other pollutants. Port service operations are contributors, and their activities influence the operational emissions.

2.1.1 Emission reduction matters

Maritime transport accounts for around 2–3% of global greenhouse gas (GHG) emissions, contributing to global warming (driving sea level rise, ocean acidification, and extreme weather events), and regional air pollution (impacting coastal communities' health through SO_x, NO_x, and particulate matter).

Activities in the port area generate multiple types of pollution (air, water, soil, noise, and light emissions) that contribute to climate change, harm human health, degrade marine and terrestrial ecosystems, as emphasized in Figure 1.

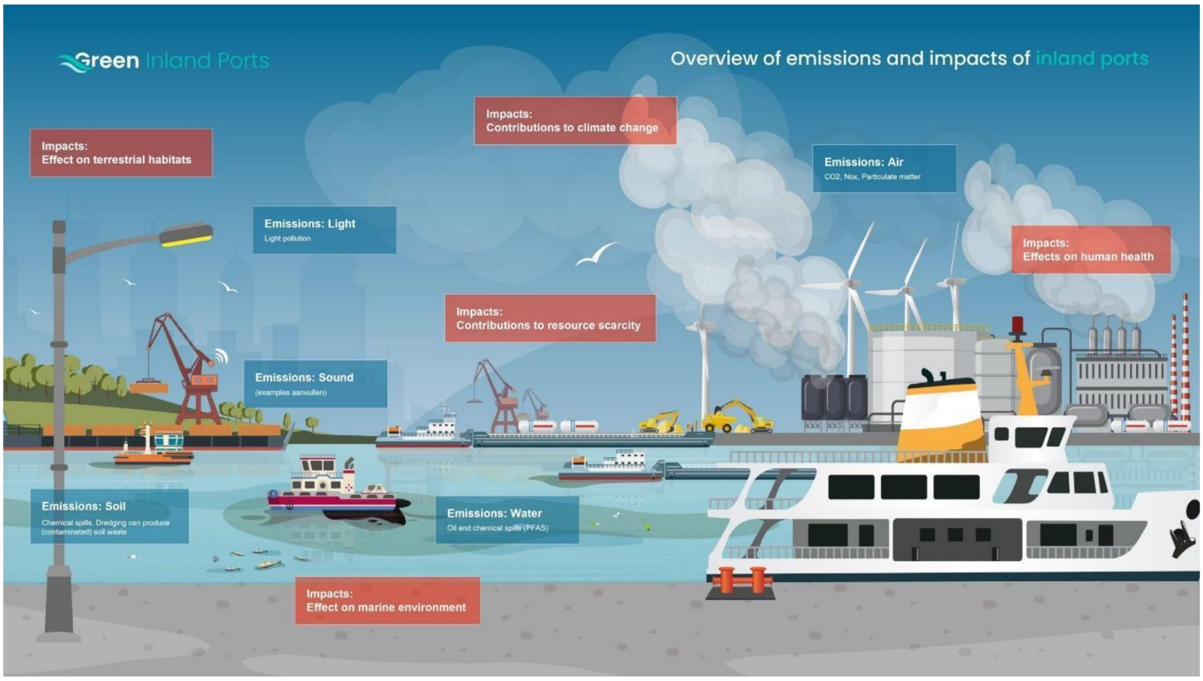

Figure 1 Overview of emissions and impact of inland ports, Source: https://green-inland-ports.eu/

2.1.2 Port sustainability measures

As a response, ports adopt measures that can be broadly grouped into technical, operational, and regulatory categories, each addressing different aspects of emission reduction to protect surrounding communities and ecosystems.

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Technical measures

These involve physical infrastructure, equipment, and technology upgrades to reduce emissions and environmental impacts.

- Low-/zero-emission port ships (hybrid, battery-electric, LNG, or methanol-powered tugs and pilot boats).
- Onshore Power Supply (OPS) provides shore-side electricity so vessels can turn off engines while at berth.
- Emission capture and treatment systems. E.g. scrubbers, whose use is restricted in certain ports or at anchorage (North-standard, 2025) due to the toxins released with discharged water; onboard carbon capture (OCC), where captured CO_2 is compressed, liquefied, and stored in onboard tanks.

Operational measures

These are changes in procedures, scheduling, and human behaviour to reduce fuel use and emissions without necessarily changing hardware.

- Adjust vessel speeds for optimal fuel efficiency.
- Tidal window planning (to schedule manoeuvres when currents and tides assist movements).
- Assign the minimum number of tugs needed without compromising safety.
- Use AI or port community systems to reduce waiting times and idle running.
- Crew training for green operations (e.g., fuel-saving manoeuvres).

Regulatory measures

These involve policies, incentives, and compliance frameworks that set environmental standards for port operations.

- Fee reductions for vessels meeting emission performance standards.
- Mandatory reporting of emissions for port service operators.
- Integration with IMO/EU frameworks (Green Deal, Fit for 55, FuelEU, EU ETS/IMO NZF).
- Transparent ESG (Environmental, Social, and Governance performance) disclosures to stakeholders.

2.1.3 Examples of adopted practices

Port of Rotterdam deployed hybrid tugs and installed OPS for cruise terminals, cutting CO_2 and particulate emissions during layovers. They introduced a geofence system, which is part of the first phase of the Just-in-Time sailing project aimed at reducing CO2 emissions and improving ship movement efficiency (Bahtic, 2024).

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Port of Gothenburg estimates a decrease of 6,000 tons of CO2 emissions in the port area per year thanks to the conditions created by Digital Port Call (Bahtic, 2024).

Among the most significant operational measures yet implemented for CO2-intensity reduction is Just-in-time concept. The savings from reduced idle time at anchor and reduced fuel consumption under way would add up to emissions savings of about 15 percent (MaritimeExecutive, 2022).

Acting at regulatory level, Port of Los Angeles uses differentiated port fees to reward low-emission vessels and operators, encouraging investment in clean technology (PortofLosAngeles, n.d). They invested in electric tugboat, which could deliver operators up to 50% savings compared to diesel vessels (Habibic, 2025).

Port of Amsterdam. The Svitzer company reported that fuel consumption on the Svitzer Taurus tug (new design of tug), has been on average 15% lower compared to its existing fleet of 11 tugboats operated in the same port (Morrissey, 2025).

In Auckland, hybrid-electric tugs reduced fuel consumption by up to 30% per job, indirectly supporting ship operators' compliance with CII (Carbon Intensity Indicator) scores (Kosmajac, 2024).

Virtual Arrival clause for voyage charter parties (BIMCO, 2013). Traditional voyage charter parties often incentivise ships to steam at full speed to tender Notice of Readiness (NOR) ASAP, so laytime starts and demurrage risk shifts, even if a berth won't be free. This can lead to "sprint-and-wait" behaviour and extra fuel burn. A Virtual Arrival (VA) clause solves this by letting owner and charterer agree a calculated time of arrival (CTA) based on confirmed port delay; the ship slows to "eco speed", and laytime is calculated as if the ship had arrived at the CTA (projected ETA).

Just in Time Arrival clause (BIMCO, 2021). This clause enables owners and charterers to adjust vessel speed through shared information, so the ship can berth on arrival with minimal waiting. It includes a fair cost-sharing mechanism for extra voyage time versus fuel savings, while improving port utilisation and reducing emissions. The Just-in-time concept is among the most significant operational measures yet implemented for CO2-intensity reduction. The savings from reduced idle time at anchor and reduced fuel consumption under way would add up to emissions savings of about 15 percent (MaritimeExecutive, 2022).

Retrofitting ships with SHaPoLi/EPL systems to comply with the Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII) requirements set by the International Maritime Organization (IMO) restricts immediate access to the full manoeuvring power range of the main engine, which may be detrimental to safe and efficient navigation, especially in demanding pilotage areas (Crossley, 2024).

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The port service sector plays an important role in emission reduction, with the operations of pilots, tugs, and mooring services directly influencing a vessel's overall fuel consumption and emissions during port calls.

2.2. Overview of EU and IMO regulations and their indirect impact on port services and their clients

The regulatory frameworks governing maritime decarbonizations are being developed at both the European Union (EU) and International Maritime Organization (IMO) levels, introducing ambitious measures for reducing GHG emissions across the sector. While many of these measures, such as the European Green Deal, Fit for 55, FuelEU Maritime, the extension of the EU Emissions Trading System (EU ETS) to shipping, and the IMO's Net-Zero Fuels (NZF) initiative, primarily target ship operators, their influence extends well beyond the vessels themselves. Port service providers, though often outside the direct scope of these regulations, are affected through their clients' needs.

In this context, the following paragraphs provide a brief overview of the relevant EU and IMO regulatory frameworks, offering the understanding needed to adapt port service operations and support clients in meeting their decarbonizations obligations.

2.2.1 European Green Deal (2019)

The European Green Deal, launched in 2019, is the EU's overarching strategy to achieve climate neutrality by 2050. It sets the policy direction for all subsequent EU climate legislation, including maritime-specific measures such as the Fit for 55 Package, FuelEU Maritime, and the extension of the EU ETS to shipping presented in the following sections.

Although the European Green Deal does not impose direct obligations on port service vessels, it is the foundation of the regulatory frameworks shaping the maritime industry. Its objectives influence how shipping companies plan their decarbonization pathways, which in turn affects operational expectations for pilots, tug masters, and port operators. Clients will increasingly prioritize service providers capable of contributing to greener port calls through efficient maneuvers, reduced idling, and adoption of low-emission technologies.

2.2.2 Fit for 55 Package (2021)

The Fit for 55 Package is a collection of legislative proposals introduced by the European Commission in 2021 to ensure the EU achieves at least a 55% reduction in greenhouse gas (GHG) emissions by 2030 compared to 1990 levels.

As part of the legislative package, the Commission promotes the use of renewable, low-carbon fuels and clean energy technologies for ships, essential to support decarbonisation in the sector.

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For the maritime sector, the package integrates shipping into the EU's broader climate framework by:

- Expanding the EU Emissions Trading System (EU ETS) to include CO_2 emissions from large ships (greater than 5000GT) operating within the EU and between the EU and third countries.
- Introducing FuelEU Maritime, which sets limits on the GHG intensity of the energy used on board ships (greater than 5000GT).
- Encouraging the use of alternative fuels and shore-side electricity through infrastructure regulations (AFIR – Alternative Fuels Infrastructure Regulation).

Fit for 55 **Important for shipping companies**	**Fit for 55** **Relevant for port service providers**
Costs - Shipping companies will need to buy allowances for their CO_2 emissions under the EU ETS, increasing operational costs if they do not reduce emissions. Operations - They must plan voyages, speeds, and fuel choices more strategically to minimize both emissions and costs. Reputation - Compliance supports corporate sustainability commitments and helps maintain contracts with environmentally conscious charterers and cargo owners.	Direct impact • Currently, the main Fit for 55 measures only to ships above 5,000 GT engaged in commercial voyages. • Most port service vessels (tugs, pilot boats, mooring craft) are below this threshold and are not directly regulated under these schemes. • Indirect effects • Clients (shipowners) will expect efficient, low-emission port operations to help them reduce fuel use and emissions during port calls. • Early adoption of cleaner technologies (e.g., hybrid/electric tugs) positions port service providers as preferred partners.

2.2.3 FuelEU Maritime (adopted 2023, entering into force 2025)

FuelEU Maritime is a regulation that entered into force on 1 January 2025 and was adopted by the EU to increase the share of renewable and low-carbon fuels in the fuel mix of international maritime transport within the EU. The FuelEU Maritime sets requirements on the annual average GHG intensity of energy used by ships trading within the EU or European Economic Area (EEA). This intensity is measured as GHG emissions per energy unit (gCO2e/MJ) and, in turn, GHG emissions are calculated in a Well-to-Wake perspective. The calculation takes into account

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emissions related to the extraction, cultivation, production and transportation of fuel, in addition to emissions from energy used on board the ship. The baseline for the calculation is the average well-to-wake GHG intensity of the fleet in 2020.

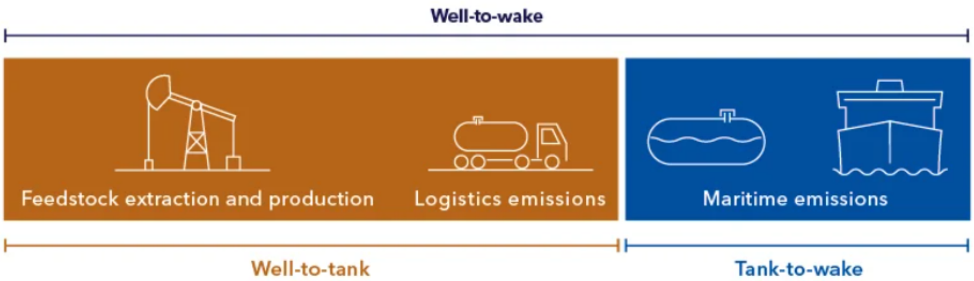

Figure 2. Well-to-wake in shipping (DNV, 2025)

Targets cover not only CO2 but also methane and nitrous oxide emissions over the full lifecycle of the fuels used onboard. The targets will ensure that the greenhouse gas intensity of fuels used in the sector will gradually decrease over time, starting with a 2% reduction in 2025, increasing to 6% in 2030, and accelerating from 2035 to reach an 80% reduction by 2050.

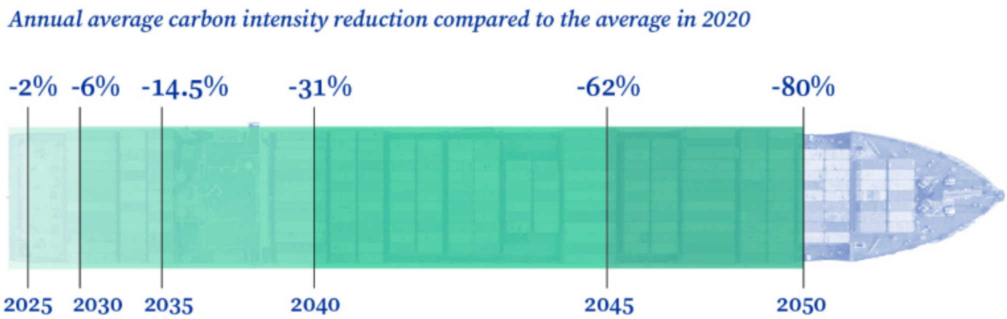

Figure 3. Annual Average Carbo Intensity reduction, (DGMOVE, 2025)

FuelEU **Important for shipping companies**	**FuelEU** **Relevant for port service providers**
Compliance with GHG Intensity Targets – FuelEU Maritime sets progressively stricter limits on the greenhouse gas intensity of the energy used on board ships from 2025 onwards, driving the adoption of	Direct impact • Port service vessels are generally below the 5,000 GT threshold and are not directly subject to FuelEU Maritime, but

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cleaner fuels (e.g., LNG, methanol, biofuels, ammonia, electricity). Operational planning – Shipowners must optimize routes, fuel blends, and engine use to meet annual GHG intensity targets. Penalties – Non-compliance will result in financial penalties.	the ships they serve must comply. Indirect effects • Pilots and tug masters need to adapt maneuvers to support vessels with alternative propulsion systems. • Ship operators will expect port services to operate efficiently and avoid delays, reducing the ship's overall fuel consumption during port calls. • Early adoption of hybrid/electric tugs or shore charging for service ships can attract business from carriers prioritizing low-carbon logistics.

2.2.4 EU ETS Emissions Trading System extension to shipping (adopted 2023, phased in from 2024)

The EU ETS is an emissions cap-and-trade system that aims to reduce GHG emissions by setting a limit, or cap, on GHG emissions for certain sectors of the economy. Each year, a limited number of EU Allowances (EUAs) is made available for trading in the market, and this is reduced yearly in order for the EU to meet its target of a 55% reduction in GHG emissions by 2030 relative to 1990, and net zero by 2050. Each EUA gives companies a right to emit GHG emissions equivalent to the global warming potential of one tonne of CO2 equivalent.

Since January 2024, the EU ETS has been extended to cover emissions from shipping. The EU ETS covers CO2 (carbon dioxide), CH4 (methane) and N2O (nitrous oxide) emissions, but the two latter only as from 2026.

In practice, shipping companies have to purchase and surrender (use) EU ETS emission allowances for each tonne of reported CO2 (or CO2 equivalent) emissions in the scope of the EU ETS system. It is the role of administering authorities of EU Member States to ensure compliance using similar rules as for the other ETS sectors.

To ensure a smooth transition, shipping companies only have to surrender allowances for a portion of their emissions during an initial phase-in period:

2025: for 40% of their emissions reported in 2024;

2026: for 70% of their emissions reported in 2025;

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2027 onwards: for 100% of their reported emissions.

Figure 4. EU ETS introduction timeline, (DNV, 2025)

EU MRV – Monitoring, Reporting and Verification

Since 1 January 2018, large ships over 5 000 gross tonnage loading or unloading cargo or passengers at ports in the European Economic Area (EEA) must monitor and report related GHG emissions. Monitoring, reporting and verification (MRV) of information must be done in conformity with the MRV Maritime Regulation (EC, 2023).

The overall purpose of EU MRV emissions collection and reporting is to assess the environmental impact of maritime transport and to serve as the basis for carbon tax determination through the EU ETS and Fuel EU Maritime regulations. The EU MRV is applicable for ships above 5000 GT on EU-related voyages.

Starting from 1 January, 2025, the revised EU MRV regulations encompassed general cargo ships between 400 and 5000 GT, as well as offshore ships of 400 GT and above (this included tugs which would do offshore work and anchor tugs - harbor tugs will not be affected). In accordance with the EU MRV regulation, a vessel's Monitoring Plan (MP) must be verified by an independent and accredited verifier, such as DNV, LR. The content of the MP is predefined by the EU MRV regulation and includes a description of the method chosen to monitor and report emissions. Starting 2024, vessels are required to have updated MRV Monitoring Plans. These updates include the addition of Outline of the overall control system (OoCs) and several changes to prepare for the EU Emissions Trading System (EU ETS).

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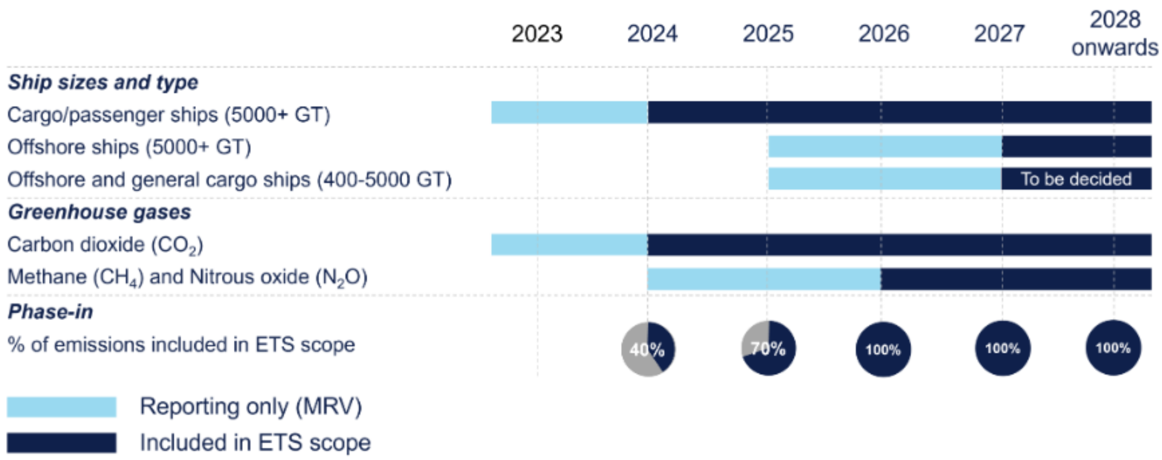

Figure 5. EU MRV reporting timeline, (DNV, 2025)

EU ETS **Important for shipping companies**	**EU ETS** **Relevant for port service providers**
Shipping companies must purchase and surrender EU ETS allowances for each tonne of CO_2 emitted on EU-related voyages. Companies must surrender allowances for 40% of 2024 emissions (in 2025), 70% of 2025 emissions (in 2026), and 100% from 2027 onwards. Large ships must have an EU-compliant Monitoring Plan, collect and report emissions data, and undergo verification by accredited bodies. From 2025, certain smaller ships (400–5000 GT) are also included. Companies must submit by 30 April of each year a verified emissions report through THETIS MRV (for each ship that has performed maritime transport activities in the European Economic Area) The report shall include the following: ● Quantity of fuel used, each type of fuel used and emission factor for each type of fuel; ● Total aggregated CO2 emitted;	Direct impact - Port service vessels are generally not directly covered by the EU ETS, but clients will seek to reduce fuel consumption and emissions during port calls to minimize their own ETS costs. Indirect effects ● Pilots, tug masters, and mooring crews will be expected to work efficiently to reduce the time ships spend with engines running. ● Understanding that client vessels must collect accurate emissions data means port service providers should coordinate to avoid unnecessary maneuvers, delays, and fuel use that will be reflected in MRV records. ● Port services that adapt to just-in-time schedules and minimize waiting times are preferred by

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• Aggregated CO2 emissions from all voyages between ports under a Member State's jurisdiction; • Aggregated CO2 emissions from all voyages to or from ports under a Member State's jurisdiction; • CO2 emissions which occurred within ports under a Member State's jurisdiction at berth; • Total distance travelled; • Total time spent at sea; • Total transport work; • Average energy efficiency. • Information relating to the ship's ice class and to navigation through ice. ETS costs incentivize just-in-time arrivals, speed optimization, and minimizing port stay duration.	shipping companies aiming to optimize ETS compliance.

2.2.5 IMO Net-Zero Fuels (NZF) initiative (2023, following the revised IMO GHG Strategy)

Following the adoption of the Revised IMO GHG Strategy in 2023, the IMO introduced the Net-Zero Fuels (NZF) initiative to accelerate the development, supply, and uptake of alternative fuels capable of achieving net-zero greenhouse gas emissions across the maritime sector by or around 2050. The initiative recognizes that the transition from fossil-based marine fuels to sustainable alternatives (such as green ammonia, green methanol, hydrogen, and advanced biofuels), will be essential for meeting global decarbonizations targets.

IMO NZF **Important for shipping companies**	**IMO NZF** **Relevant for port service providers**
The NZF initiative creates a clear market signal that low- and zero-carbon fuels will be the long-term standard, influencing fleet investment decisions, fuel supply chain development, and operational planning.	While not directly regulated, pilots, tug masters, and port operators will encounter an increasing number of vessels using alternative fuels. This may require adjustments in operational procedures (e.g., handling LNG, methanol, or ammonia-fueled

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Operators will need to be ready to handle vessels with alternative propulsion systems and fuel requirements.	ships), enhanced safety protocols, and investment in compatible port infrastructure (such as alternative fuel bunkering or charging facilities). Early familiarity with these fuels and their handling requirements will help for client trust during the energy transition.

2.3. Port services not specifically falling within these regulations for the time being

Although most current EU and IMO decarbonization measures focus on vessels above 5,000 GT engaged in international or EU-related voyages, port service ships such as tugs, pilot boats, and mooring vessels are, for the time being (2025), outside the direct scope of these regulations. This exemption does not exempt the sector from change.

Their operations influence the overall emissions, and can contribute through:

- Well-coordinated maneuvers improve operational efficiency by reducing ship engine use.
- Hybrid or battery-electric tugs reduce emissions during maneuvering.
- Aligning pilotage with optimal tide and current conditions minimizes fuel burn.
- Efficient berth allocation and just-in-time arrivals avoid vessel queuing and prolonged anchorage, reducing unnecessary fuel consumption.
- Minimizing tug idling time during standby or between operations saves fuel and lowers emissions.
- Using shore-based power for service vessels between assignments reduces auxiliary engine running hours.
- Effective communication between pilot, tug master, and bridge team ensures precise and minimal-power maneuvers.
- Training crews in eco-handling techniques for both tugs and pilot boats maximizes energy efficiency without compromising safety.

Understanding which ship categories are covered by the EU ETS and MRV Maritime Regulation in 2025 helps port service providers (not falling within these regulations) identify where client compliance obligations originate and anticipate how these requirements may indirectly influence their own operations. This awareness enables better alignment with client needs and preparation for potential future regulatory inclusion. Ship categories subject to EU ETS and MRV Maritime Regulation:

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- MRV Maritime Regulation applies to ships of 5 000 gross tonnage (GT) and above in respect of the greenhouse gas emissions released during their voyages from or/and to ports in the European Economic Area (EEA).
- Starting from 1.01.2025, MRV Maritime Regulation applies to offshore ships of and above 5 000 GT, as well as offshore ships and general cargo ships below 5 000 GT but not below 400 GT (this included tugs which would do offshore work and anchor tugs - harbor tugs will not be affected).
- Ships are subject to the MRV Maritime Regulation regardless of their flag.

Categories of ships excluded: warships, naval auxiliaries, fish-catching or fish-processing ships, ships not propelled by mechanical means, government ships used for non-commercial purposes.

2.4. The need to be proactive, energy saving and emission reduction theories and practices

Undoubtedly, waiting for regulations to mandate change is no longer a competitive option. Port service providers who adopt energy-saving and emission-reduction measures early position themselves as preferred partners for shipping companies.

2.4.1. Guiding principles

Even in the absence of direct legal obligations, port service providers are subject to the decarbonization imperatives of their clients and the broader supply chain as well as public expectations. Therefore, they must act for proactive integration of sustainability measures, guided by the below principles:

- Shipowners must meet IMO and EU climate targets.
- Charterers and cargo owners demand greener supply chains.
- Ports and service providers who cannot demonstrate low-emission operations risk losing clients to greener competitors.

2.4.2 Key theories and practices

Operators need to make informed choices that improve fuel efficiency, minimize long-term environmental impacts, and maintain safe port service operations. For this reason, an integrated approach is required:

- Operational behavior – Small, consistent adjustments in daily practices can cumulatively lead to significant emission reductions. *Examples: Reduce tug engine idling between assignments, optimize vessel speed during approaches, plan maneuvers to take advantage of tides and currents, and coordinate closely with the bridge team to avoid unnecessary repositioning.*
- Life Cycle thinking – Consider the total environmental impact of equipment and operations, from acquisition to disposal, to choose the most sustainable

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options. *Examples: Choose hybrid or electric propulsion systems for new tugs, source low-maintenance and energy-efficient equipment, use recyclable or renewable materials where possible, and plan maintenance to extend equipment lifespan while reducing waste.*

2.5. Importance of aligning with client expectations and future-proofing operations.

Client expectations are evolving as quickly as regulatory frameworks. Shipping companies, charterers, and cargo owners prioritize those service providers that can demonstrate low-emission operations, operational efficiency, and readiness to work with alternative fuel technologies. Therefore, port service providers are required to align with these expectations, not only about meeting current requirements, but also to ensure long-term relevance and competitiveness.

Future-proofing operations means anticipating changes to be ready for the future. For pilots, tug masters, and port operators, this include adopting eco-handling techniques, supporting just-in-time vessel arrivals, reducing idle time, upgrading to hybrid or electric craft, and staying informed about alternative fuel handling protocols.

In order to meet and even to exceed client expectations, port service providers shall build strong partnerships, secure business, and train the personnel to remain competitive in a market where environmental performance is an important factor.

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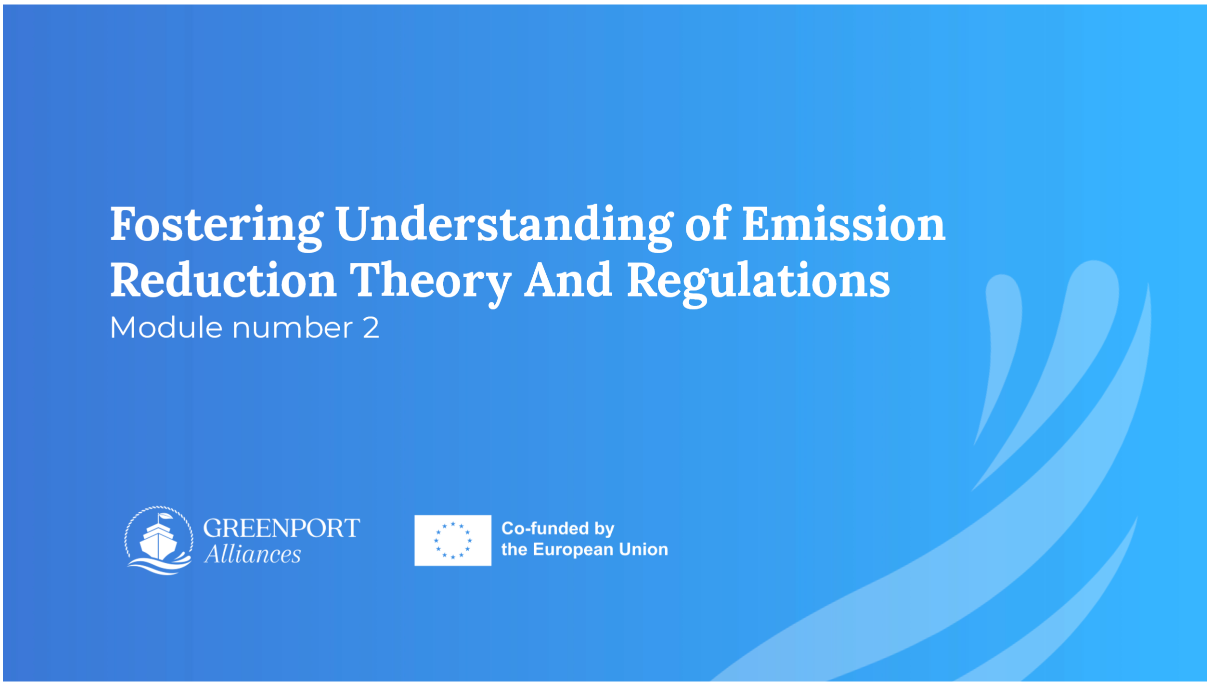
Chapter 2 Supporting material



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GREENPORT Alliances

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Module objectives

- **Understand the link between energy efficiency and emission reduction.**
- **Identify the main EU and IMO regulatory frameworks (**Green Deal, Fit for 55, FuelEU, EU ETS, IMO NZF).
- **Recognize the indirect effects of regulations on port service operations.**
- **Describe proactive measures to align operations with sustainability goals.**

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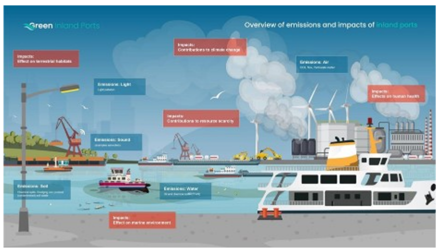
Why emission reduction matters

ENVIRONMENTAL IMPACT OF MARITIME TRANSPORT AND PORTS

- **Global emissions**: Maritime transport contributes 2–3% of global greenhouse gas (GHG) emissions, influencing climate change and ocean health.



- **Environmental impacts**:
  - ❑ *Climate*: Sea level rise and extreme weather events.
  - ❑ *Ocean*: Acidification and ecosystem disruption.
- **Port-specific pollution**: Port areas contribute to air, water, soil, noise, and light pollution, affecting local environments and communities.
- **Operational influence**: Port service operations — including tug assistance, pilotage, and vessel handling — have a direct effect on ships' overall fuel consumption and emissions.

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Sustainability measures in ports

TECHNICAL

- Low-/zero-emission service vessels (hybrid, electric, LNG, methanol).
- Onshore Power Supply (OPS).
- Emission capture and treatment systems.

OPERATIONAL

- Tidal window planning and optimized vessel speeds.
- Minimum tug deployment without compromising safety.
- Digital solutions to reduce waiting times and fuel use.

REGULATORY

- Fee reductions and incentives for greener ships.
- Mandatory emission reporting.
- Integration with IMO and EU frameworks.

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Examples of best practices

ACROSS THE WORLD, PORTS ARE ADOPTING INNOVATIVE SOLUTIONS THAT COMBINE TECHNOLOGY, DIGITALISATION, AND INCENTIVES TO REDUCE EMISSIONS AND IMPROVE EFFICIENCY.

- **Rotterdam**: Hybrid tugs and OPS → lower CO_2 and particulate matter.
- **Gothenburg**: Digital Port Call → –6,000 tons CO_2 per year.
- **Los Angeles**: Differentiated fees + electric tugboats.
- **Amsterdam**: Next-gen tug design → 15% fuel savings.
- **Auckland**: Hybrid-electric tugs → 30% less fuel per operation.

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Being proactive & future-proof

WAITING FOR REGULATION IS NOT A COMPETITIVE OPTION. PORTS AND OPERATORS MUST ACT NOW TO MEET ENVIRONMENTAL AND MARKET DEMANDS

GUIDING PRINCIPLES

- Achieve IMO and EU climate targets.
- Support greener supply chains.
- Maintain competitiveness against "greener" rivals.
- Enhance operational resilience through energy-efficient and adaptive practices.

KEY ACTIONS

- Eco-handling and just-in-time arrivals
- Deploy hybrid/electric service vessels.
- Prepare for alternative fuels (LNG, methanol)
- Train crews in sustainable operational practices

Key takeaways & next steps

- Reducing emissions in maritime operations is not only a **regulatory requirement** but also a **business opportunity** that enhances competitiveness and reputation.
- **Port service providers play a strategic role** in this transition, as their choices in equipment, vessel operations, and coordination practices directly influence environmental performance.
- The **early adoption of innovative technologies** — such as hybrid and electric vessels, Onshore Power Supply (OPS), and digital optimisation tools — **allows operators to stay ahead of regulatory demands while improving efficiency and market positioning**.
- **Continuous training and awareness are critical to ensure that sustainable practices** become part of daily operations, embedding a culture of long-term excellence and responsibility

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Chapter 2 Assessment Questions

1. **Maritime transport accounts for a notable share of global GHG emissions. Which of the following best reflects this contribution and its impacts?**
   A. Less than 1%, negligible effect on the climate
   B. 2–3%, linked to sea-level rise, acidification, and coastal health impacts
   C. 5–6%, causing minor disruptions only to ecosystems
   D. 10–12%, mostly unrelated to shipping efficiency

2. **Which of these measures is classified as operational in reducing port-related emissions?**
   A. Installing OPS infrastructure at container berths
   B. Retrofitting tugboats with hybrid propulsion systems
   C. Adjusting vessel speed profiles to minimise fuel consumption
   D. Introducing differentiated port fees

3. **The EU's "Fit for 55" package requires:**
   A. All ships regardless of size to purchase allowances
   B. Only non-EU flagged ships to comply
   C. A 55% reduction in GHG emissions by 2030 relative to 1990 levels
   D. Passenger ships only to adopt LNG or methanol fuels

4. **The EU ETS requires surrender of allowances for 40% of emissions in 2025, 70% in 2026, and 100% from:**
   A. 2025
   B. 2026
   C. 2027
   D. 2035

5. **The IMO Net-Zero Fuels initiative aims primarily to:**
   A. Reduce noise emissions at ports
   B. Ban HFO in the Arctic region only
   C. Accelerate supply and uptake of ammonia, methanol, and hydrogen to achieve net-zero around 2050
   D. Mandate LNG for all international voyages

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Chapter 3: Industry ecosystem and technological landscape

The modern maritime port environment is undergoing a rapid transformation, driven by decarbonization targets, technological innovation, and evolving client expectations. For pilots and tug masters, particularly, these changes are not abstract policy matters—they directly influence how ships are handled, how assistance is provided, and how safety is maintained alongside efficiency and environmental performance.

The "*industry ecosystem*" refers to the network of stakeholders that interact in port operations: shipowners, charterers, terminal operators, port authorities, tug and pilotage companies, regulators, and technology providers. Each plays a role in shaping operational practices. For example, a shipping company's decision to operate methanol-powered vessels affects pilot maneuver approaches, tug assistance patterns, and even berth allocation by the port authority.

The "*technological landscape*" encompasses the new systems, fuels, and tools entering service—such as Onshore Power Supply (OPS), LNG and ammonia propulsion, emission monitoring sensors, and emission reduction equipment like ShaPoli. These technologies aim to improve efficiency and reduce environmental impact, but they also require new knowledge, skills, and coordination between vessel crews and port service providers.

In this session, participants will explore how these industry and technology shifts intersect with daily pilotage and towage work. Through real-life case examples and operational scenarios, the aim is to build awareness of current trends, understand their practical implications, and identify ways to adapt working practices. By the end of the session, pilots and tug masters should recognize opportunities to integrate new tools and procedures that enhance operational performance and environmental stewardship.

3.1. Port requirements – Onshore Power Supply (OPS)

In modern port operations, Onshore Power Supply (OPS) is emerging as a key tool for reducing emissions and improving air quality. Also known as "cold ironing" or "shore connection", OPS allows ships to shut down their auxiliary engines while berthed and connect to the port's electrical grid. The result is a substantial reduction in CO_2, NO_x, SO_x, and particulate matter, along with quieter port environments.

For pilots and tug masters, OPS is more than an environmental measure—it directly influences how berthing operations are conducted. Because the vessel's connection points must align precisely with the OPS interface on the quay, maneuvering requires greater accuracy in terms of arrival speed, approach angle, and final stopping position for making all fast. Achieving this alignment on the first

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attempt is critical, as any need to reposition the vessel (after agreeing on all fast positions) increases time, fuel use, and operational complexity.

OPS also calls for behavioral shifts. Traditional berthing often requires repeated micro-adjustments after the initial contact. With OPS, the priority becomes arriving *connection-ready*, minimizing the time auxiliary engines run alongside. This requires close coordination between the pilot, tug masters, mooring crews, and shore power technicians.

While the International Maritime Organization (IMO) encourages ports to offer OPS as part of its 2023 GHG Strategy, it is not mandatory at the global level. The IMO provides guidance, promotes relevant technical standards (e.g., IEC/IEEE 80005-1 for high-voltage shore connections), and has issued interim safety guidelines.

On the other hand, specific vessels in core TEN-T network ports must use OPS starting in 2030, and in additional TEN-T ports starting in 2035, according to the European Union's Alternative Fuels Infrastructure Regulation (AFIR).

The table below summarizes an OPS implementation roadmap, showing voluntary IMO guidance alongside mandatory EU requirements and the operational implications for pilots and tug masters.

Table 1 – Roadmap for OPS implementation in ports (IMO guidance vs EU AFIR requirements)

Phase	**Port actions**	**IMO guidance (voluntary)**	**EU AFIR requirements (mandatory)**	**What this means for pilots & tug masters**
1. Policy & gap analysis	Review OPS status, target berths/ship types, and check grid capacity.	Encourage OPS provision in line with IMO GHG Strategy 2023.	From 2030: OPS mandatory for container & passenger ships at core TEN-T ports; from 2035: extended to more TEN-T ports.	Expect OPS at high-traffic container/passenger berths first; adjust job planning accordingly.
2. Stakeholder & demand assessment	Engage lines, terminals, pilots, tugs, and grid operators. Gather compatibility data.	IMO OPS workshop materials for collaborative planning.	Needed to prove readiness for mandatory OPS vessels.	Provide input on a realistic approach and assist with times for OPS berths.

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3. Technical standards & design	Plan OPS to IEC/IEEE 80005-1 standards; upgrade grid; define connection points.	Refer to IMO interim safety guidelines.	The same standards apply to meet compliance.	Train for berth-specific "final alignment zone"; agree on tug methods to achieve cable reach without repositioning.
4. Procedures & safety	Develop SOPs for OPS checks, safety zones, and emergency disconnects.	MEPC.1/Circ.794 and OCIMF OPS guidance.	Required for EU compliance audits.	Use OPS-specific pre-job briefs, safe-zone discipline, and minimal repositioning after final alignment.
5. Pilot berth trial	Test OPS connection at one berth/ship class, refine timings.	Encourage trials for training.	Supports operational readiness proof.	Practice "connection-ready" arrivals: steady final approach, minimal corrections.
6. Scale-up & scheduling	Expand OPS, integrate JIT arrivals to match OPS crew slots.	IMO encourages JIT arrival for GHG reduction.	OPS is used compulsorily when the berth is equipped and the vessel is in scope.	Adjust speed to hit the OPS slot; coordinate tug release once the cable latches.
7. Training & certification	Train pilots, tug crews, and mooring teams; run emergency disconnect drills.	IMO recommends OPS safety and procedural training.	Training may be checked in compliance inspections.	Practice "stop-push-hold" techniques; clear comms with OPS lead.
8. Monitor & improve	Log connection times, delays, fuel/emissions savings.	Share results to promote adoption.	Required for EU reporting.	Participate in debriefs and suggest berth markings or tug angles to

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				minimise retries.

Source: Adapted from IMO (2023) Strategy on Reduction of GHG Emissions from Ships; IEC/IEEE 80005-1:2019; EU Regulation (EU) 2023/1804 (AFIR); OCIMF (2022) Shore Power Guidelines.

Understanding both the regulatory context and its practical implications, pilots and tugmasters can better anticipate OPS-related requirements, adapt their maneuvering techniques, and contribute to smoother, safer, and cleaner port operations.

OPS is no longer a theoretical concept or a distant regulatory target—it is already a reality in many major ports. Within the EU, ports such as Rotterdam, Antwerp-Bruges, Gothenburg, and Barcelona have operational OPS systems at selected berths, serving containers, RoRo, and passenger vessels. Under the EU Alternative Fuels Infrastructure Regulation (AFIR), OPS use is already compulsory in certain circumstances at some ports that have chosen to implement the requirement ahead of the 2030 deadline. For example, several Scandinavian ports have made the OPS connection mandatory for passenger ferries on specific routes to improve local air quality.

Globally, OPS is in daily use in ports like Los Angeles, Vancouver, Shanghai, and Singapore, often supported by local environmental regulations or incentive schemes. In some jurisdictions, such as California, a shore power connection is legally required for certain vessel types during berth stays, with penalties for non-compliance.

For pilots and tugmasters, this trend means OPS-aligned maneuvering and connection readiness are now standard operating practices, not just preparations for future rules. Understanding the requirements, precise berthing techniques, and behavioral changes needed for OPS systems today will ensure smoother operations and better environmental performance wherever they are implemented.

3.2. Trends in shipping – alternative fuel vessels (LNG, methanol, ammonia)

The global shipping industry is diversifying its fuel mix in response to increasingly strict emission targets and decarbonization strategies. While heavy fuel oil (HFO) still dominates, more vessels are entering service powered by Liquefied Natural Gas (LNG), methanol, and, increasingly in pilot projects, ammonia. Each of these fuels comes with distinct operational characteristics, safety protocols, and environmental profiles that directly affect how pilots and tug masters carry out their work, as well as how other stakeholders in port operations—terminal operators, mooring crews, port authorities, and environmental officers—plan and coordinate their activities.

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LNG-fueled vessels are already well-established in many trades, particularly the container, cruise, and tanker sectors. LNG offers significant reductions in SO_x, NO_x, and CO_2 compared to conventional fuels but requires cryogenic storage and strict safety zoning during operations. For pilots, these restrictions may mean modified approach patterns to respect exclusion zones on deck during berthing. Tug masters may be instructed to keep a greater lateral distance from bunker station areas when pushing or holding alongside. Terminal operators and mooring crews must be aware of the restricted access zones and coordinate the use of equipment accordingly to ensure safe operations.

Methanol-fueled vessels are gaining popularity because methanol can be stored at ambient temperatures and used in dual-fuel engines, allowing flexibility between conventional and alternative fuels. However, methanol is toxic and flammable, and its vapours are heavier than air. Pilots may encounter slightly different engine response characteristics, while tug masters must consider that methanol spillages can create hazardous atmospheres around the hull. Terminal operators may need to implement additional ventilation measures in enclosed areas during cargo operations.

Ammonia-fueled vessels are still at an early stage, with most examples requiring a demonstration or limited commercial deployment. Ammonia produces no CO_2 at the point of use; however, it is highly toxic and corrosive, significantly increasing operational safety requirements. Pilots must be aware of enhanced evacuation procedures, and tug masters may need to operate from positions that limit crew exposure in the event of a leak. Port safety teams and emergency response units must be trained to manage ammonia-related incidents.

Behavioral change aspect

The introduction of alternative fuels demands more than technical awareness—it requires pilots, tug masters, and other stakeholders to adapt their routines and communication. Boarding preparations may now include confirmation of fuel type and related safety measures. Bridge briefings must cover differences in propulsion response. Tug, pilot, and terminal communication should clearly identify restricted zones and contingency plans.

Industry examples

- The Port of Rotterdam regularly handles LNG-fueled container ships, such as CMA CGM's *Jacques Saadé* class, which require coordinated tug positioning to avoid LNG bunker manifolds during berthing.
- Maersk's methanol-fueled Laura Maersk has demonstrated that dual-fuel operation can be seamless, but pilots still receive specific guidance on fuel system safety before boarding.
- In Japan, the first ammonia-fueled tug, the A-Tug, began trials in 2024, with strict safety drills conducted on all assistance vessels prior to operations.

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To help operational teams quickly compare the practical implications of different alternative fuels, Table 2 summarizes the key characteristics of LNG, methanol, and ammonia from the perspective of pilots, tug masters, and other port stakeholders, including terminal operators, mooring crews, and port safety officers. We intend this overview to serve as a quick-reference guide during pre-arrival planning and operational briefings.

Table 2 – operational considerations for LNG, methanol, and ammonia-fueled vessels

Fuel type	Key characteristics	Pilot considerations	Tug master considerations	Typical precautions
LNG	Cryogenic liquid at −162 °C; low emissions of SO_x, NO_x, CO_2; requires insulated tanks and specialized bunkering.	Respect safety exclusion zones during berthing. Adjust your approach to avoid areas near the bunker manifold. Consider potential changes in engine response resulting from dual-fuel operation.	Maintain a safe lateral distance from the LNG bunker station when pushing; avoid exposure to exhaust during gas mode.	Confirm fuel type in pre-arrival brief; observe “no ignition source” zone; comply with port LNG handling SOPs.
Methanol	Liquid at ambient temp; toxic, flammable; vapors heavier than air; compatible with dual-fuel engines.	Check for slightly different acceleration profiles; ensure methanol-specific hazards are discussed in the bridge briefing.	Avoid positioning that traps crew near potential vapor accumulation points; manage towline to prevent contact with bunker areas.	Wear appropriate PPE near deck-level bunker manifolds; ensure good ventilation during operations alongside.

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Ammonia	Zero CO_2 at point of use; highly toxic, corrosive; pungent odor; currently limited operational use.	Familiarize with enhanced emergency evacuation routes; minimize close-quarters operations near ammonia storage tanks.	Operate from positions reducing crew exposure; avoid pushing against areas near ammonia fuel storage; prepare for rapid disengagement.	Strict adherence to safety drills; use of respirators where required; immediate reporting of suspected leaks.

Source: Adapted from DNV (2024) "Alternative Fuels for Shipping", IMO Interim Guidelines on Safety for Ships Using Alternative Fuels, and port authority operational advisories.

Alternative-fuel vessels are no longer occasional visitors in major ports—they are becoming a regular part of daily operations. LNG-fueled ships already form a significant share of new-build deliveries, while methanol-powered vessels are entering liner trades, and ammonia-fueled projects are transitioning from trials to early commercial use.

In several ports, such as Rotterdam, Singapore, and Yokohama, pilots, tug masters, terminal operators, and safety teams are now expected to be fully conversant with the handling characteristics, safety measures, and berth restrictions associated with these fuels. We anticipate that this trend will continue to accelerate as global and regional emission regulations become increasingly stringent. The ability to adapt maneuvering techniques, respect fuel-specific safety zones, and maintain clear, multi-stakeholder communication will be an essential part of professional competence in the years ahead. It is worth noting that uncertainty within the industry is hindering shipping companies' investment in adopting alternative fuels. Specifically, with the lack of a clear route as to what will be the main future fuel, the cost of adapting vessels to burn this fuel, as well as the limited availability of these fuels, is a concern. The EU needs to invest in developing a future fuel network.

3.3. Use of ShaPoli systems on client vessels

The Shaft Power Limitation (ShaPoli) system is a technology that limits or monitors the maximum power output from a ship's main engine. Its primary purpose is to help vessels comply with IMO's Energy Efficiency Existing Ship Index (EEXI) requirements and improve their Carbon Intensity Indicator (CII) ratings. By controlling the shaft power, the system reduces fuel consumption and greenhouse gas emissions, especially during maneuvers and transits at lower speeds. In the port operations environment, ShaPoli can provide valuable real-time feedback to all stakeholders.

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However, in some ports around the world, there are claims that ShaPoLi systems are problematic in pilotage, which are grounded in real operational experiences and supported by regulatory commentary. Ports may request that these systems be disabled when they limit maneuverability or delay responses – especially under tight navigation conditions where "engine kicks" are essential tools for pilots.

Why pilots and ports raise concerns about ShaPoLi systems

1. Reduced maneuvering responsiveness

ShaPoLi systems restrict shaft power (and similarly, EPL <Engine Power Limitation> systems limit engine output), potentially reducing the vessel's acceleration and deceleration, especially during fine-tuned maneuvers. Quick responses are crucial in narrow channels or congested pilotage areas, and this can hinder them.

2. Engine revs build slowly – eliminating "engine kicks".

Pilots frequently use "engine kicks", which are short bursts of forward or astern power, to smoothly control momentum when docking or avoiding obstacles. The smoothing of engine revs by ShaPoLi eliminates this subtlety, which could lead to a greater need for tug assistance and higher operating costs, particularly in congested port conditions.

3. Risks to safety in restricted waterways

Being unable to quickly override these systems can jeopardize safety in situations where full thrust may be required due to tides, currents, weather, or proximity. The Australasian Marine Pilot Institute (AMPI) has formally expressed worry about these limitations in pilotage zones.

4. Regulatory guidance for override access

IMO's regulations (notably MEPC.335(76), MEPC.375(80), and MEPC.390(81)) require that ShaPoLi/EPL systems be overridable, especially when safety or navigation demands it. Ships must keep updated pilot cards, wheelhouse posters, and maneuver booklets to reflect performances with and without power limits.

Moreover, authorities such as AMSA (Australia) stress that pilot exchanges must confirm both the availability of overrides and the ship's immediate maneuvering capabilities before boarding.

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5. Policy in US Waters Requires Immediate Override if Necessary

The US Coast Guard mandates that if maneuvering information hasn't been updated (e.g., on pilot cards), ShaPoLi systems must be deactivated before entering restricted US waters; otherwise, vessels risk noncompliance. Overriding during pilotage is not a violation as long as it's safely executed and properly logged.

Reminder! When establishing towage requirements, keep in mind that ShaPoli systems pose an added risk during maneuvering.

Behavioral change aspect

The introduction of ShaPoLi represents a transition from experience-based estimation to data-driven decision-making in port operations. Pilots and tugmasters should be provided with, and actively request, shaft power data during pre-arrival exchanges, while port and terminal authorities are expected to incorporate these parameters into berth planning systems. Effective implementation requires a cultural adjustment towards enhanced transparency, ensuring that vessel performance information is systematically shared among ship operators, pilotage organizations, towage providers, and terminal operators

Industry examples

Several ports have already acknowledged the operational importance of knowing a vessel's shaft power status prior to arrival. For example, the Port of Southampton (UK) requires vessels fitted with Shaft Power Limitation (ShaPoLi) or Engine Power Limitation (EPL) systems to notify Vessel Traffic Services (VTS) well in advance of entry. This requirement arises from the risks that ShaPoLi systems pose during vessel maneuvering.

This requirement is published in the port's official *Port User Navigation Guidelines* and is intended to ensure that pilots are fully aware of any propulsion restrictions before boarding. By obtaining this information early, pilots can assess whether the vessel's maneuverability under prevailing conditions—such as wind, tide, or traffic—will require modified approaches or additional tug assistance. Tug operators and terminal planners can then adjust their schedules accordingly, avoiding last-minute changes and potential delays.

This type of procedural integration shows how ShaPoLi is not only a compliance tool for IMO's EEXI and CII regulations but also a valuable part of multi-stakeholder port planning. It encourages proactive communication between the ship's master, the pilotage service, tug companies, and terminal operators, ensuring that any operational limitations are understood and managed well before the vessel reaches the pilot boarding area.

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Table 3 – Benefits and challenges of using ShaPoli in port operations

Aspect	Benefits	Challenges
Operational planning	More accurate tug allocation; better ETA to berth; improved safety margins in strong weather.	Requires early data sharing between the ship, the pilotage, and the port authority.
Fuel & emissions	Supports eco-efficient maneuvering; measurable fuel and emission savings.	May increase berthing time if power limits are too restrictive for local conditions.
Training	Enhances pilot/tug master situational awareness; introduces data-driven planning.	Crews must understand how to interpret and apply shaft power data.
Multi-stakeholder coordination	Improves communication between the ship, pilots, tugs, terminal, and VTS.	Inconsistent data formats or a lack of interface compatibility can hinder adoption.

Source: Adapted from IMO MEPC.335(76) – EEXI Implementation Guidelines, ClassNK (2023) "Shaft Power Limitation Systems", and operational reports from European container terminals.

As ShaPoLi systems become more widespread, ports that incorporate shaft power data into operational planning will achieve gains in both efficiency and safety. Reliable shaft power information that is available before and during maneuvers can improve the smoothness of operations and help pilots and tugmasters avoid unplanned delays. For terminal operators, VTS, and safety teams, access to this data supports better berth management and resource allocation. The main challenge lies in ensuring that all stakeholders receive timely and accurate information and that they have the skills required to apply it effectively.

3.4. Emission monitoring tools and their usability for crews

Emission monitoring tools are now a regular part of environmental management in many ports. Their primary role is to measure pollutants such as Sulphur oxides (SO_x), nitrogen oxides (NO_x), carbon dioxide (CO_2), and particulate matter (PM) from ships and port service craft. These tools can be fixed to port infrastructure, mounted on mobile platforms like drones or patrol boats, or installed on board vessels. The collected data supports compliance with MARPOL Annex VI, informs operational adjustments, and enables ports to meet regional air quality targets.

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For pilots, emissions data provides valuable feedback on how maneuvering choices—engine loads, speed profiles, and tug usage affect emissions. Tug masters can adjust power applications and idle times to minimize fuel waste and reduce emissions peaks. Terminal operators can plan berth assignments to prevent overlapping high-emission operations, thereby minimizing environmental impact. Port authorities and environmental officers use the data to enforce compliance and guide policy.

Industry examples

1. **EMSA's Remotely Piloted Aircraft System (RPAS) – *Port of Barcelona***
    - The European Maritime Safety Agency deploys RPAS drones equipped with pollutant sensors to monitor SO_2 and NO_x emissions from ships during approach, berthing, and at anchor.
    - The data is processed and sent to the THETIS-EU platform, which flags potential non-compliance for follow-up inspection.
    - For pilots and tug masters, drone monitoring means that maneuvers in monitored zones are under environmental scrutiny, encouraging smoother approaches and avoiding unnecessary engine surges.

2. **Protea 2000 In-Situ Infra-Red Gas Analyzer**
    - A fixed emissions analyzer using infrared spectroscopy, installed at quayside or stack level, to continuously measure SO_2, NO_x, and CO_2 directly in exhaust gas streams.
    - Rugged and designed for marine environments, it requires minimal maintenance and can deliver near-real-time results to port control systems.
    - Helps terminal operators and port authorities monitor compliance without boarding vessels and provides crews with objective data to adjust engine use.

3. **Evolution EMS by Martek Marine**
    - A marine-rated Continuous Emissions Monitoring System (CEMS) designed for shipboard use.
    - The system measures NO_x, SO_x, and CO_2 in real time and provides this data to the ship's bridge as well as to shore-based managers.

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- For pilots and tugmasters, knowing that a vessel is fitted with a system like Evolution EMS means emission impacts can be tracked for specific maneuvers—helping refine techniques for eco-efficiency.

4. **EMSYS Maritime Continuous Emissions Monitoring**
    - Uses Quantum Cascade Laser (QCL) spectroscopy to detect SO_2, NO_x, CO_2, and PM with high sensitivity.
    - It can be integrated into fixed port installations or on vessels.
    - Its capability to monitor multiple pollutants simultaneously makes it valuable for ports with diverse traffic profiles and complex emission reduction goals.

5. **Sensor-Based Online Monitoring Networks**
    - Ports increasingly deploy distributed NDIR (Non-Dispersive Infrared) and laser-based sensors along quays and anchorage areas.
    - These networks provide a spatial map of emissions, helping port planners identify hotspots and schedule traffic to minimize cumulative air quality impacts.

Operational implications

- Pilots: Adjust maneuvers to minimize engine load spikes in monitored zones.
- Tugmasters: Use emissions data to reduce unnecessary high-power use and manage bollard pull efficiently.
- Terminal operators: Optimize berth assignments to avoid simultaneous peaks from multiple vessels.
- Port authorities: Use verified, sensor-derived evidence to support inspections and report potential violations to the relevant national authorities for enforcement.

Behavioral change aspect

The integration of these tools shifts operations toward data-informed decision-making. Instead of relying solely on visual assessment or routine practice, all stakeholders can now use precise measurements to adapt behavior. This promotes transparency, encourages cooperation, and supports a shared goal of reducing port emissions.

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Table 4 – Benefits and challenges of emission monitoring tools in port operations

Aspect	Benefits	Challenges
Operational efficiency	Enables real-time adjustments to reduce unnecessary engine use; improves berth planning.	Requires integration into operational workflows without overloading crews with data.
Regulatory compliance	Provides proof of compliance with MARPOL Annex VI and regional air quality standards; supports targeted inspections.	Potential for penalties if data shows non-compliance; calibration and maintenance essential for accuracy.
Environmental performance	Identifies high-emission activities for targeted improvements; supports sustainability reporting.	Infrastructure investment can be significant for ports.
Stakeholder coordination	Encourages data-sharing between ship, port services, and environmental authorities.	Data privacy and sharing agreements may delay adoption.

Source: EMSA (2023) RPAS Programme; Protea Ltd. (2024); Martek Marine (2024); EMSYS Maritime (2024); Port of Barcelona Environmental Monitoring Programme; MARPOL Annex VI Guidelines.

Emission monitoring systems are moving from pilot projects to permanent infrastructure in many ports. They are not just enforcement tools—they are catalysts for behavioral change across all port stakeholders. For pilots, tug masters, terminal operators, and port authorities, the ability to access and respond to accurate emissions data is becoming a standard professional requirement. Those who adapt early will be better positioned to deliver safe, efficient, and environmentally responsible port operations.

3.5. Case examples – cleaner-fuel tug & pilot vessels (HVO, hybrid, hydrogen, electric)

Port service vessels, including tugs, pilot launches, and workboats, are undergoing a green transformation by utilizing cleaner fuel options such as Hydrotreated Vegetable Oil (HVO),

hybrid systems, hydrogen dual-fuel, and electric propulsion. These innovations are reshaping operational routines, handling characteristics, and maintenance needs. For pilots, tug masters, and other stakeholders (terminal operators, port authorities, environmental officers), understanding these technologies is now part of professional competence.

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Industry examples

1. HVO – Hydrotreated Vegetable Oil

Svitzer's EcoTow services:

- In the UK, Svitzer switched five tugs serving the South Hook LNG terminal from marine diesel to HVO under a long-term contract, cutting CO_2 emissions while keeping service reliability intact.
- In London, all 10 Svitzer tugs operating on the Thames by January 2022 were converted to HVO, supporting "EcoTow" services that achieve up to ~90% carbon reduction (tank-to-wake).

2. Hybrid diesel-electric tugs

- A notable historical example is the Damen ASD 2810 Hybrid tug, delivered to Iskes Towage in Amsterdam in 2012. It uses diesel-electric propulsion to reduce emissions by 20–60% and fuel use by up to 30%.

3. Hydrogen dual-fuel tugs

- The Hydrotug 1, operated by Port of Antwerp-Bruges and CMB.TECH, is the world's first hydrogen-powered tugboat, featuring dual fuel (hydrogen + traditional) BeHydro V12 engines. It offers a 65% reduction in fuel consumption and stores up to 415 kg of compressed hydrogen, eliminating emissions equivalent to approximately 350 cars per year.

4. Fully electric pilot boats / hybrid concepts

- Damen Shipyards is advancing its sustainability agenda by delivering fully electric e-ferries and waterbuses, and preparing hybrid tug models (e.g., RSD Tug 2513) designed for future electric conversion.

Table 5

Fuel/Technology	**Example Vessel / Operator**	**Benefits**	**Operational considerations**
HVO	Svitzer EcoTow tugs (UK, London)	~90% lifecycle CO_2 reduction	Same handling; supply chain and maintenance adjustments

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Diesel-Electric (Hybrid)	Damen ASD 2810 Hybrid (Iskes Towage, Amsterdam)	20–60% emissions reduction	Dual modes; battery usage; maintenance of complex systems
Hydrogen Dual-Fuel	Hydrotug 1 (Port of Antwerp-Bruges)	65% fuel/emission reduction	Hydrogen bunkering; safety protocols; crew training
Electric / Hybrid	Damen e-ferries / hybrid tugs (various)	Zero local emissions; quiet	Charging infrastructure; schedule integration

These examples show that decarbonized service craft are no longer theoretical. HVO conversions are operational today; hybrid and hydrogen vessels are being tested and scaled; electric alternatives are being prototyped. Pilots, tug masters, and port stakeholders will increasingly encounter these technologies. To operate safely and efficiently, they must adapt their procedures, scheduling, refueling planning, and inter-agency coordination.

3.6. Challenges for uptake – limited availability and high cost of alternative fuels

While alternative fuels such as HVO, LNG, methanol, ammonia, hydrogen, and battery-electric power are gaining momentum in the maritime sector, their adoption in port service craft and short-sea operations still faces significant barriers. Two of the most cited obstacles are limited fuel availability and high operating costs as well as high initial build costs. These challenges affect not only the operators of tugs and pilot launches, but also pilots, tug masters, terminal operators, and port authorities responsible for integrating these technologies into daily operations.

Limited availability

- **Infrastructure gaps**: Many ports lack dedicated bunkering or charging facilities for alternative fuels. For example, hydrogen bunkering is currently available only in a handful of ports worldwide (e.g., Antwerp-Bruges, Kobe, Singapore). Even in the EU, LNG bunkering infrastructure is concentrated in certain major hubs, leaving smaller ports reliant on truck delivery, which limits turnaround speed.
- **Supply chain constraints**: HVO production capacity, while growing in Northern Europe, remains insufficient for large-scale, year-round supply to all ports.

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Operators like Svitzer have had to coordinate with multiple suppliers to ensure consistent HVO availability for their UK fleet.

- **Compatibility issues**: Not all vessels are fitted for every fuel type, and retrofitting is often costly and complex.

High cost

- **Fuel price premiums**: Alternative fuels often cost significantly more than marine diesel oil (MDO). HVO can be 20–50% more expensive, while hydrogen and methanol can be up to 2–3 times more expensive, depending on market conditions.
- **Capex for new builds or retrofits**: Hybrid and hydrogen tugs involve substantial capital investment. The *Hydrotug 1* in Antwerp-Bruges, for instance, required both vessel development and hydrogen bunkering infrastructure—costs supported by public funding and private investment. Given the scale of investment required, consideration should be given to establishing dedicated funding mechanisms—through public grants, green finance, or port authority support—to accelerate the development of alternative-fuel tugs and pilot boats.
- **Operational expenses**: Maintenance for hybrid propulsion or fuel-cell systems can be higher due to complexity, and battery replacement cycles add to lifecycle cost.

Stakeholders impact

- **Pilots and tug masters**: Must adapt to operational scheduling based on fuel or charging availability, which can affect job readiness and service response times.
- **Terminal operators**: May face berth delays if fuel bunkering or charging conflicts with cargo operations.
- **Port authorities**: Need to balance sustainability targets with financial feasibility, often seeking grants or incentives to offset high initial costs.

Industry examples

- The Port of Los Angeles and Port of Long Beach have advanced clean-fuel tug projects but still face challenges scaling them due to infrastructure and cost constraints, relying on funding from the California Air Resources Board (CARB) to offset expenses.

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- In Norway, electric ferries have been highly successful due to government subsidies, but similar support is often missing for port service craft, slowing uptake in other countries.
- In Singapore, LNG bunkering capacity is robust, but hydrogen and ammonia projects are still in the demonstration stage, with full-scale adoption planned for the late 2020s.

Table 6 – Main challenges for uptake of alternative fuels in port service vessels

Challenge	Description	Example impact
Fuel availability	Limited bunkering/charging facilities in smaller ports; supply chain bottlenecks.	Tug must operate on diesel if HVO not available; delays in hydrogen trials.
High fuel cost	Alternative fuels priced above MDO; market volatility.	Increased operating costs for HVO-fueled fleets without subsidies.
Infrastructure investment	Need for bunkering stations, charging systems, safety upgrades.	Hydrotug 1 required new hydrogen bunkering system in Antwerp-Bruges.
Operational adaptation	Scheduling adjustments for fuel/charging availability; crew retraining.	Electric pilot boat requires downtime for charging during peak periods.

Source: Svitzer UK EcoTow programme (2023); Port of Antwerp-Bruges Hydrotug 1 project; Port of Los Angeles & Long Beach CAAP reports; Norwegian Maritime Authority e-ferry programme.

The environmental and operational benefits of cleaner fuels are clear, but without reliable availability and competitive pricing, large-scale adoption will remain slow. Successful implementation requires coordinated action: investment in port infrastructure, government incentives to offset costs, and stakeholder collaboration to adapt operations. For pilots, tug masters, and all port service providers, understanding these constraints is essential for realistic planning and advocating for solutions that enable a sustainable but practical transition.

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Chapter 3 Supporting material

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Shaping the Future of Port Operations

SESSION OBJECTIVES

- **Gain a clear understanding of how decarbonisation, technological innovations, and evolving client expectations are shaping modern port operations**.
- **Examine real-life scenarios** to see how these trends directly influence ship manoeuvring, tug assistance, and day-to-day operational decision-making.
- **Learn how emerging technologies and operational practices can be applied** to improve coordination, efficiency, and adaptability in port operations.
- **Discuss strategies** to maintain high safety standards, optimize operational efficiency, and reduce environmental impact through informed decision-making.

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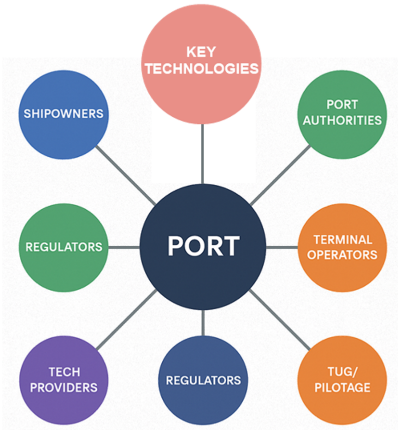
Industry ecosystem & technological landscape

RAPID TRANSFORMATION OF PORTS
Decarbonisation, technological innovation, evolving customer expectations.

ECOSYSTEM
Shipowners, charterers, terminal operators, port authorities, tug and pilotage companies, regulators, technology providers.

DIRECT IMPACT ON PILOTS AND TUG MASTERS
Safety, efficiency, environmental performance.

Key technologies: Onshore Power Supply (OPS), LNG/methanol/ammonia propulsion, ShaPoLi systems, emissions monitoring tools.



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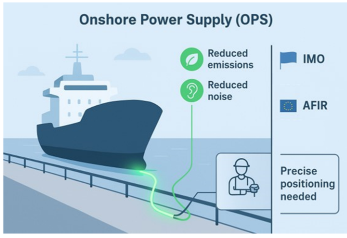
Onshore Power Supply (OPS)

OPERATIONAL IMPLICATIONS

- Requires highly accurate berthing to align vessels with onshore power connection points.
- Demands careful coordination between pilots, tug masters, mooring teams, and shore power technicians.

BENEFITS

- Significant reduction of CO_2, NO_x, SO_x, and particulate matter emissions.
- Quieter port environment, improving local air quality and community wellbeing.



REGULATORY CONTEXT

- **IMO**: Voluntary guidelines for shore power adoption.
- **EU (AFIR):** Mandatory implementation by 2030 for TEN-T core ports.

CONSEQUENCE

New operational routines and collaboration protocols are necessary to ensure safe, efficient, and compliant shore power usage.

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Alternative fuel vessels

LNG

- ❑ **Helps reduce greenhouse gas emissions and air pollutants.**
- ❑ **It requires cryogenic storage, careful handling, and the establishment of strict safety zones around vessels and infrastructure.**

METHANOL

- ❑ **Provides dual-fuel flexibility for engines, supporting smoother transition from conventional fuels.**
- ❑ **Its main challenges are toxicity and flammability, which demand rigorous safety measures.**

AMMONIA

- ❑ **Produces zero CO_2 emissions during use.**
- ❑ **It is highly toxic and corrosive, requiring specialized handling and equipment to ensure crew and environmental safety.**

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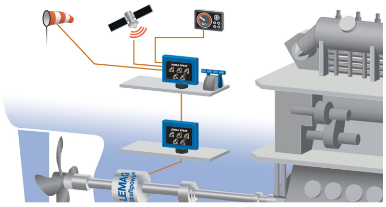
ShaPoLi systems

- **PURPOSE**: Limits or monitors maximum shaft output to ensure compliance with EEXI (Energy Efficiency Existing Ship Index) and CII (Carbon Intensity Indicator) regulations.
- **BENEFITS**:
  - ❑ Reduces fuel consumption and greenhouse gas emissions.
  - ❑ Provides improved operational data to support port planning and scheduling.
- **CHALLENGES**:
  - ❑ Slower engine responsiveness during critical manoeuvres.
  - ❑ Reduced availability of "engine kicks" for fine control.



- **OPERATIONAL IMPACT**: Early communication of power limitation data through pilot cards, VTS systems, and tug allocation planning to ensure safe and efficient port operations.

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Emission monitoring tools

- **Modern ports are increasingly adopting advanced monitoring solutions** such as EMSA drones, onboard systems, fixed quayside sensors, and networked detectors.
- These technologies generate real-time environmental data that can be shared among stakeholders **to improve both efficiency and compliance**.

BENEFITS FOR STAKEHOLDERS

- ❑ **Pilots** receive direct feedback on their manoeuvring choices, supporting safer and more fuel-efficient navigation.
- ❑ **Tug masters** can optimise power use, reducing unnecessary fuel burn and emissions.
- ❑ **Terminal operators** gain accurate data for berth scheduling, helping to avoid emission peaks during busy periods.
- ❑ **Port Authorities** can rely on evidence-based insights to ensure regulatory compliance and monitor overall environmental performance

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GREENPORT Alliances

Module number 3 | Industry ecosystem and technological landscape

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Chapter 3 Assessment Questions

1. **OPS (Onshore Power Supply) is increasingly used because:**
   A. It reduces voyage time by increasing vessel speeds
   B. It allows ships to switch off auxiliary engines at berth, cutting SOx, NOx, CO_2 and noise emissions
   C. It ensures compliance with MARPOL Annex I oil pollution rules
   D. It eliminates the need for tugboat assistance in berthing

2. **Which operational hazard is most associated with LNG-fuelled ships during port calls?**
   A. Cryogenic storage at −162°C and strict safety zoning
   B. Non-toxic vapours at ambient temperature
   C. Odourless leaks and simple handling procedures
   D. Complete immunity to combustion risks

3. **Which property makes methanol a distinct challenge in port operations?**
   A. Cryogenic temperature storage required
   B. High corrosiveness comparable to ammonia
   C. Toxic, flammable vapours heavier than air requiring ventilation protocols
   D. Harmless in case of minor spillage

4. **ShaPoLi systems are criticised in pilotage because:**
   A. They permanently disable engines
   B. They reduce acceleration/deceleration and eliminate short "engine kicks" required for tight manoeuvres
   C. They increase vessel speed in restricted waters
   D. They automatically override pilot orders

5. **Which European port requires advance notification of ShaPoLi/EPL systems before entry to manage risks?**
   A. Rotterdam
   B. Antwerp
   C. Southampton
   D. Barcelona

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Chapter 4: Operational strategies for energy saving and emission reduction

In the modern maritime industry, reducing fuel consumption and cutting emissions are no longer optional goals — they are operational necessities. Stricter international regulations, growing regional environmental requirements, and commercial pressures for efficiency are prompting ports and maritime service providers to adopt smarter, cleaner ways of working. For pilots, tug masters, pilot vessel crews, terminal operators, and port authorities, this shift requires rethinking established practices to achieve efficiencies without compromising navigational safety or operational reliability.

While advances in vessel design and the adoption of alternative fuels are important long-term drivers of decarbonization, operational strategies remain among the fastest and most cost-effective ways to deliver measurable results. Adjusting vessel speeds on approach, scheduling movements around favorable tides, optimizing tug deployment, and using real-time fuel and emissions data are examples of methods that can yield substantial savings. These are often referred to as "operational quick wins" because they typically require little to no new infrastructure and can be implemented using existing resources, provided there is effective planning, coordination, and stakeholder engagement.

The benefits extend beyond environmental gains. Lower fuel consumption reduces operating costs; improved efficiency can shorten turnaround times, ease port congestion, and enhance safety by reducing unnecessary vessel movements.

4.1. Techniques using existing resources

Energy saving and emission reduction in port operations do not always require new equipment or major investments. Many gains can be achieved by optimizing the use of existing resources – from adjusting vessel speed profiles to improving tug deployment and scheduling.

For pilots, tug masters, pilot vessel crews, terminal planners, and VTS personnel, this means utilizing current tools, procedures, and assets more efficiently to deliver measurable fuel and emission savings.

Main techniques

1. Eco-speed adjustments

- Reduce approach speed to the minimum necessary for safe control, avoiding "rush and wait" scenarios.
- Use existing VTS communications to align speed with berth readiness.

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2. Tug use optimization

- Select appropriate tug type and power for the job.
- Avoid prolonged idle time at the job site by coordinating pilot boarding and tug departure times.

3. Tidal window scheduling

- Plan movements to coincide with favorable currents, reducing propulsion and tug power demands.
- Use publicly available tide tables and port tidal forecasts.

4. Real-time monitoring

- Use existing engine monitoring systems and portable pilot units (PPUs) with fuel overlays.
- Apply emissions monitoring data from shore-based sensors or drones.

5. Behavioral change

- Brief shipmasters, tug crews, and mooring teams on energy goals before each operation.
- Reinforce efficient handling habits through post-job debriefs.

Industry examples

- Port of Rotterdam – Adjusting pilotage speed instructions based on berth readiness reduced average waiting times and cut unnecessary fuel burn.
- Port of Los Angeles & Port of Long Beach – Vessel Speed Reduction Program incentivizes slower steaming near port, reducing NO_x, SO_x, CO_2 and fuel costs.
- Port of Gothenburg – RoRo departures scheduled with favorable tides achieved up to 15% tug fuel savings.

Table 7 – Examples of energy saving using existing resources

Technique	Example port	Result
Eco-speed adjustments	Rotterdam	Less idle time; reduced approach fuel use
Tug use optimization	Antwerp-Bruges	Fewer high-power tug minutes

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Tidal window scheduling	Gothenburg	Up to 15% tug fuel saving
Real-time monitoring	Barcelona	Live feedback improved operational choices
Behavioral change	Los Angeles/Long Beach	Participation rate >90% in speed program

Source: Port Authority sustainability reports (2022–2023)

4.2. Eco speed steaming: benefits and implementation

Eco speed steaming is the practice of operating a vessel at the lowest safe and practicable speed for the prevailing conditions and operational requirements. While this approach is common in ocean passage planning, it is increasingly applied in port approaches, harbor transits, and pilotage waters to reduce fuel consumption, emissions, and operating costs.

For pilots, tug masters, pilot vessel crews, terminal planners, and VTS, eco speed steaming is a coordinated process – aligning the vessel's speed profile with berth readiness, tug availability, and other traffic movements to achieve environmental and operational efficiency without compromising navigational safety.

A good example of how ports can proactively encourage ships to slow down prior to crossing an ocean is The Ports of Los Angeles and Long Beach. They introduced a new queuing system in late 2021, where container vessels are assigned a berth slot based on their departure time from the previous port rather than when they arrive near the coast. This allows ships to "slow steam" across the Pacific, spreading them out at sea rather than congesting anchorages near shore—resulting in improved navigational safety and significantly better air quality by reducing idle time near populated areas (Schuler, 2021).

Principles

- Hydrodynamic resistance rises exponentially with speed; even small reductions in speed result in disproportionately large fuel savings.
- A 10% reduction in speed can deliver 10–30% lower fuel use, depending on vessel type and draught (CE Delft/Seas-at-Risk, 2019).
- Eco speed steaming also reduces engine wear, noise emissions, and risk of wake damage in confined waters.
- The objective is just-in-time (JIT) arrival — matching ETA to berth readiness so the vessel can proceed directly to berth without waiting at anchor or alongside.

Benefits of stakeholders

Stakeholder group	Benefits of eco speed steaming
Pilots	Smoother handling during approach; reduced need for last-minute speed changes
Tug masters	Easier and safer engagement; less idle or holding time awaiting the vessel
Pilot vessel crews	Safer, more fuel-efficient boarding operations; reduced high-speed runs
Terminal planners	Improved berth utilization and reduced congestion
VTS	Better traffic flow management and less anchorage congestion

Implementation steps

1. Pre-arrival planning

- Receive berth readiness updates from VTS or terminal.
- If the berth is unavailable, recommend a reduced speed early enough for the master to adjust the ETA.

2. Coordination with tugs and pilot vessel

- Set tug departure to match revised ETA.
- Adjust pilot vessel boarding run to a revised schedule.

3. Speed profile management

- Use PPUs to monitor SOG vs. ETA.
- Make incremental speed changes to optimize fuel use and arrival time.

4. Real-time monitoring and adjustment

- Monitor tides, currents, wind, and adjust target speed accordingly.
- Revise plan if berth availability changes, in coordination with VTS.

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Industry examples

1. **Port of Los Angeles & Port of Long Beach – Vessel Speed Reduction Program (VSRP)**
    - Ships slow to ≤12 knots within 20–40 nm of port for incentives.
    - In 2022: ~66 t DPM, ~749 t NO_x, ~575 t SO_x, and ~31,000 t CO_2 reduced.

2. **Port of Rotterdam – JIT Arrival Trials**
    - Coordinated reduced-speed approaches when berths were not ready.
    - Achieved ~8% fuel savings in the last 24 hours before entry.

3. **Port of Gothenburg – Green Steaming Study**
    - STM Validation Project showed up to ~34% savings when optimizing arrival to avoid anchoring.

Table 8 – Fuel and CO_2 savings from reduced approach speed

Speed (knots)	**Fuel per NM (kg)**	**Total fuel for last 12 NM (kg)**	**CO_2 emissions (kg)**
15	150	1,800	5,706
13	125	1,500	4,755
12	110	1,320	4,178

Source: Adapted from CE Delft/Seas-at-Risk (2019) and MARPOL Annex VI Guidelines

The data in Table 8 is illustrated in Figure 6, showing the steep, non-linear rise in fuel consumption with increased vessel speed. The visual illustrates how modest speed reductions during final approach can yield substantial fuel and CO_2 savings.

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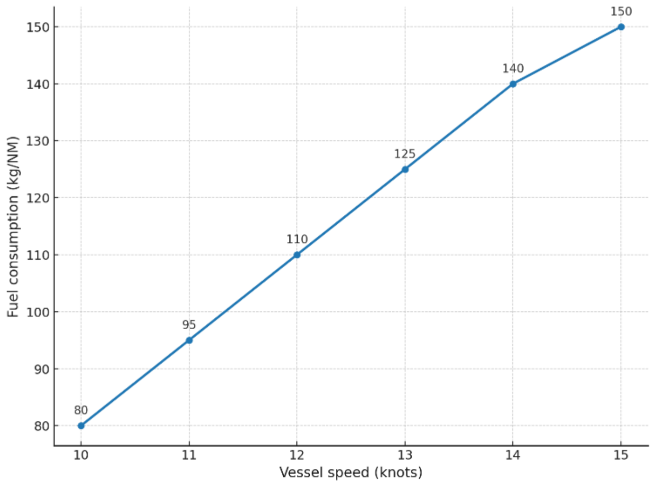

Figure 6 – Relationship between vessel speed and fuel consumption
Source: CE Delft/Seas-at-Risk, 2019

Behavioral change focus

- Pilots: Shift from "arrive early" to "arrive at optimal speed" planning.
- Tug masters: Match tug rendezvous to eco-speed arrival, avoiding idle holding.
- Pilot vessel crews: Align boarding runs with optimized arrival times.
- Terminal planners: Enable berth scheduling flexibility.
- VTS: Provide traffic sequencing to maintain optimal speed flow.

Table 9 – Summary of eco speed steaming benefits

Stakeholder group	Operational change	Expected benefit
Pilots	Adjust approach speed to match the berth	Reduced fuel/emissions; improved safety
Tug masters	Coordinate tug rendezvous with eco-speed	Lower tug fuel burn; less idle time
Pilot vessel crews	Plan efficient boarding runs	Reduced fuel use; safer transfers
Terminal planners	Align berth readiness with ETA	Minimize vessel idle time
VTS	Sequence arrivals to support eco-speed	Reduced congestion; improved flow

Source: Compiled from POLA/POLB (2023), Port of Rotterdam (2023), STM Gothenburg (2014).

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4.3. Scheduling with tidal windows to optimize fuel use

Tidal conditions influence vessel handling, fuel consumption, and emissions during port approaches, berthing, and unberthing. Scheduling ship movements to coincide with favorable tidal windows can significantly reduce propulsion demands, especially for large or heavily loaded vessels.

For pilots, tug masters, pilot vessel crews, terminal planners, and VTS, this practice requires proactive coordination and real-time communication. By harnessing tidal currents and optimal water depths, port operations can achieve measurable efficiency gains without compromising safety.

Principles

- Favorable tidal current: Assists the vessel's propulsion, reducing engine load.
- Slack water: Minimizes hydrodynamic forces on the hull, allowing more precise maneuvering. Precise maneuvering is with the current from ahead.
- Adverse tidal current: Increases fuel demand and tug assistance needs.
- Tidal height: May provide necessary under-keel clearance in shallow approach channels or berths.

Benefits for stakeholders

Stakeholder group	Benefits of tidal window scheduling
Pilots	Shorter duration of pilotage due to favorable current from the stern
Tug masters	There is potential for lower bollard pull requirements when currents are favourable; however, manoeuvres like large vessel swings may still require the full power of the tug or even higher.
Pilot vessel crews	Reduced high-speed running and improved safety
Terminal planners	Optimized berth utilization
VTS	Smoother traffic flow and reduced congestion

Implementation steps

1. **Tide data analysis**
    - Review tide tables, current forecasts, and local tidal patterns.
    - Identify windows where currents or water depth align with vessel needs.

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2. Movement planning

- Integrate tidal data into pilotage schedules and tug dispatch plans.
- Adjust ETAs/ETDs to match optimal tidal conditions where feasible.

3. Multi-stakeholder coordination

- Pilots, tug masters, and terminal planners agree on target windows.
- VTS sequences vessel movements accordingly.

4. Real-time adjustments

- Monitor live tidal/current data and adapt movement plans if conditions change.

Industry examples

1. Port of London

- Large deep-draft vessels scheduled to berth/unberth on high water to ensure under-keel clearance.
- Reduces the need for high engine loads during maneuvers.

2. Port of Gothenburg

- RoRo departures aligned with ebb tide reduced tug fuel burn by up to 15%.

3. Port of Brisbane

- Bulk carriers departing on the flood tide to minimize time in shallow approach channels.

Table 10 – Effect of tidal current on fuel use during harbor transit

Current condition	**Transit distance (nm)**	**Average SOG (kn)**	**Fuel used (kg)**	**CO_2 emitted (kg)**
Favorable 2 kn	6	10	660	2,092

Slack water	6	8	800	2,536
Adverse 2 kn	6	6	1,050	3,329

Source: Adapted from MARPOL Annex VI emission factors and pilotage fuel studies (Port of London Authority, 2023)

The data in Table 10 are visualized in Figure 7, which clearly shows the substantial increase in fuel use when maneuvering against an adverse current and the savings possible with a favorable tide.

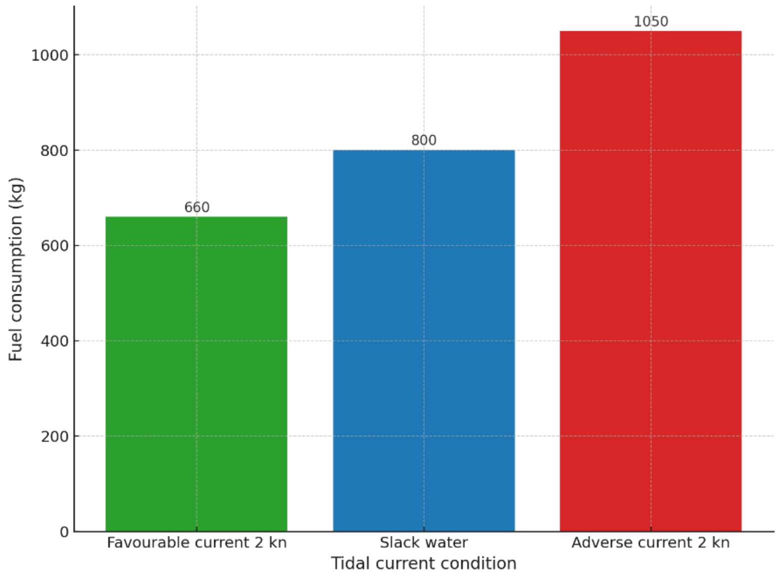

Figure 7 – Influence of tidal current on fuel consumption
Source: Adapted from Port of London Authority and Port of Brisbane pilotage data, 2023

Behavioral change focus

- Pilots: Incorporate tidal optimization into standard passage planning.
- Tug masters: Optimise bollard pull deployment by aligning tug use with favourable tidal conditions, while ensuring safety in strong current manoeuvres.
- Pilot vessel crews: Avoid high-speed runs against strong currents.
- Terminal planners: Build flexibility into berth schedules.
- VTS: Provide timely tidal/current updates to all operational stakeholders.

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Table 11 – Summary of tidal window scheduling benefits

Stakeholder group	**Operational change**	**Expected benefit**
Pilots	Plan for a favorable tide	More efficient maneuvers
Tug masters	Align tug use with tide	Reduced fuel/emissions
Pilot vessel crews	Schedule for slack/favourable tide	Safer, lower fuel boarding
Terminal planners	Match cargo readiness to tide	Avoid delays and idle time
VTS	Sequence to optimise tidal use	Better traffic flow

Source: Compiled from Port of London Authority (2023), Port of Gothenburg (2022), Maritime Safety Queensland (2023)

4.4. Real-time fuel consumption visualization for port service craft

Real-time fuel consumption visualization involves collecting and displaying fuel use data from port service craft, such as tugs, pilot boats, and other harbor vessels, during operations. This data can be shown directly to operators, pilots, VTS, and port management, enabling them to monitor efficiency, identify waste, and make immediate adjustments.

For tug masters, pilot vessel crews, terminal planners, and VTS, the ability to see live fuel data transforms decision-making from reactive to proactive, supporting more efficient power use, optimized maneuvers, and reduced emissions.

Principles

- Data capture: Sensors measure fuel flow, engine load, and RPM in real time.
- Data display: Information is presented on onboard displays or shore dashboards.
- Decision support: Crews can adjust operations on the spot based on live feedback.
- Performance analysis: Data can be stored for post-operation review to improve future performance.

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Benefits for stakeholders

Stakeholder group	Benefits of real-time fuel visualization
Pilots	Adjust approach speed and tug use for optimal efficiency
Tug masters	Fine-tune power application to meet needs without overuse
Pilot vessel crews	Maintain safe, efficient cruising speeds
Terminal planners	Assign low-consumption craft to sensitive areas
VTS	Monitor and guide traffic with fuel efficiency in mind

Implementation steps

1. **Install monitoring equipment**
   - Flow meters, engine control system interfaces, and data loggers on service craft.
2. **Integrate with displays**
   - Onboard displays for crews; PPUs for pilots; dashboards for port control.
3. **Train crews**
   - Ensure all operators understand the metrics and how to act on them.
4. **Link to performance reviews**
   - Use logged data for monthly/quarterly operational efficiency reports.

Industry examples

1. **Port of Los Angeles – Tug monitoring trial**
   - Tugs fitted with live fuel meters reduced average fuel use by 8% after crews adjusted throttle use.

2. **Port of Gothenburg – Emissions dashboard**
   - Centralized system showing live data from tugs, pilot boats, and visiting vessels.
   - Pilots use data to adjust speed profiles in real time.

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3. Port of Barcelona – EMSA drone-assisted checks

- Drones monitor exhaust plumes; results fed into compliance dashboards to support operational adjustments.

Table 12 – Example of tug fuel use before and after real-time feedback

Tug operational profile	Avg. fuel use (l/h)	CO_2 emissions (kg/h)
Before monitoring adjustments	550	1,749
After monitoring adjustments	505	1,604

Source: Port of Los Angeles tug fuel study, 2023

The figures in Table 12 are presented in Figure 8, highlighting the visible drop in fuel consumption after implementing real-time visualization and feedback.

Figure 8 – Tug fuel use before and after real-time monitoring
Source: Port of Los Angeles tug fuel study, 2023

Behavioral change focus

- Pilots: Incorporate live fuel data into maneuver planning.
- Tug masters: Actively adjust throttle to match operational demand.
- Pilot vessel crews: Avoid unnecessary high-speed runs by monitoring real-time use.
- Terminal planners: Use data to assign the most efficient craft for each job.
- VTS: Factor fuel efficiency into traffic sequencing decisions.

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4.5. Encouraging behavioral change through data-driven feedback

Technology and data can only deliver fuel and emissions savings if they are accompanied by behavioral change. In the context of port operations, behavioral change refers to the consistent adoption of operational practices that prioritize efficiency and environmental performance without compromising safety.

For pilots, tug masters, pilot vessel crews, terminal planners, and VTS, data-driven feedback is a proven way to influence behavior. When stakeholders can see the direct results of their actions — in terms of fuel use, emissions, time saved, and operational efficiency — they are more likely to adopt and sustain improved practices.

Principles

- Visibility: Operators need to see how their actions affect performance in real time and in post-operation reports.
- Relevance: Data must be directly linked to actions the operator can control.
- Timeliness: Feedback is most effective when given promptly after the event.
- Positive reinforcement: Highlighting improvements motivates continued adherence to best practices.

Benefits of stakeholders

Stakeholder group	**Benefits of data-driven feedback**
Pilots	Align approach/tug plans with efficiency goals
Tug masters	Fine-tune power use for minimal fuel burn
Pilot vessel crews	Adjust cruising speeds for efficiency
Terminal planners	Plan operations to avoid vessel idle time
VTS	Sequence traffic to maintain optimal speed flow

Implementation steps

1. **Define performance metrics**
    - Fuel consumption, $CO_2/NO_x/SO_x$ emissions, average speeds, tug idle time.

2. **Collect data**
    - Use onboard monitoring, PPUs, shore sensors, and operational logs.

3. Provide targeted feedback

- Post-operation reports, performance dashboards, or debrief sessions.

4. Recognize achievements

- Publicly acknowledge crews or teams that achieve efficiency gains.

Industry examples

1. Port of Los Angeles – Green Dock Program

- Incentivizes vessel operators who meet specific efficiency targets, with public recognition for high performers.

2. Port of Rotterdam – Fuel efficiency reports

- Pilots receive post-job reports showing speed profiles and fuel use, linked to operational decisions.

3. Svitzer – Tug fuel performance program

- Tug masters receive monthly reports comparing fuel use across similar jobs, fostering peer learning.

Table 13 – Example of tug fuel performance feedback report

Tug name	Avg. fuel use/job (litres)	Previous month (litres)	Change (%)	Comments
Tug A	450	480	-6.3	Improved throttle control
Tug B	500	495	+1.0	Strong winds increased load
Tug C	470	470	0.0	No change

Source: Adapted from Svitzer internal reporting template, 2022

The sample in Table 13 can be visualized as Figure 9 making it easier to compare performance quickly between reporting periods and identify trends.

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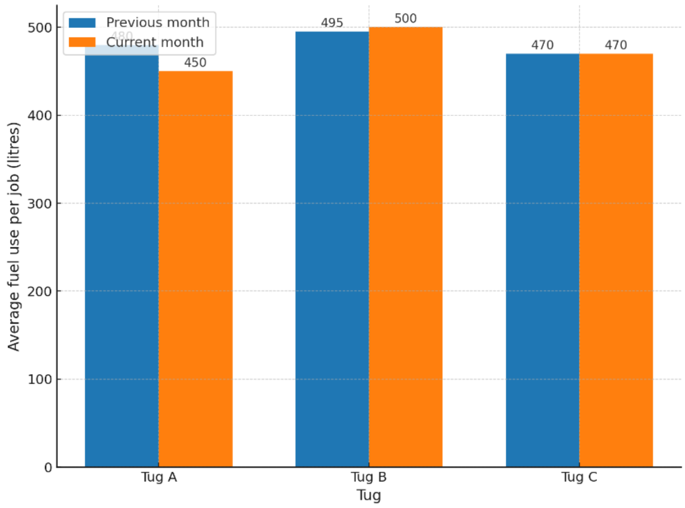

Figure 9 – Tug average fuel use per job, current vs. previous month

Source: Adapted from Svitzer internal reporting template, 2022

Behavioral change focus

- Pilots: Use fuel and speed profile reports to adjust planning for similar future jobs.
- Tug masters: Aim to consistently reduce throttle peaks while meeting manoeuvring requirements.
- Pilot vessel crews: Maintain optimal cruising speeds between jobs.
- Terminal planners: Adjust berth planning to support efficient movement flows.
- VTS: Use data to identify where sequencing changes could improve fuel performance.

4.6. Tug energy saving, before and after a job

Tug operations are among the most fuel-intensive activities in port. Fuel is consumed not only during direct assistance (pushing, pulling, escorting) but also during transit to/from the job and idle/standby time. Significant energy savings can be achieved by focusing on both pre-job preparation and post-job return, without compromising safety.

For pilots, tug masters, pilot vessel crews, terminal planners, and VTS, this requires careful coordination so that tugs arrive exactly when needed, operate at the most efficient power settings during the job, and return without unnecessary detours or idle time.

Principles

- **Before the job**:
    - Synchronize tug departure from the station with the pilot's boarding ETA to prevent waiting under power.
    - Choose the most efficient tug for the job (bollard pull and location).
    - Plan approach to the assisted vessel to minimize high-RPM maneuvers before contact.

- **During the job**:
    - Use intermittent thrust or drift assist where safe, instead of continuous high bollard pull.
    - Communicate with the pilot to anticipate power changes, avoiding unnecessary throttle adjustments
    - Ensure optimal tow line length to maximize energy efficiency. The length is to be agreed with the pilot.

- **After the job**:
    - Depart at eco-speed back to the station.
    - Avoid unnecessary loitering near berths or in fairways.
    - Shut down auxiliary engines not needed for immediate readiness.

Benefits of stakeholders

Stakeholder group	Benefit of optimized before/after job actions
Pilots	Reduce tug idle time while awaiting vessel
Tug masters	Lower total fuel use per job; less wear on engines
Pilot vessel crews	More predictable tug engagement times
Terminal planners	Better tug availability for subsequent jobs
VTS	Reduced traffic congestion and fuel waste in port fairways

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Industry examples

1. Port of Rotterdam – Central tug dispatch

- A scheduling platform synchronizes tug departure with pilot boarding, reducing average tug idle time at vessel by 15%.

2. Svitzer – EcoTow SOPs

- Hybrid tugs prioritized for jobs near base; power modes adjusted before and after contact.

3. Port of Antwerp-Bruges – Hydrogen tug operations

- "Hydrotug 1" runs in zero-emission mode during low-load phases (before and after maneuver).

Table 14 – Example tug fuel use before, during, and after a job

Phase of operation	Avg. fuel use (l/h)	Duration (min)	Fuel consumed (litres)	CO_2 emitted (kg)
Transit to job	250	10	41.7	133
Standby/idle	150	5	12.5	40
Active assist	1,000	20	333.3	1,060
Return to base	250	10	41.7	133

Source: Adapted from IMO GHG Study (2020) and industry tug fuel audits

The distribution of fuel consumption in Table 14 is illustrated in Figure 10, showing the large share consumed during the active assist phase, as well as the notable contributions from the before- and after-job phases that can be optimized.

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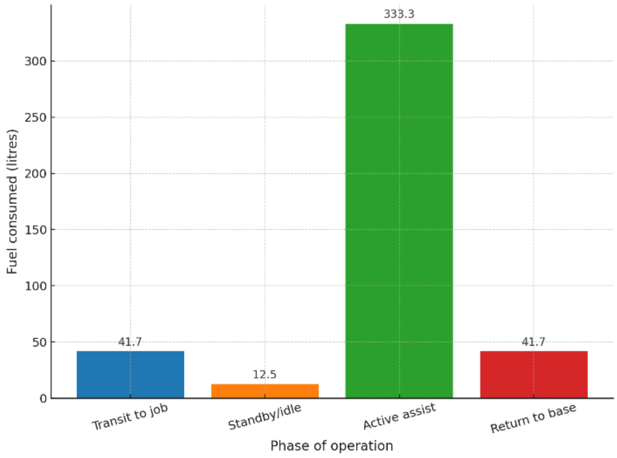

Figure 10 – Tug fuel use by job phase
Source: Adapted from IMO GHG Study (2020) and industry tug fuel audits

Behavioral change focus

- Pilots: Coordinate pilot boarding and tug departure times to minimize pre-job idle.
- Tug masters: Optimize transit and return speeds; avoid overpowering before or after contact.
- Pilot vessel crews: Provide precise boarding ETAs to reduce tug waiting.
- Terminal planners: Sequence tug jobs to limit repositioning runs.
- VTS: Provide early traffic and berth clearance updates to support efficiency.

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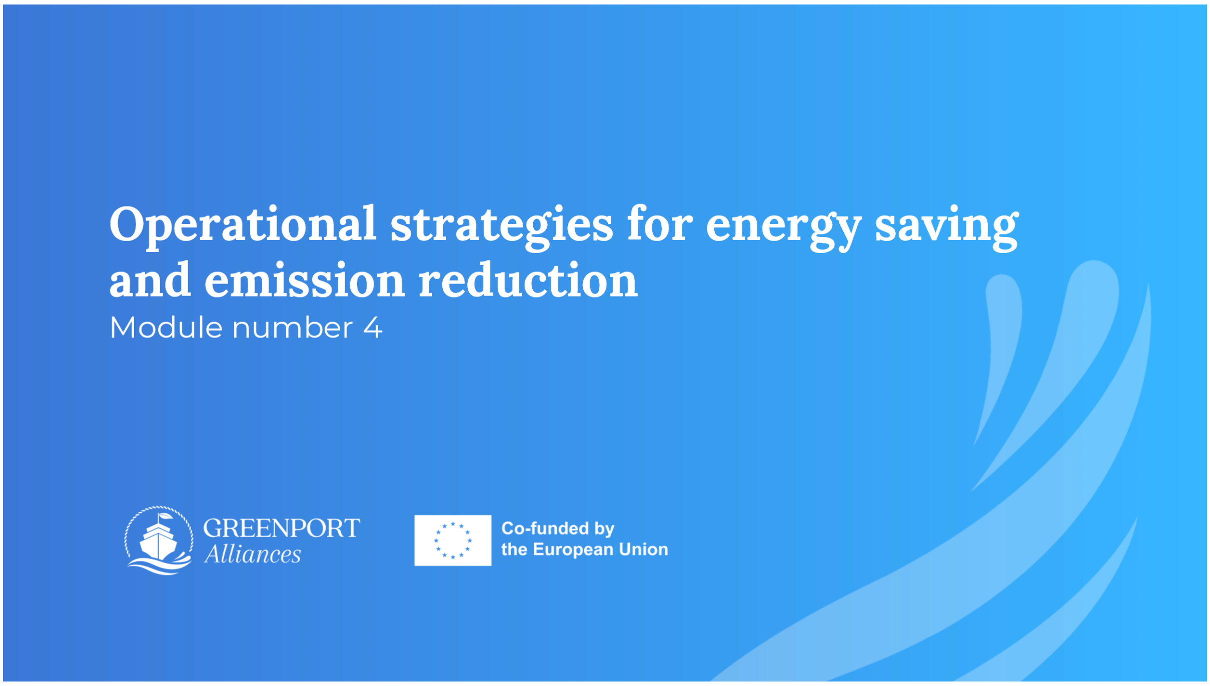
Chapter 4 Supporting material



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Operational strategies for energy saving and emission reduction in ports

SESSION OBJECTIVES

- **Analysis of established operational strategies** aimed at optimizing energy consumption and reducing emissions, with a focus on practical and measurable solutions.
- **Practical application in port operations**, taking into account daily challenges and the typical operational variables of ports.
- **A multi-stakeholder approach** that promotes coordination among ships, pilotage services, tug operators, terminal planners, and port authorities.
- **Real-world cases and concrete data** to demonstrate the tangible benefits of the strategies implemented.
- **Scenario-based exercises** that allow participants to apply the strategies in realistic port conditions

Techniques using existing resources

OPERATIONAL STRATEGIES FOR ENERGY EFFICIENCY AND EMISSION REDUCTION

Eco-speed: adjust approach speed based on berth availability.

Optimised tug deployment: use the right tug, minimise idle time.

Tidal windows: schedule movements with favourable currents.

Real-time monitoring: PPUs, sensors, drones.

Behavioural change: pre-briefings and debriefings for crews.

TECHNIQUE	EXAMPLE PORT	RESULT
Eco-speed adjustments	Rotterdam	Less idle time; reduced approach fuel use
Tug use optimisation	Antwerp-Bruges	Fewer high-power tug minutes
Tidal window scheduling	Gothenburg	Up to 15% tug fuel saving
Real-time monitoring	Barcelona	Live feedback improved operational choices
Behavioural change	Los Angeles/Long Beach	Participation rate >90% in speed program

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GREENPORT Alliances
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Eco-speed steaming

SAFE MINIMUM SPEED STRATEGY

Concept: Maintaining a safe minimum speed during approach and transit can lead to 10–30% fuel savings.

Benefits: Enables smoother manoeuvres, reduces idle time, and helps alleviate port congestion.

Real-World examples: Successfully implemented in major ports such as Los Angeles/Long Beach, Rotterdam, and Gothenburg.

Key Principle: Align vessel arrival with berth availability through Just-in-Time (JIT) Arrival.

STEKEHOLDER GROUP	BENEFITS OF ECO SPEED STEAMING
Pilots	• Smoother handling during approach. • Reduced need for last-minute speed changes.
Tug masters	• Easier and safer engagement. • Less idle or holding time awaiting vessel.
Pilot vessel crews	• Safer, more fuel-efficient boarding operations. • Reduced high-speed runs.
Terminal planners	• Improved berth utilisation and reduced congestion.
VTS	• Better traffic flow management and less anchorage congestion.

GREENPORT Alliances
Co-funded by the European Union

Scheduling with tidal windows

Tidal conditions strongly affect **fuel use, emissions, and manoeuvring safety** during approaches, berthing, and unberthing.

By aligning ship movements with **favourable tidal windows**, ports can reduce propulsion demands and achieve safer, more efficient operations.

PRINCIPLES

Favourable currents → assist propulsion, cut fuel use.

Slack water → precise manoeuvring, safer pilot boarding.

Adverse currents → higher fuel demand, greater tug support.

Tidal height → ensures under-keel clearance.

STAKEHOLDER GROUP	BENEFITS OF TIDAL WINDOW SCHEDULING
Pilots	Shorter duration of pilotage due to favourable current from the stern.
Tug masters	There is potential for lower bollard pull requirements when currents are favourable
Pilot vessel crews	Reduced high-speed running and improved safety
Terminal planners	Optimised berth utilisation
VTS	Smoother traffic flow and reduced congestion

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GREENPORT Alliances
Co-funded by the European Union

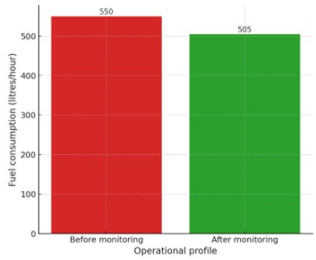
Real-time fuel consumption visualisation

A system for **live monitoring of fuel consumption** across tugs, pilot boats, and other harbour craft.

Data is continuously collected and presented in real time, allowing **crews, pilots, VTS operators, and port managers** to make informed decisions immediately, rather than waiting for post-operation reports.

HOW IT WORKS

- **Data capture**: Sensors measure fuel flow, engine load, and RPM in real time.
- **Data display**: Information is visualised on onboard screens for crews and on shore dashboards for managers.
- **Decision support**: Crews receive actionable insights to adjust speed, power, and manoeuvres instantly.
- **Performance analysis**: Historical data supports post-job reviews to identify efficiency improvements and optimise fuel use over time.



GREENPORT Alliances
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Encouraging behavioural change through data-driven feedback

Leveraging data to drive behavioural change is key to achieving lasting fuel efficiency and emissions reduction.

- Data alone cannot reduce fuel use and emissions; **behavioural change is essential**.
- Operators adopt efficient practices when they **see the impact of their actions**.
- Feedback must be **visible, relevant, timely, and positively reinforced**.
- Stakeholders benefit by **aligning operations, optimizing fuel, adjusting speeds, reducing idle time, and improving traffic flow**.
- Implementation involves **defining metrics, collecting data, providing feedback, and recognising achievements**.

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GREENPORT Alliances
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Tug energy saving, before and after a job

Tug operations are highly fuel-intensive, not only during active assistance but also in transit and idle time.

Significant savings possible by optimising pre-job preparation and post-job return.

BEFORE THE JOB

- Synchronise tug departure with pilot boarding ETA
- Select the most efficient tug (bollard pull & location)
- Plan approach to minimise high -RPM manoeuvres.

DURING THE JOB

- Use intermittent thrust/drift assist where safe
- Coordinate with pilot to avoid unnecessary power changes
- Optimise towline length

AFTER THE JOB

- Depart at eco-speed back to the station.
- Avoid unnecessary loitering near the berth or in fairways.
- Shut down auxiliary engines not needed for immediate readiness

GREENPORT Alliances

Module number 4 | Operational strategies for energy saving and emission reduction

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Chapter 4 Assessment Questions

1. **Eco-speed steaming is effective because:**
   A. It increases cargo turnover
   B. It reduces crew workload
   C. Small reductions in vessel speed lead to disproportionately large fuel and CO_2 *savings*
   D. It eliminates the need for tug assistance
2. **Tidal scheduling can deliver energy efficiency primarily by:**
   A. Reducing cargo handling times
   B. Increasing speed against adverse currents
   C. Aligning departures with favourable currents and sufficient under-keel clearance
   D. Avoiding OPS connection delays

3. **Real-time fuel monitoring benefits tug masters by:**
   A. Showing historic averages of bunkering
   B. Allowing immediate throttle adjustments to avoid unnecessary overuse of power
   C. Reducing maintenance costs only
   D. Enabling replacement of VTS services

4. **Which is an example of "before and after job" energy savings for tugs?**
   A. Running auxiliaries continuously
   B. Departing earlier than required
   C. Synchronising tug departure with pilot boarding ETA
   D. Using maximum bollard pull before making fast

5. **Behavioural feedback systems in ports are most effective when:**
   A. Reports are delivered annually
   B. Operators receive timely, job-specific data linking their choices to fuel and emissions outcomes
   C. Only aggregated fleet reports are shared
   D. Crews rely solely on simulator exercises

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Chapter 5: Communication and stakeholder engagement

In sustainable port operations, communication is more than a procedural requirement – it is the mechanism that enables coordination, safety, and efficiency among multiple stakeholders. Digital platforms, such as port management software or port community systems, enable all parties—pilots, tug masters, port authorities, terminal operators, and technology providers—to access and update real-time operational data, resulting in better planning, improved efficiency, and reduced environmental impact.

Clear, timely, and targeted communication ensures that operational goals are understood, responsibilities are coordinated, and environmental objectives are integrated into everyday decision-making. This is particularly important in the context of green port strategies, where operational changes, such as eco-speed steaming, optimized tug deployment, or coordinated berthing, require rapid information exchange and collaborative decision-making among multiple actors.

Modern maritime operations also introduce new tools, such as Portable Pilot Units (PPUs), collaborative platforms, and Augmented Reality (AR), that support situational awareness and planning. However, these tools must be thoughtfully integrated to recognize their limitations and vulnerabilities, including cyber threats, GNSS spoofing, and jamming.

This session will explore the roles of various stakeholders in sustainable port operations, the behavioural aspects of change management, planning and information exchange techniques, experiential exercises to reinforce communication skills, and the safe integration of digital aids in stakeholder engagement strategies.

5.1 Roles of various stakeholders in sustainable port operations

Sustainable ports' operations depend on many people and organizations working together. Each stakeholder has a specific role, and smooth communication between them is essential for both safety and environmental performance.

When all parties know their responsibilities and share the right information at the right time, operations can be smoother, safer, and more fuel-efficient. This is especially important when applying eco-navigation techniques, just-in-time (JIT) arrivals, and energy-saving tug operations.

5.1.1 Main stakeholder groups

Table 15 shows the main groups involved in port operations and their key sustainability responsibilities.

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Table 15 – Key stakeholders and their roles in sustainable port operations

Stakeholder group	Typical representatives	Main role in sustainability
Pilotage services	Pilots, pilot organizations	Plan safe approach speeds; promote eco-navigation; coordinate arrival timing
Towage providers	Tug masters, dispatchers	Use the right tug power; avoid idle running; optimize operations before and after jobs
Pilot boat services	Coxswains, crew	Conduct safe, fuel-efficient transfers; avoid unnecessary high-speed runs
Vessel Traffic Service (VTS)	VTS officers, schedulers	Sequence ship movements; share tide/current information; monitor berth readiness
Terminal operations	Berth planners, supervisors	Communicate berth availability; ensure cargo readiness; reduce delays
Ship operators	Master, bridge team, owners	Follow speed limits; manage engine power; share fuel/emissions data
Port authority/environmental office	Harbour master, environmental staff	Monitor emissions; ensure compliance; promote green port policies

Source: Adapted from IMO (2003), IMO (2014), EcoPorts (2024), IAPH (2024)

5.1.2 Responsibilities during a port call

Each stakeholder has specific tasks at different stages of a port call. If these are not coordinated, fuel and time may be wasted. Table 16 gives an example of who is responsible (R), accountable (A), consulted (C), or informed (I) for common sustainability-related tasks.

Table 16 – Responsibilities for sustainability-related port tasks

Task/phase	Pilotage	Towage	Pilot boat	VTS	Terminal	Ship	Environmental office
Pre-arrival speed advice	R/A	C	C	A	C	R	I
Tidal-window planning	R	R	C	A	C	C	I

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Tug dispatch	C	R/A	I	C	C	I	I
Berth readiness updates	I	I	I	C	R/A	I	I
Approach speed adjustment	R	C	C	C	I	R	I
Fuel/emissions data collection	C	R	R	I	I	R	A
Post-job debrief	R	R	R	C	C	C	I

Source: Adapted from IMO Model Course 4.05 and industry practice

Table 16 utilises the RACI framework to illustrate which stakeholders are involved in each sustainability-related task during a port call and in what capacity. This helps clarify roles, avoid duplication, and ensure that no important task is left unmanaged.

RACI

- **R – Responsible**: The person or group that performs the task. They are directly involved in completing the work.
- **A – Accountable**: The person or group ultimately answerable for the result. They have decision-making authority and are responsible for sign-off.
- **C – Consulted**: Those who provide information or advice to support the task. Communication is two-way.
- **I – Informed**: Those who need to be kept updated on the task's progress or completion. Communication is one-way.

How to read the table

- The rows display key operational tasks that impact fuel efficiency and emissions, such as pre-arrival speed advice, tidal window planning, or emissions data collection.
- The columns list stakeholder groups (e.g., Pilotage, Towage, VTS, Terminal, Ship, Environmental office).
- The letters in each cell indicate the stakeholder's role for that specific task. For example:
    - In "Pre-arrival speed advice," Pilotage is both Responsible and Accountable (R/A) — they plan and authorise the advice — while VTS is Accountable (A) for providing accurate traffic data, and the Ship is Responsible (R) for following the agreed plan.

- In "Fuel/emissions data collection," the Environmental office is Accountable (A) for reporting and compliance, while the Ship, Towage, and Pilot boat services are Responsible (R) for gathering the actual data.

5.1.3 Essential information to be shared

To make operations efficient and reduce emissions, certain key messages must be exchanged at specific times. Table 17 presents the most significant "checkpoints" for effective communication.

Table 17 – Key communication checkpoints and messages

Checkpoint	**Sender → Receiver(s)**	**Key message**	**Effect on sustainability**
12 hours before arrival	Terminal / VTS → Pilot / Ship	Berth window; cargo readiness	Avoids anchoring and extra manoeuvring
3 hours before arrival	Pilot → Ship / Tug / VTS	Updated speed plan	Reduces approach fuel use
60 minutes before pilot boarding	Pilot boat → Pilot / Tug	Boarding time and location	Prevents high-speed runs
Tug rendezvous	Towage → Pilot / Ship	Tug ETA, type, and power	Minimises idle time
Alongside	Pilot / Towage → Terminal	Arrival time and tug use	Feeds fuel/emissions reporting
After job	Pilot / Towage → All	Lessons learned	Improves future behaviour

Source: Adapted from Port of Rotterdam (2023) and POLA/POLB programs

5.1.4 Common problems and quick solutions

Table 18 – Common problems and quick solutions

Problem	**Impact**	**Quick solution**
Late berth updates	"Rush and wait" situations	Mandatory updates 12h and 3h before arrival
Overpowered tug allocation	High fuel burn	Match tug power to job needs

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Unplanned high-speed pilot transfers	Extra fuel, safety risk	Align boarding with JIT arrival
No access to fuel/emissions data	Poor behaviour change	Use live dashboards and post-job reports

Table 18 shows how small communication gaps or poor coordination can quickly undermine both efficiency and environmental objectives. For example, late berth updates often lead to "rush and wait" situations where vessels speed up unnecessarily, only to wait at anchor or alongside. This wastes fuel and increases emissions. We can avoid such inefficiencies by enforcing mandatory updates 12 hours and 3 hours before arrival. All parties, including the terminal and the ship, must make these updates.

Similarly, overpowered tug allocation may not seem problematic at first, but high bollard pull settings consume significantly more fuel than required for the job. Matching tug power to the actual operational need prevents unnecessary engine load and reduces greenhouse gas emissions. Unplanned high-speed pilot transfers are another common issue — they not only increase fuel use but also create additional safety risks. Aligning pilot boarding with just-in-time (JIT) arrival schedules can minimize these runs.

Finally, lack of access to fuel and emissions data prevents crews and planners from seeing the direct impact of their actions. Live dashboards, combined with post-job reports, provide stakeholders with real-time feedback and help establish lasting behavioral changes.

In all these cases, proactive communication and timely information exchange are central to the solution. By addressing these problems systematically, port stakeholders can improve operational performance while also meeting environmental sustainability targets.

5.1.5 Stakeholders' information flow

The figure below illustrates the information flow between key stakeholders during the different stages of a typical port call, highlighting the messages that support both safe navigation and sustainable operations.

The circular layout places all stakeholder groups—Pilotage, Towage, Pilot Boat, Vessel Traffic Service (VTS), Terminal, Ship, and Environmental Office—around the

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perimeter, indicating that no single actor is always central. Communication lines (arrows) indicate the direction of the information exchange, while the labels on each arrow summarise the critical messages shared.

During the pre-arrival stage, terminals and VTS provide pilots with key information, including berth availability, cargo readiness, traffic conditions, and tidal forecasts. Based on this input, the pilot determines the optimal boarding time and communicates it to the ship. The vessel can then adjust its speed, accordingly, supporting just-in-time (JIT) arrival and reducing unnecessary fuel consumption."

During the approach stage, the pilot boat confirms boarding time and location with the pilot, and towage services communicate tug estimated time of arrival (ETA) and type. VTS may update the ship directly on traffic sequencing.

At the alongside stage, pilots and towage providers share arrival time and tug usage information with the terminal. Pilots also send fuel and emissions data to the environmental office, enabling monitoring and compliance reporting.

In the post-job stage, the pilot debriefs towage services with operational findings, towage shares lessons learnt with pilot boat crews, and the pilot provides feedback to the ship's bridge team.

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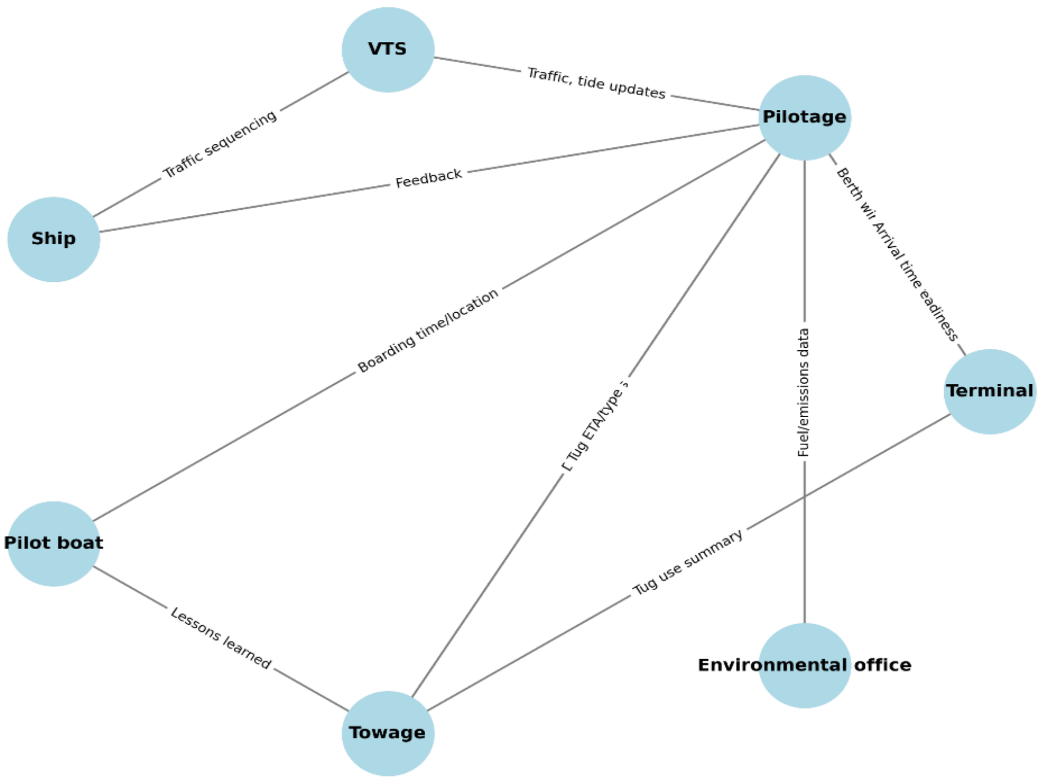

Figure 11 – Example of stakeholder information flow during a port call

By structuring communications in this way, the diagram emphasises that sustainability benefits come from timely, targeted exchanges: fewer idle periods for tugs, optimised approach speeds, reduced high-speed pilot transfers, and better use of fuel and emissions data. Clear communication loops not only improve operational efficiency but also reinforce behavioural change across all parties involved in port operations.

5.2 Behavioural change: the role of training, leadership, and peer influence

Behavioural change is a critical factor in achieving sustainable port operations. Even with advanced technology, fuel-saving strategies and environmental policies will only succeed if people change their operating habits.

Training, strong leadership, and peer influence are three powerful tools for promoting these changes. Together, they can create a culture where efficient and eco-friendly practices become routine rather than exceptions.

5.2.1 Why behavioural change matters

Small, consistent adjustments in operational behaviour—such as reducing approach speeds, optimising tug use, or aligning boarding schedules—can significantly cut fuel consumption and emissions. These changes are often cost-neutral but require awareness, motivation, and reinforcement.

5.2.2 Role of training

Training builds the knowledge and skills needed to apply sustainable practices safely. It ensures that crews understand both how to perform specific actions and why they are important.

- Formal courses – provide theory, regulations, and case studies.
- Simulator exercises – allow safe practice of eco-navigation and energy-saving manoeuvres.
- On-the-job mentoring – reinforces correct practices in real situations.

Table 19 – Training methods for promoting sustainable behaviours

Method	**Example activity**	**Sustainability benefit**
Classroom course	Emission reduction workshop	Increases awareness of environmental impact
Simulator training	Tug coordination in tidal windows	Reduces fuel by optimising timing
Peer-to-peer mentoring	Tug master showing throttle control techniques	Builds practical habits

Source: Adapted from IMO Model Course 4.05 and industry training programs

Table 19 provides a summary of three primary training approaches aimed at encouraging environmentally responsible behaviors in port operations. Each method includes a practical example that illustrates the connection to sustainability outcomes.

- **Classroom course** – This form of training is a structured learning setting where participants are introduced to the theory, regulations, and best practices of sustainable maritime operations. For example, an emissions reduction workshop can help participants understand how operational decisions affect fuel consumption and greenhouse gas output. The main sustainability benefit is an increased awareness of environmental impacts and regulatory requirements.

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- **Simulator training** – Here, trainees use realistic navigation and tug-handling simulators to practise operational strategies such as coordinating tug movements with favourable tidal windows. This allows crews to refine their timing, power usage, and coordination without incurring real-world risks. The sustainability benefit is the reduction of fuel consumption through improved operational timing and efficiency.

- **Peer-to-peer mentoring** – In this approach, experienced colleagues informally share practical techniques with less experienced operators. For example, a tug master may demonstrate throttle control methods that reduce fuel use while maintaining manoeuvre effectiveness. The benefit is the gradual embedding of efficient habits across teams.

The table makes clear that training should not rely on a single method. Instead, combining formal instruction, realistic simulation, and informal peer guidance ensures that knowledge is not only learned but also **applied and reinforced** in everyday port operations. This integrated approach increases the likelihood that sustainable practices become standard operating procedures rather than one-off initiatives.

5.2.3 Role of leadership

Leaders set the tone for operational culture:

- By example – A pilot who consistently applies just-in-time arrival influences the whole bridge team.
- By communication – Leaders explain decisions and share performance data openly.
- By recognition – Publicly acknowledging good practices motivates others to follow.

5.2.4 Role of peer influence

Colleagues can have as much influence as formal leaders. When operators see peers using fuel-saving techniques successfully, they are more likely to adopt them.

- Observation – Learning from others during joint operations.
- Informal feedback – Quick tips shared between colleagues.
- Healthy competition – Comparing fuel use reports between crews.

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5.2.5 Behavioural change cycle

Figure 12 below shows the five key stages involved in creating and sustaining behavioural change for greener, more efficient port operations. The stages are arranged in a circular flow to emphasise that this is a continuous process rather than a one-off action.

1. **Awareness** – The process begins with recognising that current practices affect both operational efficiency and environmental performance. Awareness may come from regulatory requirements, training sessions, or feedback from previous operations.

2. **Knowledge** – Once aware of the need for change, stakeholders need the technical knowledge and skills to act. This includes understanding eco-navigation techniques, just-in-time (JIT) arrival planning, tug fuel optimisation, and safe integration of new technologies.

3. **Action** – Knowledge is applied in real operations. This might involve adjusting vessel approach speeds, coordinating tug departures to minimise idle time, or aligning pilot boarding with optimal schedules.

4. **Feedback** – After actions are taken, performance data (such as fuel consumption, emissions levels, or operation times) is collected and reviewed. This feedback helps identify whether the new behaviour is achieving the desired results.

5. **Reinforcement** – Positive results are reinforced through recognition, peer support, and continued leadership emphasis. Reinforcement makes the behaviour part of the standard operating culture, increasing the likelihood that it will be repeated.

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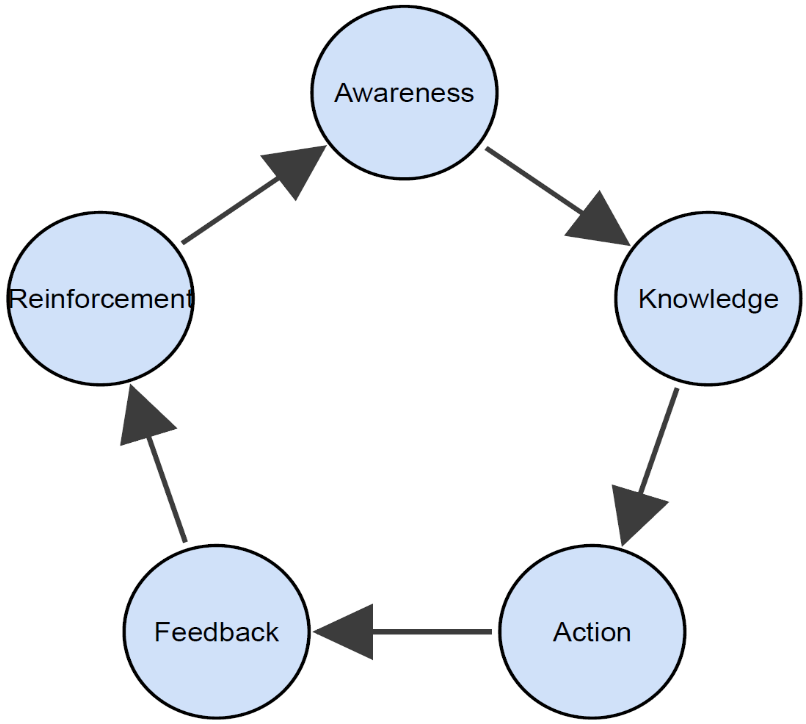

Figure 12 – Cycle of behavioural change in sustainable port operations

Source: Adapted from EMSA (2023) training guidelines

From reinforcement, the cycle loops back to awareness — as operations, regulations, and technologies evolve, new challenges and opportunities emerge, restarting the process.

This cycle helps explain why training, leadership, and peer influence are central to lasting change: they drive each stage forward, ensuring that sustainable practices become embedded in daily port operations rather than fading after initial adoption.

5.3 Good planning of effective communication with all players involved

Effective communication planning is not just about selecting the right words or channels — it is about ensuring that the right information reaches the right person at the right time. In sustainable port operations, where timing and coordination directly affect fuel consumption and emissions, poor communication can quickly lead to inefficiencies and safety risks.

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5.3.1 Why planning is important

- Operational efficiency – Accurate, timely messages help avoid delays, idle time, and "rush-and-wait" cycles.
- Safety – Well-timed communications reduce the risk of misunderstandings in dynamic port environments.
- Sustainability – Coordinated actions reduce unnecessary vessel movements, tug use, and fuel burn.

5.3.2 Steps for effective communication planning

Table 20 – Steps for planning effective communication in port operations

Step	Action	Purpose	Example in practice
1. Identify stakeholders	List all involved parties	Avoid missing key actors	Pilotage, towage, VTS, terminal, ship's bridge team
2. Define information needs	Specify what each needs to know	Avoid overloading or under-informing	Tug ETA, berth readiness, tidal windows
3. Choose communication channels	Select method for each message	Ensure reliability	VHF radio, direct call, digital platform
4. Set timing and frequency	Decide when and how often to update	Keep everyone aligned	T-12h, T-3h, T-60min before operation
5. Establish feedback loops	Confirm message was understood	Prevent errors	"Read-back" of critical instructions

Source: Adapted from IMO Model Course 4.05 and port authority operational guidelines

Table 20 outlines a five-step process for ensuring that communication in port operations is efficient, reliable, and supportive of sustainability goals. Each step specifies an action, its purpose, and a practical example.

1. **Identify stakeholders** – The first task is to determine all the individuals and organisations who need to exchange information. This avoids leaving out

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key actors, which could cause delays or unsafe situations. *Example:* Listing pilotage, towage, VTS, terminal staff, and the ship's bridge team before planning communications.

2. **Define information needs** – Each stakeholder requires specific operational data to fulfil their responsibilities. By clearly defining what information is required, unnecessary messages can be avoided, and important details are not missed. *Example:* Tug ETA, berth readiness status, or tidal window timing.

3. **Choose communication channels** – Selecting the most suitable channel for each type of message ensures that communication is reliable and clear. *Example:* Using VHF radio for urgent navigation instructions, and digital platforms for structured data sharing.

4. **Set timing and frequency** – This ensures that updates are sent at the right moment and often enough to keep operations aligned, without overwhelming recipients. *Example:* Providing key updates 12 hours, 3 hours, and 60 minutes before the start of operations.

5. **Establish feedback loops** – It is essential to confirm that messages are understood. Closed-loop communication methods, such as repeating back instructions, reduce the risk of misunderstanding. *Example:* A tug master confirming a speed reduction order by restating it over the radio.

This structured approach helps prevent errors, supports just-in-time (JIT) operations, and contributes to fuel savings and emission reductions by avoiding idle times and unnecessary manoeuvres.

5.3.3 Choosing the right channel

Different channels serve different purposes:

- VHF radio – Immediate, short operational messages.
- Mobile or satellite calls – Confirm detailed plans or resolve complex issues.
- Digital platforms (e.g., port community systems) – Share structured operational and environmental data.

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- Face-to-face briefings – Best for multi-party coordination before complex jobs.

Selecting the right communication channel is critical because it affects speed, clarity, and reliability of message delivery. In busy port environments, poor channel choice can lead to missed instructions, delays, or unsafe situations.

Key considerations when choosing a channel:

- Urgency of the message – Urgent operational changes (e.g., tug repositioning due to a traffic conflict) require immediate channels such as VHF radio or direct voice calls.
- Complexity of the information – Detailed coordination involving multiple data points (e.g., berth change, updated cargo readiness, and tidal restrictions) may be better handled via digital platforms or face-to-face briefings, where information can be presented clearly and verified.
- Reliability and redundancy – Environmental conditions, equipment limitations, or cyber risks can disrupt certain channels. Having a backup method (e.g., a mobile phone as a secondary to VHF) ensures continuity.
- Record-keeping requirements – Some operational or environmental data must be logged for compliance. In these cases, using a digital platform or written confirmation is essential.

Examples of appropriate channel use:

- VHF radio – “Pilot boat to tug Alpha: confirm ETA to rendezvous point.”
- Digital platform (port community system) – Uploading a confirmed tug schedule with berth alignment and tide window data.
- Face-to-face briefing – A pre-departure meeting between pilot, tug master, and terminal planner to confirm a complex manoeuvre sequence.

Choosing the right channel is not about preference alone — it is about matching the urgency of the message, the complexity of the content, and the operational context with the tool that will deliver it most effectively, while maintaining a fallback in case of failure.

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5.3.4 Feedback and confirmation

A common problem in busy port environments is assuming that a message was understood. Techniques like closed-loop communication, where the receiver repeats back the instruction, are essential for avoiding errors. For example:

Pilot: "Reduce speed to 8 knots until the boarding point." Tug master: "Confirm, reducing to 8 knots until boarding point."

5.3.5 Communication planning framework

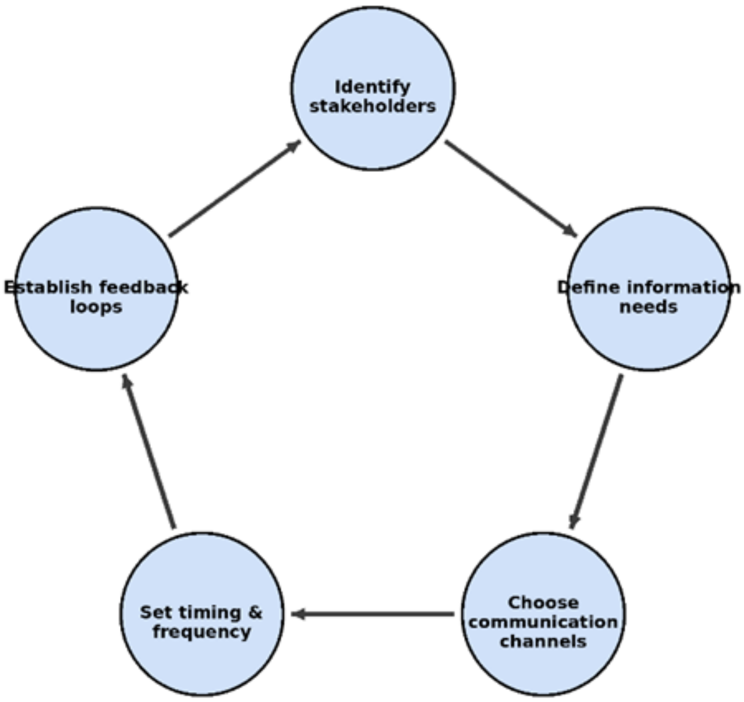

Figure 13 – Communication planning framework for sustainable port operations
Source: Adapted from EMSA (2023) operational communication guidelines

This diagram illustrates the five essential steps for planning effective communication in sustainable port operations. The steps are arranged in a circular sequence, showing that communication planning is a continuous process that must be revisited before, during, and after operations to maintain efficiency, safety, and environmental performance.

1. **Identify stakeholders** – The first step is to clearly determine who needs to be involved in the information exchange. This includes pilots, tug masters, pilot boat crews, VTS, terminal planners, ship operators, and environmental officers. Without complete stakeholder mapping, key players may be overlooked, causing gaps in coordination.

2. **Define information needs** – Each stakeholder requires specific operational details to perform their role effectively. For example, pilots need tidal and traffic data, tug masters need confirmed ETAs and power requirements, and terminal planners need cargo readiness information.

3. **Choose communication channels** – Different channels are suited to different purposes. VHF radio is ideal for urgent operational instructions. Mobile or satellite calls work well for detailed planning. Digital platforms handle structured data sharing, and face-to-face meetings are best suited for complex, multi-party discussions.

4. **Set timing & frequency** – Good planning includes deciding when information should be sent and how often updates are needed. Standard checkpoints might include T-12 hours, T-3 hours, and T-60 minutes before operation. This ensures all parties are aligned without information overload.

5. **Establish feedback loops** – It is not enough to send a message; confirmation is needed to ensure it was received and understood. Closed-loop communication techniques, such as read-backs, help prevent misunderstandings that could lead to inefficiencies or safety issues.

By following these five steps, stakeholders can ensure that communication supports just-in-time (JIT) arrivals, optimised tug deployment, and minimal fuel use — all of which contribute to greener, more efficient port operations.

5.4 Eliciting the required information for smooth operations

Smooth and efficient port operations depend on timely access to accurate information. Eliciting the right information means knowing what to ask, whom to ask, and when to ask it, so that every stakeholder can make informed decisions without delays or unnecessary fuel use.

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5.4.1 Why eliciting information is critical

In port operations, every action — from a vessel adjusting its speed to a tug casting off — is the result of decisions based on available information. If that information is incomplete, late, or inaccurate, the chain of operations is disrupted.

A poorly timed update can cause vessels to accelerate unnecessarily, wasting fuel and increasing emissions, only to wait for berth clearance. Tug and pilot boats dispatched too early may idle for extended periods, burning fuel without performing useful work. Missing tidal or weather updates can lead to manoeuvres at less favourable conditions, requiring higher power and risking delays.

The environmental and operational costs of such inefficiencies are significant:

- **Fuel waste** – Avoidable consumption during idling or unnecessary manoeuvring.
- **Increased emissions** – Directly linked to wasted fuel and longer operational times.
- **Safety risks** – Reduced situational awareness can compromise vessel handling and crew safety.
- **Port congestion** – Inefficient sequencing can create bottlenecks, impacting multiple vessels.

Eliciting the right information is not just about asking questions; it's about asking the right questions, at the right time, and confirming that the answers are reliable. This process should be systematic — supported by checklists, predefined communication windows, and clear reporting protocols.

Well-structured information requests also help align environmental objectives with operational needs. For example, knowing berth readiness 12 hours in advance enables just-in-time arrival planning, which reduces approach speeds and lowers emissions. Similarly, confirming tug requirements early avoids last-minute changes that can disrupt eco-speed profiles and waste fuel.

In short, eliciting accurate and timely information is a core skill in sustainable port operations, ensuring that all stakeholders can act with precision, safety, and efficiency.

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5.4.2 Minimal operational dataset

The minimal dataset refers to the essential information that must be available and verified for each operation.

Table 21 – Example minimal dataset for a vessel arrival

Information item	Provider	Recipient(s)	Purpose
Berth readiness status	Terminal	Pilot, VTS, Ship	Align ETA and approach speed
Updated ETA	Ship / Pilot	VTS, Towage, Terminal	Coordinate tug dispatch and berth allocation
Tug configuration and power	Towage dispatch	Pilot, Ship	Match tug power to job requirements
Tide and current forecast	VTS	Pilot, Ship, Towage	Optimise manoeuvring and reduce fuel
Weather and visibility update	VTS / Meteorological service	All stakeholders	Ensure safe navigation planning

Source: Adapted from Port of Rotterdam operational guidelines and IMO Model Course 4.05

5.4.3 Communication techniques for information elicitation

- Targeted questioning – Ask for specific, actionable data ("What is the latest berth clearance time?" instead of "Is the berth ready?").
- Confirmation requests – Verify critical points through read-back or written confirmation.
- Structured checklists – Use pre-operation forms to ensure no key detail is overlooked.
- Time-bound updates – Request information at fixed intervals (e.g., T-12h, T-3h, T-60min).

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5.4.4 Information flow checkpoints

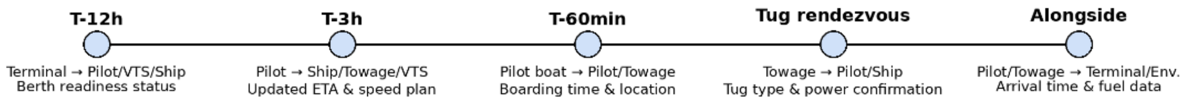

Figure 14 – Example information flow checkpoints for a vessel arrival *Source: Adapted from POLA/POLB speed reduction programme and European port best practices*

This figure presents a timeline view of the key communication checkpoints that occur from pre-arrival through to a vessel being alongside. Each checkpoint identifies when information is exchanged, who sends it, who receives it, and what operational detail is shared.

The goal is to ensure that the right data reaches the right people at the right time, supporting safe, efficient, and environmentally responsible operations.

1. **T-12h (12 hours before arrival)** – The terminal informs the pilot, VTS, and ship about berth readiness and cargo status. This early update allows just-in-time (JIT) speed planning, reducing the risk of vessels arriving too early and burning unnecessary fuel.

2. **T-3h (3 hours before arrival)** – The pilot provides the ship, towage services, and VTS with an updated ETA and a refined speed plan. This helps align tug dispatch with the vessel's actual approach, avoiding idle time and excess tug engine use.

3. **T-60min (1 hour before pilot boarding)** – The pilot boat confirms the boarding time and location with the pilot and towage. This allows all parties to adjust their timing and speed to avoid high-speed runs or prolonged waiting.

4. **Tug rendezvous** – Towage services communicate tug type, power, and estimated arrival to the pilot and ship. This ensures that the correct tug

configuration is ready exactly when needed, improving both safety and fuel efficiency.

5. **Alongside** – The pilot and towage report the vessel's arrival time and tug usage to the terminal and environmental office. This data feeds into fuel and emissions tracking systems, supporting continuous improvement and compliance reporting.

By structuring communications along these checkpoints, port stakeholders can coordinate movements precisely, reduce unnecessary fuel burn, and ensure smooth transitions through each operational phase.

5.5 Experiential communication exercises

Experiential exercises allow participants to practise communication skills in realistic, simulated port scenarios, where they can apply theory under time pressure and operational constraints. The aim is to build confidence in exchanging clear, timely, and targeted messages with all stakeholders while prioritising both safety and sustainability.

5.5.1 Purpose of experiential communication exercises

- Strengthen practical skills learned in earlier sections.
- Recreate realistic time pressures and decision-making environments.
- Demonstrate the link between good communication, fuel efficiency, and emission reduction.
- Provide a safe space to make mistakes and learn corrective actions.

5.5.2 Exercise design principles

Table 22 – Principles for designing experiential communication exercises

Principle	**Application**	**Benefit**
Realism	Use accurate vessel data, weather, and tidal conditions	Increases transferability to real operations
Stakeholder interaction	Include pilots, tug masters, VTS, and terminal planners	Reinforces multi-party coordination

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Time sensitivity	Impose realistic deadlines for decision-making	Builds speed and clarity under pressure
Debriefing	Analyse outcomes immediately after exercise	Links actions to results and lessons learned

Source: Adapted from Kongsberg simulator training methodologies and IMO Model Course 4.05

5.5.3 Example exercise scenarios

1. **Last-minute berth delay** – The berth becomes unavailable 40 minutes before arrival; participants must coordinate revised ETA, tug dispatch, and speed plan.

2. **Adverse weather change** – Sudden wind shift requires reassessing tug configuration and boarding location.

3. **Tug unavailability** – One assigned tug is delayed; participants must reallocate tasks and adjust manoeuvre plans.

4. **Digital tool outage** – PPU system fails during approach; teams must switch to backup communication and navigation methods.

5.5.4 Assessment during exercises

Performance is evaluated on:

- Accuracy and completeness of information exchanged.
- Use of closed-loop communication to confirm understanding.
- Ability to adjust plans quickly without compromising safety.
- Minimisation of idle time and fuel waste through efficient coordination.

5.5.5 Communication network during simulation

Figure 5.5.1 below illustrates the communication pathways between all stakeholders participating in a simulated port operation. Each node represents a stakeholder, and the connecting lines show bidirectional communication links during the exercise.

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- **Pilot** – Acts as the central operational coordinator, exchanging information with all other parties to manage vessel approach, tug engagement, and berth readiness.

- **Tug master** – Communicates with the pilot, VTS, terminal, and ship to confirm tug availability, bollard pull, and engagement timing.

- **Vessel Traffic Service (VTS)** – Provides real-time traffic, tide, and weather updates to all relevant parties, ensuring safe and efficient movement in port waters.

- **Terminal** – Updates berth readiness, cargo status, and shore-side resources to the pilot, VTS, ship, and environmental office.

- **Ship** – Works with the pilot and tugs to adjust speed and manoeuvres; communicates status updates to terminal and VTS.

- **Environmental office** – Receives fuel consumption and emissions data, and may provide operational recommendations or restrictions to the pilot and terminal.

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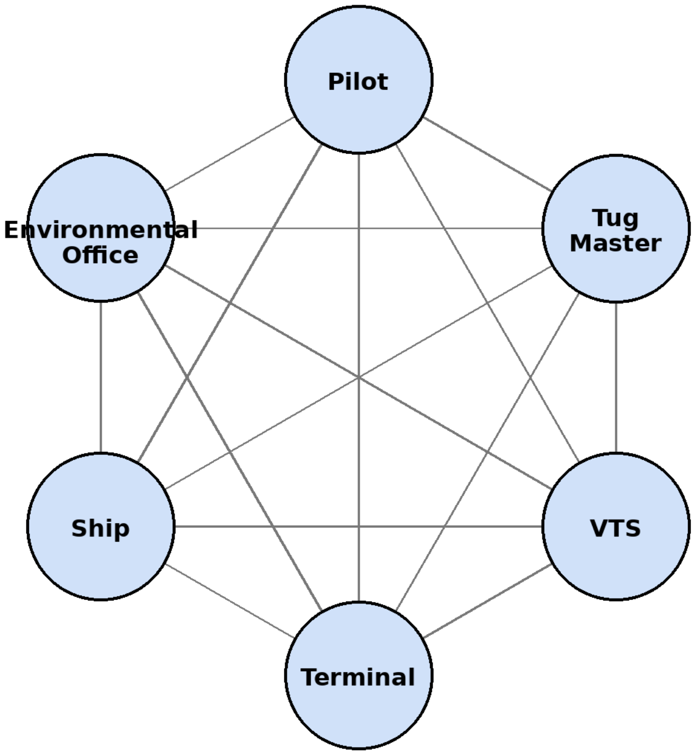

Figure 15 – Stakeholder communication network in a simulation exercise

Source: Adapted from GreenPort VET simulator session structures

In this simulation network, every stakeholder is connected to every other. This reflects the high level of coordination required in real operations, where delays, miscommunication, or missing updates from even one party can affect the entire sequence.

The exercise scenario uses this communication network to train participants in:

- Managing multiple simultaneous conversations.
- Using clear, concise, and confirmed messages.
- Prioritising critical operational and safety information.
- Ensuring environmental performance data is part of the operational dialogue.

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5.6 Clarifying the role of digital aids

Digital aids, such as Portable Pilot Units (PPUs), Virtual Reality (VR) tools, and other electronic navigation systems, are playing an increasingly important role in modern port operations.

Digital aids, such as Portable Pilot Units (PPUs), Augmented Reality (AR) applications, and other electronic navigation systems, are playing an increasingly important role in modern port operations. These tools provide real-time data and enhance situational awareness; AR, for example, has been tested in ports like Livorno to support pilotage and berth alignment. While such aids can indirectly improve coordination by ensuring more accurate and timely decision-making, they remain support tools — they must complement, not replace, professional judgment, and their limitations must be recognised.

5.6.1 What are digital aids in port operations

In modern port operations, digital aids refer to portable, networked, or immersive tools that enhance decision-making by providing timely, precise, and often visualised information. These tools are designed to supplement — not replace — the skills and judgement of maritime professionals. They enable better coordination between stakeholders, improved situational awareness, and more effective operational planning, particularly in complex or time-sensitive manoeuvres.

- **Portable Pilot Units (PPUs)**

Portable Pilot Units (PPUs) are one of the most widely recognised digital aids. A PPU is a compact, mobile navigation system carried by a pilot, usually consisting of a GNSS/GPS receiver and a display device such as a tablet or rugged laptop. By connecting to independent sensors, a PPU can provide real-time position, speed, and movement trends without relying solely on the ship's bridge equipment. This independence is particularly valuable if onboard systems are unavailable, uncalibrated, or compromised.

- **Virtual Reality (VR) training tools**

Virtual Reality (VR) training tools offer a different type of advantage. They allow pilots, tug masters, VTS operators, and other stakeholders to rehearse real-world scenarios in a fully immersive environment. By simulating port layouts, vessel behaviour, and environmental conditions, VR training helps build muscle memory for procedures, improve communication patterns, and practise responses to unusual or emergency situations — all without operational risk.

- **Integrated digital platforms**

Other integrated digital platforms, such as port community systems, emissions dashboards, and electronic reporting tools, are now standard in many ports. These systems centralise operational and environmental data, making it accessible to pilots, terminal planners, VTS, and environmental officers in real time. The result is faster coordination, fewer delays, and the ability to track performance against environmental targets.

While these technologies can transform port operations, their effectiveness depends on being used in conjunction with conventional navigation skills and sound operational judgment, rather than as a replacement for them.

5.6.2 Benefits of digital aids

Table 23 – Benefits of selected digital aids

Digital aid	Primary use	Benefit
PPU	Real-time positioning independent of ship's systems	Improved situational awareness, redundancy
VR simulation	Training and operational rehearsal	Risk-free practice of high-stress scenarios
Digital platforms	Data sharing and reporting	Faster decision-making and better coordination

Source: Adapted from IMO e-navigation strategy implementation plan and EMSA guidelines

Portable Pilot Units (PPUs)

- **Primary use** – PPUs provide real-time positioning and navigational data that are independent from the vessel's own systems. They often include tide, current, and speed-over-ground overlays.
- **Benefit** – This independence improves situational awareness and provides redundancy in case onboard navigation equipment fails or produces inaccurate readings. For pilots, it enables more precise manoeuvring in restricted waters and better timing for eco-speed arrivals.

Virtual Reality (VR) simulation

- **Primary use** – VR systems create immersive training environments that replicate real-world port layouts, vessel types, environmental conditions, and operational scenarios.
- **Benefit** – Operators can rehearse complex manoeuvres, refine communication skills, and practise responses to emergencies without any operational risk. The risk-free setting makes it easier to try different

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strategies and learn from mistakes, which strengthens decision-making skills in actual port operations.

Digital platforms

- **Primary use** – These include port community systems, emissions dashboards, scheduling tools, and cargo-handling coordination systems. They enable multiple stakeholders to share structured data in real time.
- **Benefit** – By streamlining information exchange, these platforms reduce delays, improve berth allocation efficiency, and support environmental compliance by integrating fuel and emissions monitoring into daily operations.

The table highlights that while each digital aid serves a different operational function, all contribute to better decision-making, improved coordination, and the potential for reduced fuel consumption and emissions when used effectively. The key is to integrate them into standard procedures while maintaining manual skills and alternative workflows for redundancy.

5.6.3 Limitations and risks

- **GNSS spoofing** – Deliberate transmission of false GPS signals to mislead navigation systems.
- **Signal jamming** – Blocking GNSS signals, leading to loss of positioning data.
- **Over-reliance** – Operators may neglect visual navigation or traditional seamanship skills.
- **Data latency** – In fast-changing conditions, delayed updates can affect decision-making.

While digital aids can significantly enhance efficiency, safety, and environmental performance in port operations, they are not without vulnerabilities. Understanding these limitations is essential to ensure they are used appropriately and that reliance on them does not compromise operational integrity.

- **GNSS spoofing**

A major concern is GNSS spoofing — the intentional broadcasting of false GPS signals to mislead navigation systems. A spoofed signal can cause a PPU or other GNSS-reliant devices to display incorrect positions, potentially leading to unsafe manoeuvres.

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- **Signal jamming**

Closely related to spoofing is signal jamming, where GPS signals are blocked entirely, causing a sudden loss of positioning capability. Both threats can disrupt operations and, if not detected, may lead to delays, unsafe approaches, or grounding risks.

- **Over-reliance on digital tools**

Over-reliance on digital tools is another operational hazard. When operators begin to depend solely on digital displays, there is a risk that traditional navigation skills — such as visual pilotage, radar plotting, and manual position fixing — may erode. This can become a problem if the digital system fails, data is corrupted, or conditions require immediate judgement beyond what the system can interpret.

- **Data latency**

Additionally, data latency can affect decision-making. Even small delays in updating positional, environmental, or traffic data can cause misjudgements in dynamic situations, especially in confined waterways or during complex manoeuvres.

Finally, the cybersecurity dimension must not be overlooked. Any digital aid connected to a network — especially port community systems — can be vulnerable to malware, hacking, or denial-of-service (DoS) attacks. Such incidents can disrupt not only navigation but also scheduling, cargo handling, and environmental monitoring.

For these reasons, digital aids must always be treated as supplementary tools rather than sole sources of navigational truth. Operators should use them in conjunction with visual observations, bridge team coordination, and independent cross-checking from multiple data sources.

5.6.4 Cyber threat considerations

As port operations become increasingly digitised, cybersecurity is no longer an optional concern — it is a core element of operational safety and resilience. Every digital aid, from a PPU to a shared emissions dashboard, is potentially vulnerable to cyber threats.

Types of cyber threats in port operations

1. **Malware and ransomware** – Malicious software can infiltrate onboard systems or shore-based platforms, locking users out of critical tools until a

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ransom is paid, or silently altering data. A compromised PPU or scheduling platform could display false timings or positions, affecting operational decisions.

2. **Data manipulation** – Altering information in port community systems, scheduling tools, or emissions reporting dashboards can mislead decision-makers. For example, modified tug dispatch data could cause delayed or premature deployment, leading to fuel waste and congestion.

3. **Denial-of-service (DoS) attacks** – Overloading a system with traffic until it becomes unavailable. If a VTS digital platform or scheduling system is disrupted during high-traffic periods, vessel sequencing and berth allocation could break down.

4. **Phishing and credential theft** – Attackers trick users into revealing login credentials, giving them access to secure systems. This can lead to unauthorized system control or data breaches.

Mitigation measures

1. **Access control and authentication** – Use strong, multi-factor authentication for all systems and restrict access to essential personnel only.

2. **Network segmentation** – Keep navigation-critical systems isolated from general office or internet-connected networks.

3. **Regular updates and patches** – Ensure software and firmware are kept current to fix known vulnerabilities.

4. **Cybersecurity training** – Teach personnel to recognise phishing attempts, suspicious activity, and the importance of password security.

5. **Incident response planning** – Have a clear protocol for reporting, isolating, and responding to suspected cyber incidents.

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In essence, digital aids are only as secure as the systems and practices surrounding them. Incorporating robust cybersecurity measures into standard operating procedures ensures that these tools remain reliable under both normal and adverse conditions.

5.6.5 Best-practice integration of digital aids

- Use cross-checking between PPU, ship systems, and visual references.
- Maintain redundant systems and backup procedures.
- Apply scenario-based VR training to improve team communication and reaction to failures.
- Include cybersecurity protocols in standard operating procedures.

For digital aids to deliver their full operational and environmental benefits, they must be integrated into daily operations in a structured way. This involves striking a balance between technology and traditional seamanship, ensuring redundancy, and maintaining security.

Checklist for integrating digital aids effectively

1. **Cross-check all data sources**
    - Compare PPU readings with ship's ECDIS, radar, and visual bearings.
    - Confirm environmental data from multiple sources (VTS, onboard sensors, external services).

2. **Maintain manual navigation and operational skills**
    - Regularly practise visual pilotage, manual plotting, and non-digital communication drills.
    - Conduct occasional "no-digital-aid" simulation runs to ensure readiness in case of failure.

3. **Implement redundant systems**
    - Ensure backup navigation devices are available and functional.

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- Maintain alternative communication channels (e.g., VHF, direct phone, written notes) in case of platform failure.

4. **Integrate into standard operating procedures (SOPs)**
    - Specify in port operation manuals how and when digital aids should be used.
    - Include steps for validating digital data before using it for critical decisions.

5. **Apply robust cybersecurity protocols**
    - Require password protection and encryption for all connected devices.
    - Keep software and firmware updated to address known vulnerabilities.
    - Enforce access controls, ensuring only authorised users operate critical systems.

6. **Train and refresh regularly**
    - Schedule recurrent training on both the technical and operational aspects of digital aids.
    - Include cyber-awareness modules in mandatory safety courses.

7. **Evaluate and update**
    - Conduct periodic reviews of digital aid performance and relevance.
    - Adjust SOPs as technology evolves or new risks emerge.

By following these best practices, digital aids become a reliable enhancement to operational safety and efficiency while supporting sustainability goals — without creating a single point of failure or new vulnerabilities.

5.6.6 Digital aids in port operations

Figure 16 below presents a three-part continuous improvement cycle for the effective use of digital aids in port operations. It is designed to help operators understand not only the advantages of these tools but also their vulnerabilities and the best ways to integrate them into safe and efficient workflows.

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1. **Benefits**
   The first segment highlights the operational and environmental value of digital aids:
   - Real-time positioning enables more precise manoeuvring and supports just-in-time (JIT) arrivals.
   - Improved situational awareness allows pilots, tug masters, and VTS to make faster, better-informed decisions.
   - Risk-free training through Virtual Reality (VR) allows crews to practise complex scenarios without operational hazards.
   - Faster coordination results from shared digital platforms that streamline communication across stakeholders.

2. **Limitations**
   The second segment addresses the vulnerabilities that can undermine these benefits:
   - GNSS spoofing and signal jamming can distort or block positioning data.
   - Over-reliance on technology may reduce traditional seamanship skills.
   - Data latency can cause decision-making delays, especially in dynamic port conditions.

3. **Safe use practices**
   The third segment outlines measures to ensure reliable and secure operation:
   - Cross-check data sources by comparing PPU outputs with radar, ECDIS, and visual cues.
   - Maintain manual skills so operations can continue in the event of a system failure.
   - Use redundant systems for navigation and communication.
   - Apply cybersecurity protocols to protect against hacking, malware, and data manipulation.

The arrows between segments indicate that this is an ongoing cycle: operators should continually review benefits, stay aware of limitations, and refine safe use practices as technology and operational conditions evolve.

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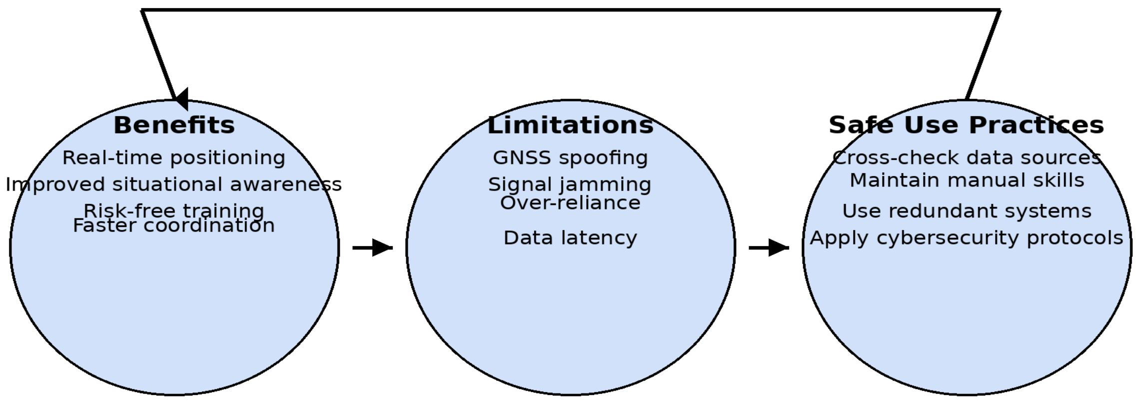

Figure 16 – Benefits, limitations, and safe use of digital aids
Source: Adapted from EMSA e-navigation guidelines and IMO cyber risk management framework

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Chapter 5 Supporting material

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Communication and stakeholder engagement

SESSION OBJECTIVES

- ❑ **Roles of key stakeholders** in sustainable port operations.
- ❑ **Change management**: behavioral aspects, planning, and information exchange techniques
- ❑ **Experiential exercises** to strengthen communication skills
- ❑ **Safe integration of digital tools** to enhance operational safety and environmental sustainability

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Stakeholders, their roles and responsibilities

IN SUSTAINABLE PORT OPERATIONS, EVERY STAKEHOLDER PLAYS A SPECIFIC ROLE THAT CONTRIBUTES TO BOTH SAFETY AND ENVIRONMENTAL PERFORMANCE.

STAKEHOLDER GROUP	TYPICAL REPRESENTATIVES	MAIN ROLE IN SUSTAINABILITY
Pilotage services	Pilots, pilot organisations	Plan safe approach speeds; promote eco-navigation; coordinate arrival timing
Towage providers	Tug masters, dispatchers	Use the right tug power; avoid idle running; optimise operations before and after jobs
Pilot boat services	Coxswains, crew	Conduct safe, fuel-efficient transfers; avoid unnecessary high-speed runs
Vessel Traffic Service (VTS)	VTS officers, schedulers	Sequence ship movements; share tide/current information; monitor berth readiness
Terminal operations	Berth planners, supervisors	Communicate berth availability; ensure cargo readiness; reduce delays
Ship operators	Master, bridge team, owners	Follow speed limits; manage engine power; share fuel/emissions data
Port authority/environmental office	Harbour master, environmental staff	Monitor emissions; ensure compliance; promote green port policies

ROLES

RESPONSIBILITIES

TASK/PHASE	PILOTAGE	TOWAGE	PILOT BOAT	VTS	TERMINAL	SHIP	ENVIRONMENTAL OFFICE
Pre-arrival speed advice	R/A	C	C	A	C	R	I
Tidal-window planning	R	R	C	A	C	C	I
Tug dispatch	C	R/A	I	C	C	I	I
Berth readiness updates	I	I	I	C	R/A	I	I
Approach speed adjustment	R	C	C	C	I	R	I
Fuel/emissions data collection	C	R	R	I	I	R	A
Post-job debrief	R	R	R	C	C	C	I

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Stakeholders’ information flow

ALL STAKEHOLDERS EXCHANGE INFORMATION. NO SINGLE ACTOR IS ALWAYS CENTRAL.

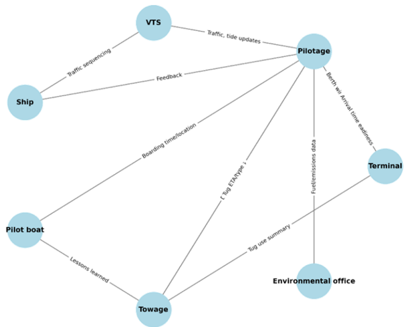
STAGES OF COMMUNICATION

PRE-ARRIVAL → Terminal & VTS provide berth, cargo, traffic, tidal data → Pilot sets boarding time → Ship adjusts speed (JIT arrival, fuel saving).

APPROACH → Pilot boat confirms boarding time/location → Towage shares ETA & tug type → VTS updates ship on sequencing.

ALONGSIDE → Pilot & Towage report arrival & tug use to Terminal → Pilot sends emissions data to Environmental Office.

POST-JOB → Pilot debriefs Towage → Towage shares lessons with Pilot Boat → Pilot gives feedback to Ship’s bridge team.



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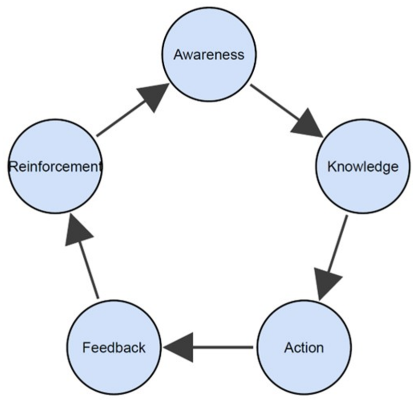
Driving sustainable behaviour in port operations

The success of any organization depends not only on technical skills but also on the behaviors and established habits of its people.

- **Training** develops knowledge and skills through courses, simulators, and mentoring, reinforcing both theory and real-world habits.
- **Leadership shapes culture** by example, open communication, and recognition of good practices.
- **Peer** influence drives change via observation, feedback, and healthy competition, embedding efficient habits.
- The **behavioural change cycle** moves from awareness → knowledge → action → feedback → reinforcement, ensuring sustainability becomes routine.



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Good planning of effective communication with all players involved

Good planning ensures the right information reaches the right person at the right time, enhancing efficiency, safety, and sustainability.

STEP	ACTION	PURPOSE	EXAMPLE IN PRACTICE
1. Identify stakeholders	List all involved parties	Avoid missing key actors	Pilotage, towage, VTS, terminal, ship's bridge team
2. Define information needs	Specify what each needs to know	Avoid overloading or under-informing	Tug ETA, berth readiness, tidal windows
3. Choose communication channels	Select method for each message	Ensure reliability	VHF radio, direct call, digital platform
4. Set timing and frequency	Decide when and how often to update	Keep everyone aligned	T-12h, T-3h, T-60min before operation
5. Establish feedback loops	Confirm message was understood	Prevent errors	"Read-back" of critical instructions

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Module number 5 | Communication and stakeholder engagement

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Chapter 5 Assessment Questions

1. ***Port community systems contribute to sustainability because they:***
   A. Record VHF radio communications
   B. Centralise berth windows, ETAs, and cargo readiness for all stakeholders in real time
   C. Replace the need for pilots in restricted waters
   D. Only monitor environmental data

2. **In the RACI framework, "Responsible" indicates:**
   A. The party directly performing the task
   B. The stakeholder approving the work
   C. A consultant giving advice
   D. The party receiving updates only

3. **Closed-loop communication in port operations requires:**
   A. Written confirmation within 24 hours
   B. The receiver repeating back instructions to confirm understanding
   C. Data upload to port community systems
   D. VHF communication only with VTS

4. **Which cyber threat can falsify positional data in digital aids such as PPUs?**
   A. Malware
   B. GNSS spoofing
   C. Denial-of-service
   D. Credential theft

5. **Best practice when using digital aids is to:**
   A. Use them exclusively and avoid traditional navigation
   B. Keep them unpatched to prevent updates
   C. Cross-check digital readings with radar, ECDIS, and visual references
   D. Minimise operator training to avoid over-complication

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Chapter 6: Summary and Reflections on Chapters 1–5

6.1. Introduction

This session serves to consolidate the main insights from the first five modules. It provides a structured recap of key themes, ranging from regulatory frameworks and technological innovations to operational strategies and behavioral change. The section also encourages reflection on how these elements interconnect, laying the groundwork for further discussion and application in the context of sustainable maritime operations and green port technologies.

- Why sustainability matters in maritime and port operations - small operational changes produce a big impact on emissions and costs.
- Safety remains the top priority – sustainability must complement, not compromise navigation safety
- Behavioural change through the COM-B framework: Capability (having the knowledge and skills to operate efficiently), Opportunity (having the right tools, systems, and conditions that enable sustainable practices), Motivation (the willingness to act, driven by client expectations and the benefits of efficiency).

6.2. Emission reduction theory & regulations

The transition towards sustainable maritime operations is influenced by international and regional regulatory frameworks.

- While port service vessels are not directly targeted by measures such as the European Green Deal (the strategy), Fit for 55 (the legislative engine), FuelEU Maritime, the EU Emissions Trading System (some of the packages contained within Fit for 55), and the IMO's Net-Zero Fuels initiative, these policies shape industry expectations and client demands.
- Understanding the principles of emission reduction, as well as the practical examples of measures like OPS, hybrid and electric tugs, or Just-in-Time arrivals, is essential for aligning port operations with the broader decarbonisation agenda.

6.3. Industry ecosystem & technology landscape

The maritime industry is undergoing a transformation shaped by decarbonisation targets, technological innovation, and evolving stakeholder expectations.

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- Emerging solutions such as Onshore Power Supply, Shaft Power Limitation systems, emission monitoring tools, and alternative fuels including LNG, methanol, and ammonia are redefining port operations.
- Practical examples: from HVO-fuelled tugs to hydrogen and hybrid propulsion systems, illustrate both progress and challenges. However, the high costs, limited "future" fuel availability, and infrastructure requirements underline that technological adoption must be accompanied by adjustments in daily operational routines.

6.4. Operational strategies for energy saving

Improving energy efficiency in port operations does not always require large-scale investments or new technologies. Reductions in fuel consumption and emissions can be achieved through operational strategies that optimise existing resources.

- Eco-speed steaming – reduced approach speed = lower fuel use
- Tidal window scheduling – optimise manoeuvres with current and tide
- Real-time fuel monitoring & visualisation
- Data-driven behavioural change & feedback loops
- Optimised tug use before/after operations.
- Improved vessel scheduling to avoid multiple pilot boat and tug trips

6.5. Stakeholder engagement & communication

Achieving sustainability in maritime and port operations relies not only on technology but also on effective cooperation and communication between all stakeholders.

- Pilots, tug masters, terminal operators, port authorities, and shipowners must coordinate their actions to ensure efficiency, safety, and environmental performance.
- Leadership and peer influence play an important role in encouraging behavioural change, while digital tools such as Portable Pilot Units, simulators, and operational dashboards can support decision-making. However, these tools complement rather than replace human judgement and must be used responsibly, with attention to cybersecurity.
- Ultimately, collaboration and clear communication remain as vital as any technological innovation.

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6.6. Reflection & Discussion questions

- Which of today's strategies (operational, technological, behavioural) seem most applicable in your local port operations?
- What barriers (infrastructure, cost, cultural resistance) do you foresee – and how might they be overcome?
- How can we balance the safety of navigation with efficiency and sustainability goals?
- What role does personal leadership (pilots, tug masters, supervisors) play in accelerating the green transition?
- From the examples discussed (Rotterdam, Gothenburg, Antwerp, Los Angeles), which practices could realistically be adapted to your port?

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Chapter 6 Supporting material

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Key points

- Sustainability matters in maritime and port operations - small operational changes produce big impact on emissions and costs.
- Safety remains the top priority – sustainability must complement, not compromise navigation safety
- Behavioural change through the COM -B framework: Capability (having the knowledge and skills to operate efficiently), Opportunity (having the right tools, systems, and conditions that enable sustainable practices), Motivation (the willingness to act, driven by client expectations and the benefits of efficiency).

Emission reduction theory & regulations

The transition towards sustainable maritime operations is influenced by international and regional regulatory frameworks.

- Global and EU frameworks are shaping expectations (Green Deal, Fit for 55, FuelEU, EU ETS, IMO NZF)
- Port service vessels may not be directly regulated, but clients are
- Practical measures: Onshore Power Supply (OPS), hybrid/electric tugs, Just-in-Time arrivals.

Source: https://www.dnv.com/maritime/insights/topics/fueleu - maritime/

Even if we are not directly targeted, the ripple effect of these regulations influences the way we work and the clients we serve.

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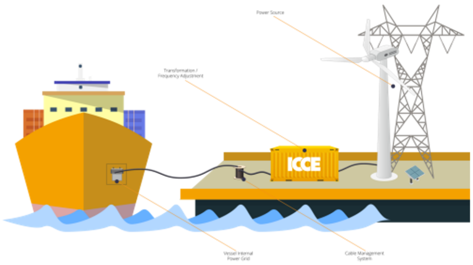
Technology and innovation in ports



Source: https://icce.com/2024/07/30/onshore -power-supply/

- ❑ Industry transformation through decarbonisation and innovation
- ❑ New solutions: OPS, Shaft Power Limitation (SHaPoLi/EPL), emission monitoring
- ❑ Alternative fuels: LNG, methanol, ammonia, hydrogen, HVO
- ❑ Challenges: high costs, limited availability, infrastructure gaps

Technology provides opportunities but also challenges; progress depends on combining innovation with practical adjustments in daily routines.

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Operational strategies

- ❑ **Eco-speed steaming** – reduced approach speed = lower fuel use
- ❑ **Tidal window scheduling** – optimise manoeuvres with current and tide
- ❑ **Real-time fuel monitoring** & visualization
- ❑ **Data-driven behavioural** change & feedback loops
- ❑ **Optimised tug use** before/after operations.
- ❑ **Improved vessel scheduling** to avoid multiple pilot boat and tug trips.

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Stakeholder engagement & communication

- **Sustainability** relies on cooperation and communication
- **Key actors:** pilots, tug masters, terminal operators, port authorities, shipowners
- **Leadership and peer influence** encourage sustainable behaviour
- **Digital tools** support decision-making but don't replace human judgement
- **Cybersecurity** and responsible use are critical.

Technology helps, but human collaboration and leadership are what truly drive sustainable change.

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Reflection & Discussion

- Which of today's strategies (operational, technological, behavioural) seem most applicable in your local port operations?
- What barriers (infrastructure, cost, culture) may you face?
- How can we balance safety of navigation with efficiency and sustainability goals?
- What role does personal leadership (pilots, tug masters, supervisors) play in accelerating the green transition?
- From the examples discussed (Rotterdam, Gothenburg, Antwerp, Los Angeles), which practices could realistically be adapted to your port?

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Module number 6 | Course Name: Sustainable Maritime Operations and Green Port Technologies

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Chapter 7: Eco Navigation Training Simulation

This module is designed to provide pilots and tug masters with practical experience in eco-navigation and ship handling by using simulators to test how operational choices affect safety, fuel efficiency, and emissions during port approaches and berthing.

7.1. Navigation scenario's objective and tasks

Simulation objective:

The objective of the simulation is to observe and identify energy-efficient ship-handling behaviours that achieve safe and effective outcomes with minimal power. Particular emphasis is placed on recognising when momentum, wind, and tide can be harnessed to support manoeuvring, and on comparing strategies that use tugs at lower power for longer durations versus short bursts at high power. By making these behaviours explicit and teachable, the exercise aims to cultivate transferable skills in energy-aware navigation and ship handling, encouraging students to reflect on their own style while aligning with broader sustainability goals.

Tasks for completing the navigation scenario:

1. Identify key best practices for protecting the environment when approaching a port
2. Assess the impact on fuel and emissions of inefficient and efficient maneuvering
3. Apply the principles of sustainable navigation and ship management
4. Consider and discuss how real-world decisions affect emissions

7.2. Simulation scenarios: Case 1 and Case 2

Simulation scenario.

Case 1. Simulate inefficient arrival manoeuvring; Case 2: Best practice manoeuvring

Simulator system	Wartsila - Transas Navi-Trainer Pro 5000, Kongsberg, or similar

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Scenario	Large vessel approaching port, requiring tug assistance, with tide and wind. The vessel must be swung to face the tide and placed safely alongside.
Navigation area	Port approach (based on the areas available at the training centre)
Environmental settings	Tide and wind
Traffic	Moderate density, 1 outbound ferry, 1 tug available
Sensors Enabled	ECDIS, Radar, Engine output monitor
Route scenario	Approach to Port through fairway Buoy xx to Berth xx
Case 1. Simulate inefficient arrival manoeuvring	Objective: Highlight the environmental and operational inefficiencies from inefficient practices Conditions: • Excessive engine use (frequent RPM changes) • Abrupt rudder movements and hard helm orders • Tug engaged late, forced to use high bollard pull • Poor use of current (tide – depending of navigation area) and wind (counteracting forces instead of using them) • No use of ECDIS for advance planning Outcomes: • Higher fuel consumption & emissions • Longer time to berth • Unstable approach, requiring repeated course corrections • Increased tug workload • Delayed docking Data to record: • Engine RPM log • Fuel/emissions output • Time to berth • Number of tug interventions

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Case 2: Best practice manoeuvring	Objective: Apply eco-navigation principles for optimal environmental performance Conditions: • Maintain steady RPM (eco-speed steaming) • Advance route planning with ECDIS, including wind/tidal/current optimisation • Early coordination with tug and VTS • Use tide and wind to assist swing manoeuvre • Tug applies moderate, steady thrust rather than repeated high-power pushes • Real-time monitoring of engine load and tug fuel consumption Outcomes: • Lower fuel consumption • Precise docking with minimal delays • Reduced emissions and better energy profile • Stable vessel handling with fewer corrections Notes to be recorded: • Log engine RPM • Fuel usage / emissions • Time to berth • Number of tug interventions

Note: In ship handling, there exist numerous strategies that can be employed to achieve identical outcomes, thereby rendering it a highly nuanced profession. Ultimately, each pilot and tug master will cultivate their individual style over time; some will rely more heavily on power, while others will skillfully utilise environmental factors. The ability to identify behavioural anomalies that result in reduced power consumption ought to be a primary objective of simulation exercises, with subsequent assessment of whether these behaviours can be effectively transmitted to students.

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7.3. Instructions to trainees

During this module, complete the exercise as follows:

- Case 1 – complete the exercise without concern for best practices
- Case 2 – complete the exercise applying all the best practices

Note: The exercises will be executed using the Navigation simulator under the guidance and supervision of the instructor.

7.4. Requirements for trainees

- Keep complete records throughout the exercise.
- Use appropriate checklists related to the operation.
- Refer to the stability and performance characteristics of the ships during preparation and throughout the exercise.
- Consider the environment throughout the exercise.
- Maintain clear and appropriate communication with all parties.

7.5. During the simulation, please pay attention to the following areas of focus

The effectiveness of eco-friendly navigation and ship management depends on the ability to balance technology, seamanship, and teamwork. To ensure both safety and sustainability, several key focus areas require particular attention. These include:

- Digital modelling: use port-specific ECDIS and tide/current overlays
- Momentum management: allow vessel inertia to assist manoeuvres instead of overusing engines
- Safety first: efficiency gains must not compromise navigational safety
- Optimised tug use: identify when tug masters can achieve more with less energy input
- Joint communication: ensure pilot and tug master exchange intentions early and clearly

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Trainee’s notes for preparation: Approach to Port

Ships particularities	
Ships type	
Gross Tonnage	
Deadweight	
Length overall	
Breadth	
Draft fore	
Draft aft	
Bow power	
Tug assistance	
Tugboat 1	
Tugboat 2	
Extras of the pilotage plan	
Depth	
Bridge mark	
Target position	
Total distance	
Monitoring fuel consumption	
Log engine RPM	
Fuel usage / emissions	
Time to berth	
Number of tug interventions	

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Data comparison table

Metric	Case 1	Case 2
Distance travelled		
Fuel used/ CO_2 emitted		
Time to berth		
Course deviation		
Tug interventions		
Fuel used by tug/ CO_2 emitted		
Total emissions		

7.6. Evaluation

During the practical assessment, the instructor will evaluate planning quality, execution of eco-navigation practices, teamwork and communication, record keeping, and the ability to reflect during debriefing.

Annex 1. Case study

Eco-navigation is more than a regulatory requirement — it is a practical strategy to reduce fuel consumption, lower greenhouse gas (GHG) emissions, and improve operational efficiency. Among the many factors that influence a ship's environmental footprint, one of the most critical is the engine's operational behaviour, particularly regarding RPM, fuel efficiency, and load management.

To illustrate this relationship clearly, a performance diagram will be analysed that reflects how a typical tugboat engine responds across various RPM levels.

The diagram highlights three key indicators:

- Specific Fuel Consumption (SFC), which measures efficiency (in grams per kilowatt-hour),
- Total fuel consumption (kg/h), which shows absolute fuel usage,
- Engine load (%), which reflects the engine's power output relative to its full capacity.

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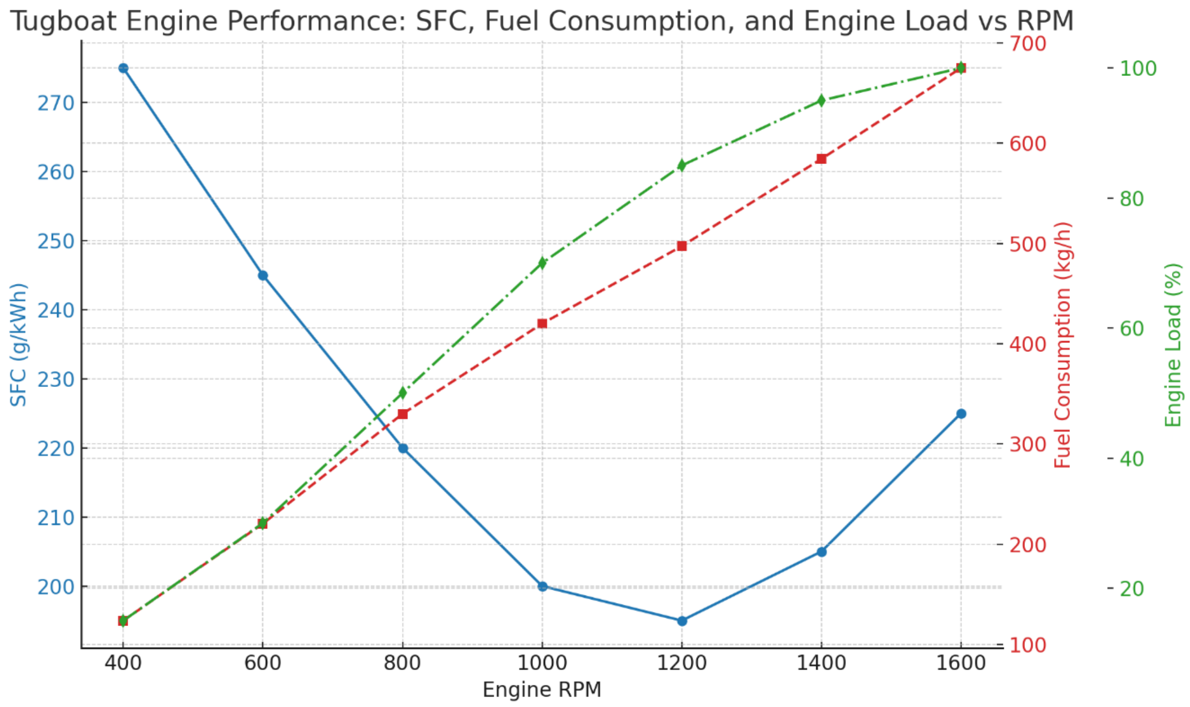

Figure 17. Tugboat engine performance curves: relationship between RPM, fuel efficiency, and engine load

(Source: Simulated performance data based on standard marine diesel engine characteristics for harbour tugboats. Developed for educational use in the GREENPORT VET course on Sustainable Maritime Operations.)

SFC and engine efficiency curve (blue line)

The blue line shows the Specific Fuel Consumption (SFC) across the RPM range. SFC indicates the amount of fuel required to produce one kilowatt-hour (kWh) of energy. As seen in the graph, SFC is high at low RPM — around 275 g/kWh at 400 RPM — due to inefficient combustion and poor turbocharger performance. As the engine approaches its optimal load range (1,000–1,200 RPM), the specific fuel consumption (SFC) drops significantly, reaching its lowest point (~195 g/kWh), indicating peak fuel efficiency. Beyond this, SFC starts to rise again slightly, suggesting diminishing returns as the engine is pushed toward maximum capacity.

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Fuel consumption trend (red dashed line)

The red dashed line shows the actual fuel consumption in kilograms per hour. Unlike SFC, this value indicates the amount of fuel the engine is consuming, regardless of its efficiency. As expected, fuel consumption increases steadily with RPM, from around 124 kg/h at 400 RPM to nearly 575 kg/h at 1600 RPM. This increase is natural because the engine is generating more power and thus requires a greater fuel input. However, the key takeaway is that a higher fuel burn rate does not always indicate inefficiency, especially when it is offset by a lower specific fuel consumption (SFC) and higher propulsion output.

Engine load dynamics (green dot-dash line)

The green line represents engine load as a percentage of total capacity, which rises proportionally with RPM. At low RPM (400), the engine is only loaded around 15%, which is inefficient for marine diesels. As RPM increases, the engine is gradually loaded more effectively, reaching 100% at 1600 RPM. This trend reflects how power output — and consequently mechanical stress and thermal efficiency — change with engine speed.

The diagram shows that:

- Operating the engine at very low RPM (e.g. 400–600) results in high SFC and low engine load, indicating poor efficiency and potential engine fouling.
- The engine reaches optimal fuel efficiency around 1000–1200 RPM, where SFC is at its lowest and load is balanced, making this range ideal for eco-efficient manoeuvring.
- At high RPM (1400–1600), the engine consumes more fuel overall, and while power increases, efficiency starts to decline again.

Understanding this curve allows navigation officers to adjust their propulsion strategies to align with sustainable navigation principles, especially when planning approaches, slow steaming, or tug operations.

The combined graph shows a clear sweet spot: operating the engine in the 1000–1200 RPM range not only keeps fuel consumption within manageable levels but also ensures maximum efficiency (the lowest Specific Fuel Consumption, SFC) and effective engine loading. This is the operating condition you want to target when

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applying eco-navigation principles. Operating below or above this range may result in higher emissions, increased maintenance needs, and reduced economic and environmental performance. In practice, this means bridge teams and engineers must coordinate carefully: balancing thrust demand, environmental conditions, and manoeuvring needs, while keeping the engine close to its optimal range for most of the voyage, especially during port approaches.

Table 26. Estimated fuel consumption and CO_2 emissions for a tugboat at different RPM and load conditions

Case	Engine RPM	Engine Load (%)	Power Output (kW)	Specific Fuel Consumption (g/kWh)	Fuel Consumption (kg/h)	CO_2 Emissions (kg/h)
Case A – Low Load	600	30%	900.0	245	220.50	686.64
Case B – Optimal Load	1200	85%	2550.0	195	497.25	1548.44
Case C – Full Load	1600	100%	3000.0	225	675.00	2101.95

- **Case A** reflects low-load operation, with the engine running inefficiently. The SFC is high (245 g/kWh), and despite lower power output, the emissions per unit of power are excessive.

- **Case B** represents the optimal operating range. Here, the engine operates most efficiently with the lowest SFC (195 g/kWh), achieving a good balance between power output and environmental performance.

- **Case C** shows maximum engine load, where total fuel and emissions are highest. Although more power is generated, the efficiency drops compared to the optimal zone.

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Chapter 7 Supporting material

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Objectives

This module is designed to provide pilots and tug masters with practical experience in eco-navigation and ship handling by using simulators to test how operational choices affect safety, fuel efficiency, and emissions during port approaches and berthing.

Navigation scenario objectives:

- Identify key environmental best practices during port approach
- Evaluate the fuel and emission impact of inefficient vs. efficient manoeuvring
- Apply sustainable navigation and shiphandling principles
- Reflect on how real-world decisions impact emissions

Scope of simulation:

Observe and identify energy-efficient ship-handling behaviours that achieve safe and effective outcomes with minimal power
Recognise when momentum, wind, and tide can be harnessed to support manoeuvring
Compare strategies that use tugs at lower power for longer durations versus short bursts at high power

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Lesson plan

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[1] Presentation of Simulation scenario and its objective
Use Navigation Simulator to run a 2-stage exercise: Case 1 - without concern for best practices, and Case 2 - applying all the best practices {Table 1)

[2] Bridge Procedures Guide - Brief review of the the four stages to achieve a safe passage plan
Appraisal, Planning, Execution, Monitoring

[3] Pre-exercise quiz
Assess learners' understanding of eco-navigation before starting the simulator session

[4] Conduct the exercise
Maintain records (Table 2) and prepare the comparison data for the two Cases (Table 3)

[5] Debriefing and evaluation
Session guided by questions – individual and group debriefing

[6] Case study
Reflect on how a typical tugboat engine responds across various RPM levels

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1. Simulation scenario

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<table>
<tr><td colspan="2">Simulator system : Wartsila - Transas Navi-Trainer Pro 5000, Kongsberg, or similar</td></tr>
<tr><td colspan="2">Scenario: Large vessel approaching port, requiring tug assistance, with tide and wind. The vessel must be swung to face the tide and placed safely alongside.</td></tr>
<tr><td colspan="2">Navigation area: Port approach (based on the areas available at the training centre)</td></tr>
<tr><td colspan="2">Environmental settings: Tide and wind</td></tr>
<tr><td colspan="2">Traffic: Moderate density, 1 outbound ferry, 1 tug available</td></tr>
<tr><td colspan="2">Sensors Enabled: ECDIS, Radar, Engine output monitor</td></tr>
<tr><td colspan="2">Route scenario: Approach to Port through fairway Buoy xx to Berth xx</td></tr>
<tr><td>Case 1. Simulate inefficient arrival manoeuvring

Objective: Highlight the environmental and operational inefficiencies from inefficient practices
Conditions
• Excessive engine use (frequent RPM changes)
• Abrupt rudder movements and hard helm orders
• Tug engaged late, forced to use high bollard pull
• Poor use of current (tide – depending of navigation area) and wind (counteracting forces instead of using them)
• No use of ECDIS for advance planning
Outcomes
• Higher fuel consumption & emissions
• Longer time to berth
• Unstable approach, requiring repeated course corrections
• Increased tug workload
• Delayed docking
Notes to be recorded
• Engine RPM log
• Fuel/emissions output
• Time to berth
• Number of tug interventions</td><td>Case 2: Best practice manoeuvring

Objective: Apply eco-navigation principles for optimal environmental performance
Conditions
• Maintain steady RPM (eco-speed steaming)
• Advance route planning with ECDIS, including wind/tidal/current optimisation
• Early coordination with tug and VTS
• Use tide and wind to assist swing manoeuvre
• Tug applies moderate, steady thrust rather than repeated high-power pushes
• Real-time monitoring of engine load and tug fuel consumption
Outcomes
• Lower fuel consumption
• Precise docking with minimal delays
• Reduced emissions and better energy profile
• Stable vessel handling with fewer corrections
Notes to be recorded
• Log engine RPM
• Fuel usage/ emissions
• Time to berth
• Number of tug interventions</td></tr>
</table>

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2. Bridge Procedures Guide

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The four stages to achieve a safe passage plan:

- Appraisal – collect and asses all relevant information required for the intended voyage
- Planning – develop and approve the passage plan, based on the outcome of appraisal
- Execution – navigate in accordance with the passage plan
- Monitoring – check the progress of the ship against the passage plan

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2. Bridge Procedures Guide (cont.)

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Coastal routes:

- Charted features and other features for safe distance;
- Available depth of water including tidal water level information;
- UKC requirements and other limiting conditions;
- Currents, tidal currents;
- Landmarks and AtoNs, availability of visual and radar fixing opportunities;
- Recommended routes and channel information, local conditions and restrictions on navigation, traffic likely to be encountered;
- Navigational warnings;
- Pilotage requirements and services, procedures (a pilotage plan is required);
- Port requirements, port facilities, procedures for port entry;
- Reporting and communication procedures;
- Details of the prospective berth and anchorages;
- Meteorological information;
- Environmental protection measures.
- Ship' routeing and reporting system, VTS;
- MSI services and communications

Berthing / pilotage:

- Arrival intentions including embarkation time, arrangements for cargo discharge and bunkering;
- Communications should be established with Pilot, port VTS and port authorities as appropriate;
- Pilotage plan subject of Master/pilot information exchange;
- Updates on local conditions such as weather, depth of water, tides and tidal streams, traffic conditions;
- Information on berthing arrangements including the use, characteristics and number of tugs, mooring boats, mooring arrangements and other external facilities.

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3. Pre-exercise quiz

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1. When handling a vessel in port, what strategies could you use to reduce engine or tug power without compromising safety? Can you think of a past example where momentum, tide, or wind helped in manoeuvring?

2. What role does early coordination with tugboats and VTS play in reducing fuel consumption during port manoeuvring?

Focus areas during simulation

- Digital modelling: use port-specific ECDIS and tide/current overlays
- Momentum management: allow vessel inertia to assist manoeuvres instead of overusing engines
- Safety first: efficiency gains must not compromise navigational safety
- Optimised tug use: identify when tug masters can achieve more with less energy input
- Joint communication: ensure pilot and tug master exchange intentions early and clearly

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4. Conduct the exercise

Requirements from trainees
- Complete records to be maintained throughout exercise
- Use of appropriate checklists relevant to operation
- Reference to sustainability and ships performance to be made during set up and throughout exercise
- Reference to environmental throughout exercise
- Clear and relevant communications to all parties

Metric	Case 1	Case 2
Distance travelled		
Fuel used/ CO2 emitted		
Time to berth		
Course deviation		
Tug interventions		
Fuel used by tug/ CO2 emitted		
Total emissions		

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5. Debriefing and evaluation

1. What specific decisions or actions in Case 1 led to higher fuel use and emissions?
Reflect on poor practices like excessive throttle use, delayed tug calls, or ignoring ECDIS guidance.

2. How did you change your navigation plan or execution in Case 2 to align with eco-navigation principles?
Reflect on strategies like early tug coordination, route monitoring, use momentum to assist manoeuvres.

3. If you were to apply what you learned from Case 2 in real port operations, what would you prioritise and why?
Connect simulator experience with real-world actions, such as planning for engine load zones or reducing thruster overuse.

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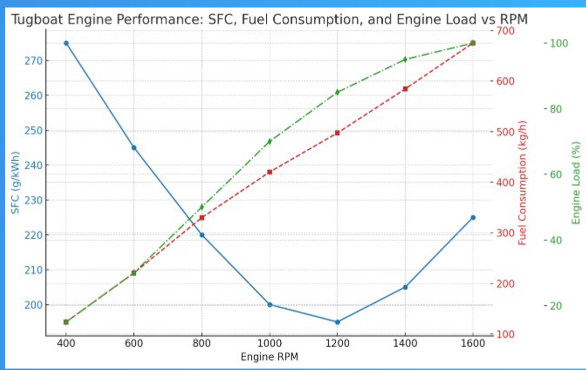
5. Case study

Eco-navigation is more than a regulatory requirement

It is a practical strategy to reduce fuel consumption, lower greenhouse gas (GHG) emissions, and improve operational efficiency.

Among the many factors that influence a ship's environmental footprint, one of the most critical is the engine's operational behaviour, particularly regarding RPM, fuel efficiency, and load management



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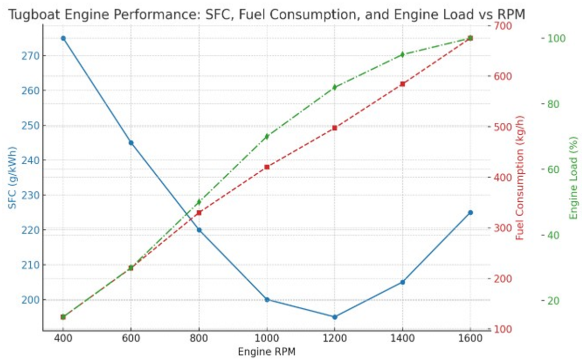
Three key indicators

Specific Fuel Consumption (SFC) which measures efficiency (in grams per kilowatt-hour)

Total fuel consumption which shows absolute fuel usage (in kg/h)

Engine load dynamics which reflects the engine's power output relative to its full capacity (in %)



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Discussions

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Case	Engine RPM	Engine Load (%)	Power Output (kW)	Specific Fuel Consumption (g/kWh)	Fuel Consumption (kg/h)	CO_2 Emissions (kg/h)
Case A Low Load	600	30%	900.0	245	220.50	686.64
Case B Optimal Load	1200	85%	2550.0	195	497.25	1548.44
Case C Full Load	1600	100%	3000.0	225	675.00	2101.95

- **Case A** reflects low-load operation, with the engine running inefficiently. The SFC is high (245 g/kWh), and despite lower power output, the emissions per unit of power are excessive.
- **Case B** represents the optimal operating range. Here, the engine operates most efficiently with the lowest SFC (195 g/kWh), achieving a good balance between power output and environmental performance.
- **Case C** shows maximum engine load, where total fuel and emissions are highest. Although more power is generated, the efficiency drops compared to the optimal zone.

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Module number 7 | Course Name: Sustainable Maritime Operations and Green Port Technologies

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Chapter 8: Final reflections and course wrap-up

The purpose of this final session is to consolidate the knowledge gained throughout the course, encouraging participants to reflect on the insights drawn from the simulation exercises. It aims to connect the theoretical foundations of sustainable maritime operations with their practical application in real-world port environments. Finally, the session provides an opportunity to define concrete next steps for implementing eco-navigation, ship handling principles, and sustainability practices in daily operations.

8.1. Group discussion on simulation insights

The first part is dedicated to a simulation scenario, with the following guiding questions for group reflection:

- How can natural elements such as tides and wind be used strategically to support efficient operations?
- In what ways does effective communication between stakeholders contribute to operational efficiency and sustainability?
- Identifying sustainable behaviours in ship handling and eco navigation.
- Were there any moments when safety might have been compromised by focusing too much on energy saving? How can safety be ensured while pursuing efficiency and energy-saving measures?
- What would you do differently next time to balance safety, time, and energy efficiency?

Suggested activity for preparing the reflection session:

- Split participants into small groups (3–4 people).
- Each group lists 3 lessons learned from the simulation.
- Share findings in plenary, linking to theory from sessions 1-5.

8.2. Consolidation of learning outcomes

Theory and practice together prove that sustainable port operations are achievable through a balance of technology, behavior, and cooperation. Trainer recaps the achievements, connecting theory to practice:

- Introduction (Session 1): Safety first; sustainability complements navigation, never compromises it.

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- Regulations (Session 2): EU & IMO frameworks (Green Deal, Fit for 55, FuelEU Maritime, ETS, NZF) set the direction, even if port services are not directly regulated.
- Technology (Session 3): Emerging solutions (OPS, ShaPoli, alternative fuels) and industry examples (HVO, hydrogen, hybrids) show innovation is real but costly.
- Operational strategies (Session 4): Quick wins from eco-speed steaming, tidal scheduling, real-time fuel monitoring, and data-driven behavioural change.
- Stakeholder engagement (Session 5): Collaboration and clear communication are as critical as new technology.
- Recap and Reflections (Session 6): Consolidation of learning outcomes, highlighting that small operational changes can make a big impact, with COM-B behavioural change framework linking capability, opportunity, and motivation to sustainable practices.
- Simulation (Session 7): Eco-navigation principles applied in practice show measurable improvements in fuel use, emissions, and teamwork.

8.3. Feedback and next steps

Consider and share with other participants how the environmental concepts and practices discussed can be applied in your own operational context.

The following questions are designed to stimulate dialogue on practical application, potential challenges, and the role of leadership and technology in driving sustainable change.

- Which eco-navigation and ship handling practices will you try to implement first in your local operations?
- What barriers (infrastructure, costs, culture) may you face, and how can they be overcome?
- How can leadership and peer influence accelerate change within your teams?
- How can communication and cooperation between different port stakeholders (pilots, tug crews, terminal planners, VTS, authorities) be improved to support sustainability goals?
- What role should digital tools play, and where must human judgement remain central?

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This course encourages players in the maritime industry to take small but consistent actions (e.g., implementing green speed practices, improving tug coordination, supporting just-in-time arrivals) that can lead to measurable change in daily operations. While these actions may seem minor at an individual level, their collective impact across ports contributes directly to the achievement of EU and IMO decarbonisation targets.

Sustainable maritime operations are not achieved by technology alone, nor by regulation alone. They require every pilot, tug master, and port operator to make informed, cooperative, and proactive decisions.

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Chapter 8 Supporting material

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Purpose of the session

- Consolidate knowledge from all modules
- Connect theory with practice from simulations
- Encourage reflection on daily application
- Define concrete next steps for sustainable operations

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Simulation insights: Reflection questions

- How can tide and wind support efficient manoeuvres?
- What role does stakeholder communication play in efficiency and sustainability?
- Which sustainable behaviours were identified during ship handling?
- Did energy-saving ever risk compromising safety?
- What would you do differently next time?

Group reflection activity: Split into small groups (3–4 participants); Each group lists 3 key lessons learned; Share in plenary session

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Consolidation of learning outcomes

- Understand sustainability concepts and environmental regulations (Green Deal, Fit for 55, FuelEU, EU ETS/IMO NZF) (Sessions 1, 2)
- Best practices and real-world examples of sustainable operations (e.g., alternative fuel, hybrid tugboats, OPS) (Sessions 3, 5)
- Emissions monitoring and digital for observing the evolution of emissions and fuel use (Session 3)
- Operational strategies: Eco Speed Steaming, scheduling with tidal windows (Session 4)
- Use energy saving techniques, identify and implement fuel-efficiency practices (Session 4)
- Change of operational behaviour to contribute to cleaner seas, green port operations, and eco-friendly logistics (Sessions 4,5,6,7,8)
- Simulation – applying eco-navigation in practice (Session 7)
- Practice teamwork, decision-making, and fuel-saving strategies in a simulated environment (Session 7)

This recap shows how each module builds towards a holistic view of sustainable port operations.

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Feedback & Next Steps

- Which eco-navigation or handling practices will you try first?
- What barriers (infrastructure, cost, culture) may arise?
- How can leadership & peer influence drive change?
- How can stakeholder cooperation be improved?
- What role should digital tools play vs. human judgement?

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Final takeaway

- ❑ Small, consistent actions → measurable improvements
- ❑ Collective impact supports EU & IMO decarbonisation targets
- ❑ Sustainable change relies on informed, cooperative decisions

Sustainable maritime operations are not achieved by technology alone, nor by regulation alone. They require every pilot, tug master, and port operator to make informed, cooperative, and proactive decisions.

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Module number 8 | Course Name: Sustainable Maritime Operations and Green Port Technologies

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Final Evaluation Test

Emission reduction theory and regulations

1. **Which pollutant from ships is linked to coastal communities' health?**
   A. Sulphur oxides (SOx)
   B. Carbon monoxide (CO)
   C. Black carbon (BC)
   D. Ozone (O_3)

2. **Which of the following qualifies as a *regulatory measure* for ports?**
   A. Crew eco-training
   B. Hybrid tug adoption
   C. Mandatory emission reporting and differentiated port fees
   D. Reduced vessel speed profiles

3. ***The FuelEU Maritime regulation is distinctive because it:***
   A. Applies only to inland waterway craft
   B. Requires the use of LNG across the EU
   C. Sets progressively stricter limits on the GHG intensity of energy used on board ships
   D. Targets only offshore support vessels

4. **Under EU ETS, shipping companies must submit verified emissions reports:**
   A. Once every five years
   B. Annually by 30 April
   C. Every voyage completion
   D. Only upon request of the port authority

5. **Which ship category remains exempt from the MRV Maritime Regulation?**
   A. General cargo ships above 400 GT
   B. Warships and naval auxiliaries
   C. Offshore vessels over 5000 GT
   D. Passenger ferries on EU voyages

Industry ecosystem and technological landscape

6. **OPS is considered a more complex operationally because:**
   A. It requires no change in berthing procedure

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B. Precise positioning is needed to align the vessel's connection points with the quay interface
C. It eliminates the need for shore technicians
D. It only applies outside the EU

7. **Which hazard is particularly associated with methanol bunkering?**
A. High storage pressure
B. Toxic, flammable vapours heavier than air that accumulate at low points
C. Cryogenic burns
D. Rapid corrosion of steel tanks

8. **Ammonia-fuelled vessels pose operational risks mainly due to:**
A. High flammability only
B. Extreme toxicity and corrosiveness requiring enhanced safety protocols
C. Compatibility with diesel engines
D. Cryogenic temperatures

9. **A key reason pilots and tug masters have expressed concern about ShaPoLi** is:
A. It reduces manoeuvring responsiveness by limiting power and removing quick "engine kicks."
B. It makes vessels exceed speed limits in port
C. It improves acceleration but consumes more fuel
D. It automatically disengages tug lines

10. **Which port authority has published user navigation guidelines requiring advance ShaPoLi notification?**
A. Barcelona
B. Hamburg
C. Southampton
D. Marseille

Operational strategies

11. **Which principle explains why eco-speed steaming saves fuel?**
A. Hydrodynamic resistance rises exponentially with vessel speed
B. Propellers become more efficient at higher speeds
C. Engines use less fuel at maximum load
D. It eliminates tidal influences

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12. **Tidal window scheduling is particularly beneficial for:**
    A. ***Deep-draft vessels requiring under-keel clearance in shallow channels***
    B. All pilot boats regardless of draft
    C. Vessels using LNG bunkers only
    D. Ferry services on fixed schedules

13. **A benefit of real-time fuel consumption displays for tug crews is:**
    A. They remove the need for tug dispatch planning
    B. They allow crews to fine-tune throttle use during active assists
    C. They predict future maintenance costs
    D. They replace emissions reporting

14. **Which pre- or post-job measure reduces unnecessary tug fuel consumption?**
    A. Idling near berths awaiting calls
    B. Returning to base at eco-speed rather than loitering
    C. Running engines continuously for readiness
    D. Departing much earlier than needed

15. **Data-driven feedback programs in ports are most effective when:**
    A. Crews receive generic yearly reports
    B. ***Operators are provided with job-specific comparisons and prompt feedback on performance***
    C. Data is aggregated only for port authorities
    D. Reports exclude emissions data

Communication and stakeholder engagement

16. **Digital platforms like port community systems improve sustainability by:**
    A. Allowing stakeholders to access and update real-time ETAs, berth readiness, and tug allocation
    B. Replacing the role of VTS entirely
    C. Collecting only emissions data
    D. Eliminating the need for environmental offices

17. **In the RACI model, who is typically *Accountable* for berth readiness updates?**
    A. Terminal operations
    B. Pilotage service
    C. Towage provider
    D. VTS

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18. Closed-loop communication reduces errors by:

A. Sending written confirmation one week later

B. Having the receiver repeat back instructions for verification

C. Uploading instructions to a port website

D. Using loudhailers on deck

19. Which cyber risk threatens digital aids by making GPS data unavailable?

A. Signal jamming

B. Credential theft

C. Ransomware

D. Data manipulation

20. Best practice when using digital aids such as PPUs is to:

A. Use them without redundancy

B. Trust them exclusively

C. Ignore simulator training

D. Cross-check with radar, ECDIS, and visual references

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FINAL REMARKS

The development of this Vocational Education and Training (VET) course represents a significant achievement within the GREENPORT Project, addressing the pressing need to align port services with European and international decarbonization strategies. The eight modules compiled in this handout provide a coherent, practice-oriented curriculum that balances theoretical understanding with applied learning, ensuring participants gain both knowledge and operational competence. Pilots, tug masters, and port service personnel are equipped with tools to enhance efficiency, reduce emissions, and contribute actively to the sustainability objectives of the maritime industry.

In line with the Grant Agreement, the course integrates key EU and IMO frameworks (Green Deal, Fit for 55, FuelEU Maritime, EU ETS, and IMO's Net-Zero Fuels Strategy), while maintaining focus on the indirect yet vital role of port service providers in supporting shipowners' compliance and competitive advantage. The structured approach—ranging from regulatory context and technological innovations to operational strategies, behavioral change, and simulation-based eco-navigation—ensures that learners build both capability and motivation to adopt sustainable practices. The use of the COM-B framework for behavior change, combined with real-time data tools and case-based learning, directly addresses the grant's emphasis on reskilling for future-proof operations.

The piloting methodology, including blended learning with a minimum of 40% face-to-face instruction and simulator sessions, guarantees the practical applicability of knowledge. This responds to WP5 requirements for testing and ensures alignment with EQAVET standards. The focus on interactive simulation exercises strengthens decision-making, teamwork, and eco-handling skills, preparing participants to meet evolving industry and client expectations. Moreover, the evaluation strategy—using KPIs on engagement, retention, and real-world CO_2 impact—supports both quality assurance and evidence-based refinement.

Ultimately, the GREENPORT VET course embodies the consortium's vision of delivering an accredited, transferable training programme that can be scaled beyond the pilot ports. By combining regulatory awareness, technological adaptation, and behavioral change, the course contributes to the European Green Deal targets and positions vocational training as a cornerstone of sustainable port transformation. Its successful implementation will not only strengthen professional competencies but also reinforce trust between VET institutions, industry stakeholders, and policymakers, ensuring lasting impact across the port services sector.

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