



From Gases and Evaporators risk assessment towards an Integrated management of sea and land pollution incidents

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**D4.2 – Report on key considerations for crisis managers operating in port areas:
Interviews with crisis manager**

31/03/2026



Co-funded by
the European Union



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IMT Mines Alès



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Work Package 4

Task 4.3

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1.Introduction

A release of LNG from an old or damaged underwater pipeline can result in a serious environmental disaster. Therefore, it is crucial to identify and understand potential incident scenarios in order to improve response strategies and mitigate impacts. This work was carried out in Task 3.2, which was organized into three subtasks.

The European MANIFESTS *Genius* research project, which aims to strengthen preparedness and response capabilities in the event of accidental pollution of coastal waters. This part of project proposes to carry out an assessment of the management of risks and accidental situations related to new propulsion energies in major European ports.

In this report, we are conducting a questionnaire aimed at collecting feedback from port authorities to propose main recommendations.

The survey is intended for port authorities and professionals involved in port governance, safety, operations, and infrastructure.

The objective is to better understand for ports:

- the current level of deployment of these new energies in ports,
- the risks and experienced in relation to the ships powered by these new fuels in ports,
- and the adaptation of port infrastructures, organizations, and regulatory frameworks in relation to the venue of these ships in ports.

The results will contribute to a broader reflection on best practices and future challenges related to new energies in the port sector.

The following report is structured as follows. After an introduction setting out the issues, the second section presents the questionnaires developed as part of this project, which were used to consult port managers, and analyses their responses (sections 3 and 4). Finally, some key recommendations and a conclusion (section 5 and 6) bring the document to a close.

2. Development of information collecting tools

Two types of questionnaires were developed, one for face-to-face interviews and the other for consulting stakeholders by email. The structures proposed for each of these are presented later in this section.

2.1. Questionnaire for the interviews

This questionnaire is divided into three sections:

- Profile of the interviewee and the current status of new energy use in the port
- Identify new energies for ship propulsion and the associated risks
- Characterise the capacity of port infrastructure to adapt to the use of new energies

The open-ended and fairly broad questions allow respondents to develop their thoughts while returning to specific points, as some of the questions overlap. All the questions are presented in the following paragraphs:

Questionnaire type 1 developed for interviews

2.1.1. Part 1: Interviewee and current infrastructure for risk control and crisis management with regard to the use of new energies

Expected outcomes: Assessment of the use of new energy sources on ships entering the port and its impact on port infrastructure.

- Can you tell us what new energies are currently being used on ships entering the port of Le Havre (within the management perimeter of the Harbour Master's Office and the port area)?
- What activities, territories and areas are affected by the development of new energies within the management perimeter of the Harbour Master's Office and the port area?
- What are the consequences of using these new energies on port infrastructure, safety and emergency procedures?
- Have you had any incidents or near-accidents on your infrastructure? If so, which ones? Did they involve a new energy source? What would the consequences have been if a new energy source had been involved?

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- Are you aware of any notable accidents in port infrastructure involving new energy sources? If so, can you describe them (causes, sequence of events, consequences)?
- What is the role of the Harbour Master's Office in managing risks and crises related to accidents involving renewable energy sources?

2.1.2.Part 2: New energies for ship propulsion: which ones and what are the associated risks?

Expected outcomes: Assess the needs and level of preparedness and/or capacity of port sites to address these issues and challenges.

- What do you think will be the next major advances in new energies for your port?
- Can you list the possible energies that are not currently used in the port but could be used in the future?
- For each of these, what do you think are the associated risks?
- What stages in the life cycle of port infrastructure are threatened by the arrival of new energies? (During transport? During storage? During distribution? During ship manoeuvring?)
- What are the key factors to consider now, and have you put a strategy in place to better anticipate these new risks?
- Are the skills of port infrastructure services sufficient to manage the risks associated with the use of new energies, or do they need to evolve? If so, how?
- Do you think that certain current legislation should be amended to better consider the risks associated with the use of new energies in ports?

2.1.3.Part 3: Evolution of port infrastructure in response to the use of new energies

Expected outcomes: Identify the overall adaptations that will be necessary to develop port infrastructure in order to manage risks.

- What would be the main obstacles to the introduction of new energies in the port?

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- In your opinion, what will be the annual requirements for new energy sources in 5, 10- or 20-years' time? In terms of quantity? Type of energy?
- If you have new energy distribution and storage infrastructure in your port, will it be sufficient to meet this future need?
- If not, how do you plan to transport and store the necessary energy?
- Are there any activities in your port that could simplify the arrival of certain types of energy? If so, which ones?
- Are structural changes to the port necessary to adapt to new energies? Which ones:
 - Lack of land
 - Financial aspects
 - Authorisation (Authorities)
 - Project acceptability (citizens)
- How do you view this development? (Risk/opportunity)

2.2. Questionnaire for consultation by email

Based on the analysis of the first three interviews (see section on interview results and analysis), a new questionnaire was developed in order to consult stakeholders via email. It is structured as follows:

1. Port infrastructure overview
2. Current Status of New Energies in the Port
3. Perceived Risks and Feedback
4. Port Preparedness and Capabilities Regarding the Use of New Energies
5. Regulatory framework and governance in the context of the use of new energies for ship propulsion
6. Infrastructure Development and Future Outlook

Title: Risk Management in Ports Related to the Use of New Energies for Ship Propulsion

Objective: This questionnaire aims to gather, through a quantitative approach, the views of port authorities regarding the development of new ship propulsion energies, the associated risks, and the adaptation of port infrastructures and organisations.

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Estimated completion time: 10–15 minutes.

1. Port infrastructure overview

1.1. Name of the Port/ Country:

1.2. Your main role within the port:

- Management / Executive
- Harbour Master's Office / Port Authority
- Safety / Security / Crisis Management
- Technical / Infrastructure
- Other (please specify)

1.3. Main port activities (multiple answers possible):

- Liquid bulk
- Dry bulk
- Pressurised liquefied gas
- Containers
- SEVESO industrial site within the port area
- Passenger traffic

2. Current Status of New Energies in the Port

2.1. Which new energies are currently present or used in your port? (Multiple answers possible)

- Liquefied Natural Gas (LNG)

Level of operational maturity:

- Experimental
- Limited
- Good
- Excellent

Main operations concerned:

- Ship-to-ship bunkering
- Truck-to-ship bunkering
- Port storage

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- Local industrial production

- Methanol

Level of operational maturity:

- Experimental
- Limited
- Good
- Excellent

Main operations concerned:

- Ship-to-ship bunkering
- Truck-to-ship bunkering
- Port storage
- Local industrial production

- Hydrogen

Level of operational maturity:

- Experimental
- Limited
- Good
- Excellent

Main operations concerned:

- Ship-to-ship bunkering
- Truck-to-ship bunkering
- Port storage
- Local industrial production

- Ammonia

Level of operational maturity:

- Experimental
- Limited
- Good
- Excellent

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Main operations concerned:

- Ship-to-ship bunkering
 - Truck-to-ship bunkering
 - Port storage
 - Local industrial production
- Batteries / Electric vehicles

Level of operational maturity:

- Experimental
- Limited
- Good
- Excellent

Main operations concerned:

- Ship-to-ship bunkering
 - Truck-to-ship bunkering
 - Port storage
 - Local industrial production
- None to date

3. Perceived Risks and Feedback

3.1. In your opinion, the most critical phases in terms of risk related to the use of these new energies are (multiple answers possible):

- Bunkering
- Storage
- Internal transport (trucks, pipelines, etc.)
- Nautical manoeuvres
- Berthing at quay

3.2. Have you already experienced:

- An incident involving a new energy
- A near-miss
- No event to date

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3.3. For each energy source, assess the perceived level of risk:

Energy	Low	Moderate	High	Very high
LNG	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Methanol	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hydrogen	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ammonia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Batteries	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3.4. Is there a specific emergency response protocol shared with local emergency services (fire brigade, civil protection) for accidents/incidents involving these new energies?

- Yes
- No

4. Port Preparedness and Capabilities Regarding the Use of New Energies

4.1. The level of preparedness of your port regarding risks related to new energies is:

- Insufficient
- Under development
- Satisfactory
- Very satisfactory

Please specify, in particular any existing gaps:

4.2. Does your port have the following? (Yes / No)

- Specific procedures Yes No
- Appropriate detection equipment Yes No
- Appropriate protective equipment Yes No

4.3. Current staff competencies are:

- Adequate
- Partially adequate
- Inadequate

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Please specify:

4.3. Does port staff benefit from the following? (Yes / No)

- Dedicated training Yes No
- Crisis management exercises Yes No

5. Regulatory framework and governance in the context of the use of new energies for ship propulsion

5.1. The current regulatory framework is:

- Clear and sufficient
- Partially adapted
- Insufficient
- Hindering development

Please specify:

5.2. Regulatory developments are needed to (multiple possible answers)

- Clarify responsibilities
- Better regulate new energies
- Harmonise practices between ports

6. Infrastructure Development and Future Outlook

6.1. Current port infrastructure can adapt to new energies:

- Yes, without major modification
- Yes, with targeted adaptations
- No, significant transformations are required

6.2. The main barriers identified are (multiple answers possible)

- Land availability
- Financial constraints
- Social acceptance
- Administrative authorisations

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- Technological uncertainties

6.3. Over a 10–20-year time horizon, the development of new energies in your port is perceived as:

- A major opportunity
- An opportunity under certain conditions
- A significant risk
- An imposed constraint

The two questionnaires described below were used: the first to conduct three interviews with major French ports, and the second to consult ports across European countries. The results are presented in sections 3 and 4 of the report respectively.

3. Analysis of collected data during interviews and initial results

The following section presents an analysis of interviews on the use of new energies and port infrastructure for the ports of Marseille, Le Havre and Saint Nazaire. At the end of this section, a cross-analysis of the three interviews allows us to draw up some initial recommendations.

3.1. Port of Marseille

Based on the audio file recorded during the interview with representatives of the Marseille harbour master's office, the following points can be highlighted.

3.1.1. Your activity & the current state of new energies in the port

a) Nature of port activity

The Grand Port Maritime de Marseille (GPMM) is clearly positioned as:

- Port and police authority (infrastructure management, security, authorisations),
- Industrial and energy facilitator, but not operator of bunkering operations (private service providers).

This distinction is fundamental: the port does not buy or sell energy, but creates the regulatory, technical and safety conditions that enable operators and shipowners to operate.

b) Current status of new energies

LNG is a dominant and mature energy

- LNG is currently the only fully operational sector.
- Marseille Fos is one of the first ports in the world to have implemented ship-to-ship LNG bunkering since 2020.
- Approximately 90 refuelling operations per year, with:
 - a dedicated supply vessel,
 - several classes of vessels already 'approved',
 - solid feedback.
- LNG is integrated into a robust administrative and safety process, which now serves as a model.

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LNG is currently the backbone of the port energy transition.

Other fuels: exploratory phase

- Methanol, hydrogen, ammonia:
 - no regular operations yet,
 - but emerging demand and pilot projects (particularly hydrogen for large pleasure craft).
- The port is deliberately adopting a technologically neutral stance:

‘We don't know which fuel will prevail, so we're keeping our options open.’

Electrification of quays

- Deployment already well advanced:
 - 9 stations equipped,
 - Objective: cruise terminals operational by 2028.
- The GPMM is ahead of European regulations (AFIR – target date 2030).
- Current limitation: fleet compatibility (many vessels not equipped).

Electrification is a concrete pillar of decarbonation.

3.1.2. New energies: current and future risks

a) Technological risks

Uncertainty regarding fuels

- No dominant fuel in the medium term:
 - U-turn by major shipowners (e.g. methanol → LNG),
 - Human and social acceptability (ammonia perceived as too dangerous),
 - Different physical and chemical risks (toxicity, flammability, dispersion).

The port is evolving in a context of unstable industrial choices.

Specific risks identified are:

- LNG: leaks, ATEX zones, cold gas management.
- Hydrogen: increased risks in liquid form, limited experience.
- Ammonia: acute toxicity, potential impact on nearby urban areas.
- Electric vehicles:
 - fires that are difficult to control,
 - maritime transport of batteries = new major risk factor.

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b) Operational risks

The apparition of the new activities generates:

- Increased port activity (lorries, ships, passengers, tourist areas).
- High dependence on operator training and strict compliance with procedures.
- Risk of complacency with the increase in the number of operations (routine effect).

c) Regulatory and legal risks

Concerning international regulatory gap:

- few mandatory standards outside LNG (IGF Code),
- proliferation of non-binding guides, recommendations and checklists.

A fact is a heavy responsibility for port authorities:

- They are the ones who grant authorisation,
- So, they are potentially exposed to legal liability in the event of an accident.

Hence the ongoing discussion on:

- Support for independent third-party organisations (such as classification societies),
- Strengthening the legal position.

3.1.3. Adaptation and development of port infrastructure

a) Guiding principle: adapt usage rather than build

The GPMM clearly favours:

- the functional adaptation of existing infrastructure,
- rather than heavy and irreversible investment.

In concrete terms:

- no large-scale construction of new dedicated quays,
- no fixed pipelines specific to each fuel,
- priority given to ship-to-ship transfers, which are more flexible and reversible.

b) Geographical selectivity

Some specific constraints:

- Not all quays are compatible with all fuels.
- Implementation of an 'energy label' system (e.g. LNG Ready).
- Choice of location based on:
 - the environment (urban areas vs industrial areas),

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- the results of hazard studies and modelling.

Example: impossibility of refuelling LNG trucks in the immediate vicinity of busy areas.

c) Developments already underway

But developments are underway:

- Isolation of electrical installations at certain stations,
- Integration of energy constraints into stopover planning,
- Development of detailed procedures:
 - reflex sheets,
 - crisis management,
 - systematic RETEX,
 - role of 'Person In Charge' (PIC) during sensitive operations.

d) Future limitations and uncertainties

The road ahead is not an easy one:

- Risk:
 - heavy investment today,
 - technologies potentially obsolete by 2040–2050.
- High dependence:
 - on shipowners' choices,
 - on international regulations (IMO, EU).
- Economic fragility of certain sectors (e.g. LNG suppliers).

3.1.4. General summary

The data collected shows that the Port of Marseille-Fos:

- is ahead of the curve in terms of LNG and electrification,
- is adopting a cautious but proactive strategy towards new energies,
- prioritises flexibility, safety and adaptability over fixed technological choices.

The port's energy transition is not seen as a simple change of fuel, but as a systemic transformation which considers:

- risks,
- uses,
- skills,
- and governance.

Figure 1 summarises the information obtained from the analysis of the interview conducted at the port of Marseille.

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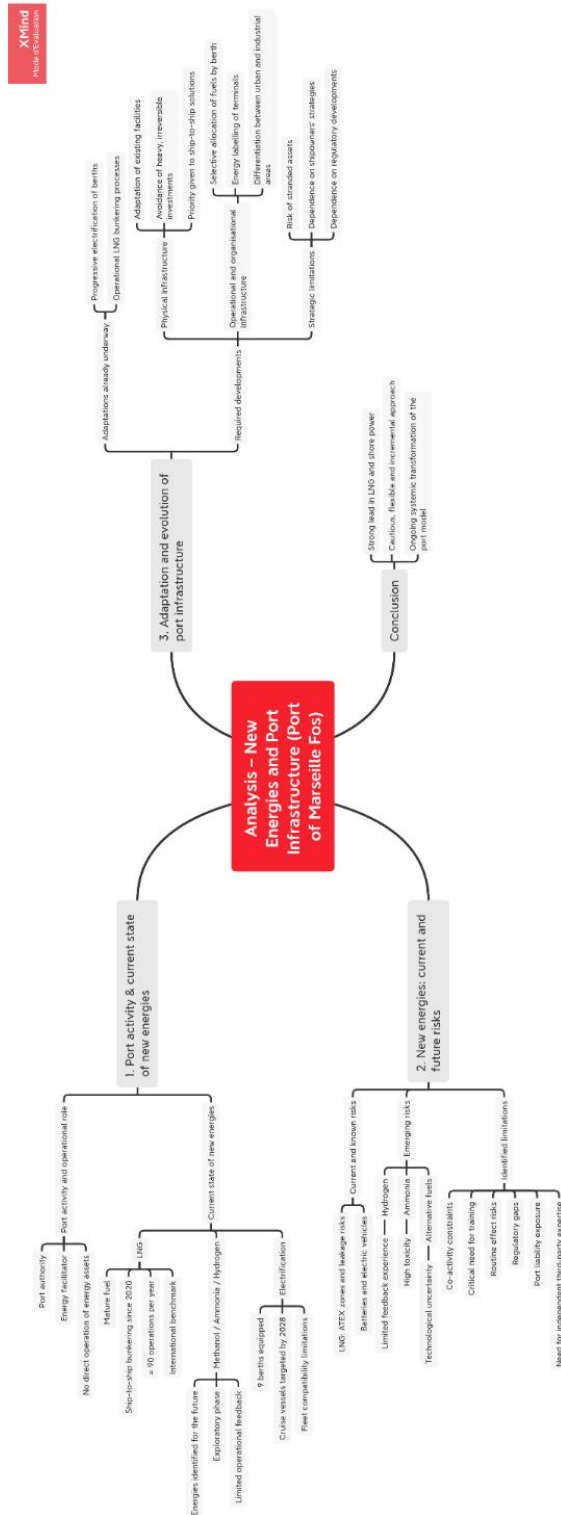


Figure 1. Information from Marseille port interview

3.2. Port of Le Havre

Based on the audio file recorded during the interview with representatives of the Le Havre harbour master's office, the following points can be highlighted.

3.2.1. Your activity & the current state of new energies in the port

a) Nature of port activity

The Port of Le Havre plays a central role in managing maritime traffic and dangerous goods, with an organisation that is highly structured around:

- the harbour master (alert relay),
- a dangerous goods office available 24 hours a day,
- procedures regulated by the Transport Code.

The port's activities mainly involve initial alerts, access control, ensuring the continuity of port operations and providing local expertise to the Commander of Rescue Operations.

b) Current status of new energies

New energies are currently being introduced gradually and are still limited in scope:

- LNG: energy already integrated, mainly via:
 - bunkering operations (ship-to-ship, truck-to-ship),
 - a floating storage vessel set up in exceptional circumstances (energy crisis).
- Methanol / Ammonia / Hydrogen:
 - identified as energies of the future,
 - not yet deployed on a large scale due to a lack of proven commercial demand.
- Transitional energies: recognition of the temporary role of LNG before a possible switch to synthetic fuels by 2050.

The port is therefore responsive and adaptable, but remains dependent on the choices made by shipowners and manufacturers, which limits its ability to fully anticipate future developments.

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3.2.2. New energies: current and future risks

a) Technological risks

The risks associated with current activities (LNG, petrochemicals, hydrocarbons) are considered to be known and generally under control, thanks to:

- proven procedures,
- alert and lockdown plans,
- close coordination with emergency services,
- systematic analysis of cargo manifests.

However, control is based on a fragile balance, as accidents occur when all safety barriers fail simultaneously, which remains a possible scenario despite a strong safety culture.

b) Operational risks

Discussions highlight several major areas of concern:

- Ammonia:
 - high toxicity,
 - risk of toxic clouds in the event of a leak,
 - proximity to the urban area of Le Havre → critical issue.
- Methanol:
 - health risks for operators (contact, inhalation),
 - significant constraints on working conditions (PPE, procedures).
- Hydrogen/synthetic fuels:
 - risks still poorly understood at port level,
 - needs for specific skills development.

c) Limitations identified

The main limitations identified are:

- Lack of shared feedback at national level.
- Absence of a stable regulatory framework for certain new energies until demand is formalised.
- Increased need for training, decision-making tools and capabilities to dispel doubts (e.g. drones, sensors).

The risk lies not so much in the energy itself as in the gap between technological innovation and operational readiness.

3.2.3. Adaptation and development of port infrastructure

a) Adaptations already underway

The port of Le Havre has demonstrated a marked capacity for adaptation:

- changes to local port regulations to incorporate LNG,
- creation of new bunkering processes,
- gradual certification of terminals,
- integration of new constraints into hazard studies.

However, these changes are being made on an ad hoc basis, in response to demand.

b) Necessary developments in the medium and long term

The discussions highlighted several key issues:

On physical infrastructure

- areas dedicated to the storage or bunkering of new energies,
- land management in a constrained context (ZAN, social acceptability),
- adaptation of existing terminals rather than creation from scratch.

On organisational infrastructure

- strengthening multi-energy crisis management capabilities,
- integration of technological tools (drones, sensors, information systems),
- cybersecurity as a new pillar of port security.

On governance and cooperation

- needs for a national or inter-port unit to:
 - pool risk analyses,
 - share feedback,
 - produce operational benchmarks.
- possible support from research, training and academic partnerships.

The main challenge is not only technical, but systemic: to simultaneously develop infrastructure, skills and governance.

3.2.4. General summary

The information presented highlights a port of Le Havre that is:

- operationally sound and experienced in risk management,

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- committed to energy transition, but constrained by market demand,
- aware of future risks, particularly those related to alternative fuels,
- awaiting a more structured framework, particularly at the national level.

The port energy transition thus appears to be a collective challenge, requiring:

- anticipation,
- shared of knowledge,
- regulatory support,
- and gradual infrastructure development.

Figure 2 summarises the information obtained from the analysis of the interview conducted at the port of Le Havre.

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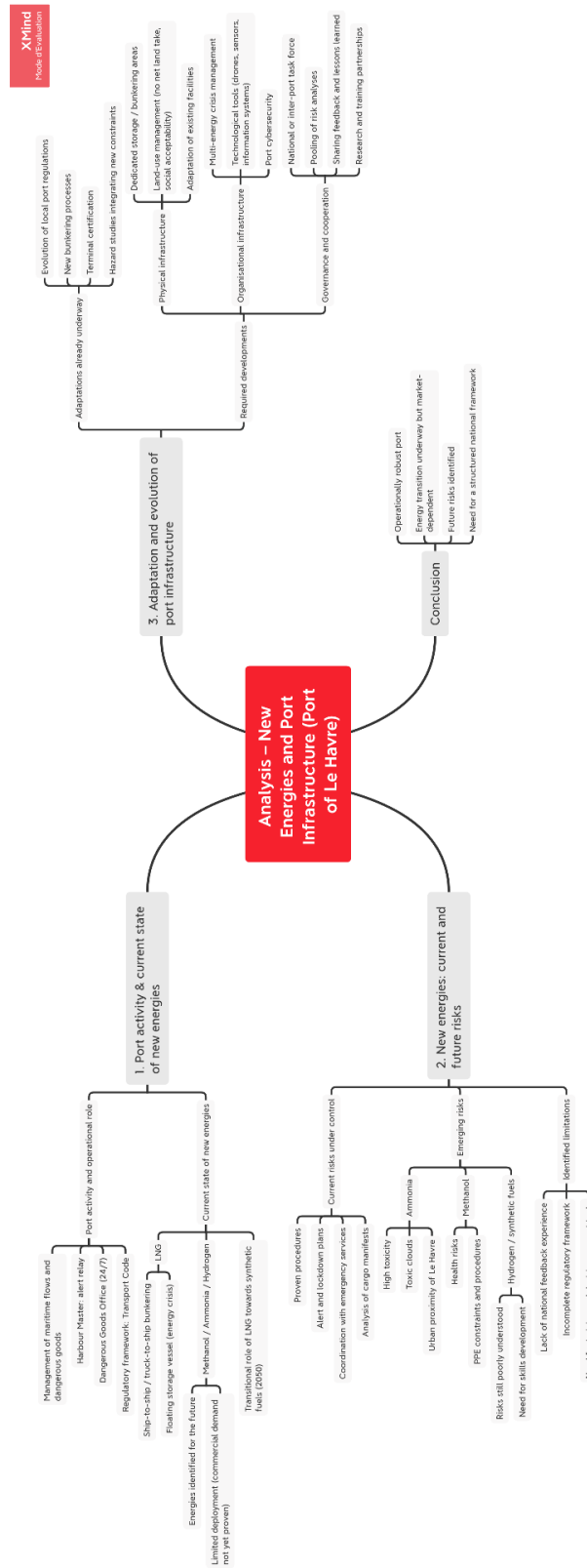


Figure 2. Information from Le Havre port interview

3.3. Port of Saint Nazaire

Based on the audio file recorded during the interview with representatives of the Saint Nazaire harbour master's office, the following points can be highlighted.

3.3.1. Your activity & the current state of new energies in the port

The activity analysed mainly concerns the harbour master's office and the port police, whose role focuses on safety, regulating port activities and providing first response in the event of an incident. The port does not directly exploit new energies but acts as the guarantor of the regulatory and operational framework.

To date, there is no large-scale operational exploitation of new energies in place. However, several developments have been identified:

- Methanol is the first concrete development, with three Louis Dreyfus ships scheduled for 2026, operating on hybrid propulsion.
- LNG has already been tested locally (hybrid dredger), but was deemed inconclusive due to a lack of technical and organisational maturity.
- Ammonia and liquid hydrogen remain a distant prospect, beyond 2030.

No port storage for these fuels is planned in the short term. The scenarios studied are based mainly on bunkering operations by truck or ship-to-ship.

3.3.2. New energies: current and future risks

The main risk identified is not storage but handling, particularly during bunkering operations.

- Methanol poses a toxicity risk to people and the environment, which is particularly acute in dense port areas and near Atlantic shipyards.
- Ammonia is perceived as the major future risk due to its high toxicity and the potential for the formation of deadly clouds.
- LNG is better known but remains associated with technical and organisational constraints.
- Batteries (electric vehicles) are an emerging risk, with fires that are difficult to control and a regulatory framework that is still insufficient.

A general lack of national regulatory standards is highlighted, with maritime port regulations only partially covering these new energies.

3.3.3. Adaptation and development of port infrastructure

The adaptation of the port relies more on organisational and procedural changes than on major infrastructure transformations.

The main guidelines identified are:

- The implementation of an approval system for bunkering operators.
- The gradual deployment of fixed detectors specific to new fuels.
- The upskilling of port officers through dedicated training courses.
- Strengthening audit, inspection and shutdown procedures for high-risk operations.
- Enhanced coordination with emergency services and neighbouring industries.

In addition, certain existing physical constraints, such as the Saint-Nazaire bridge and the draught of ships, will need to be considered in future projects.

3.3.4. General summary

The development of new energies is generally perceived as an environmental and strategic opportunity for the port. However, this transition cannot be achieved at the expense of industrial and human safety.

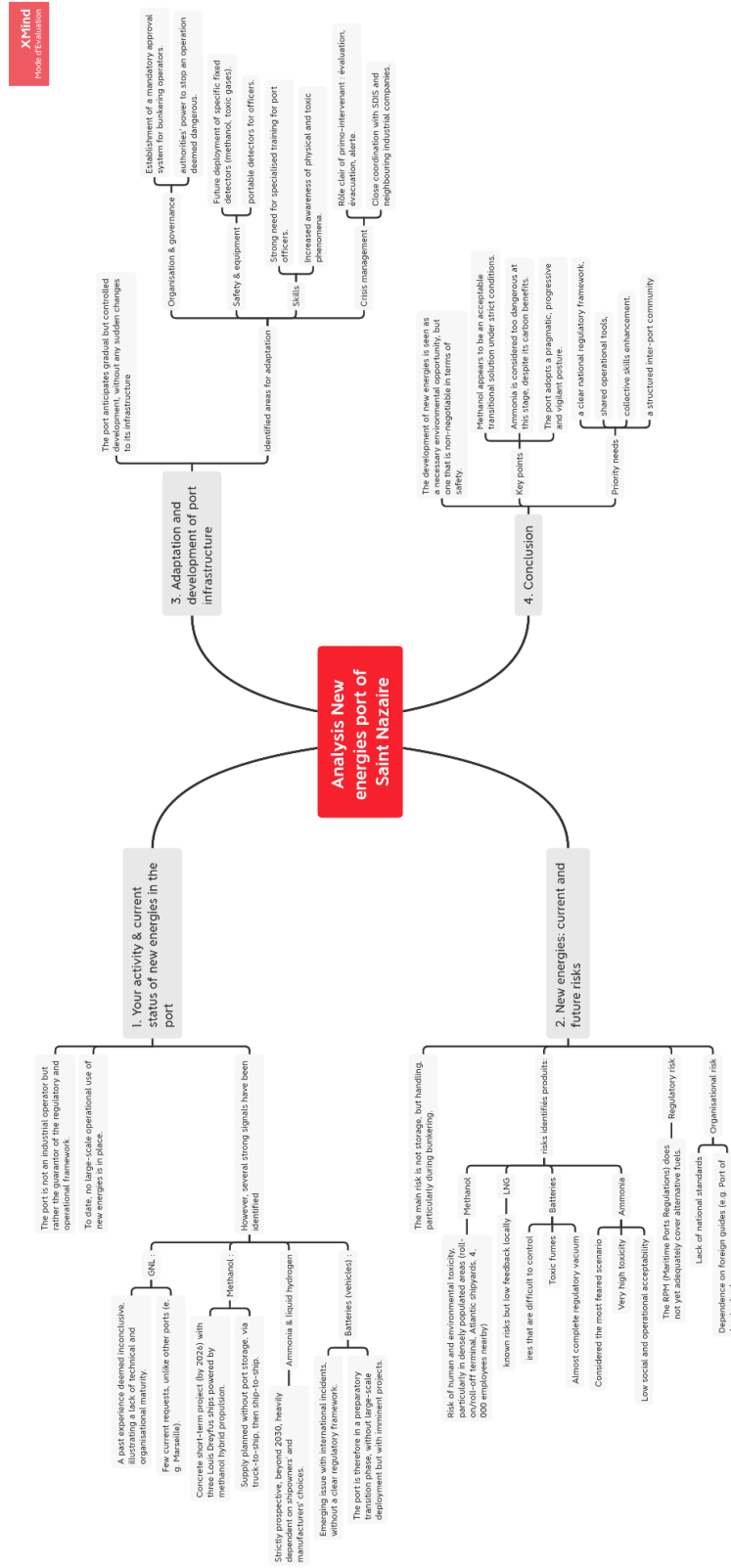
Methanol appears to be an acceptable transitional solution under strict conditions. Ammonia, on the other hand, is considered too risky at this stage despite its benefits in terms of decarbonisation.

The success of this transition depends on the establishment of a clear regulatory framework, the sharing of feedback, the development of skills among port stakeholders and close cooperation between ports, industry and government authorities.

Figure 3 summarises the information obtained from the analysis of the interview conducted at the port of Saint Nazaire.

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Figure 3. Information from Saint Nazaire port interview



3.4. Cross-analyses of the three interviews

3.4.1. Level of maturity and dynamics of ports

A common observation ...

All three ports are committed to energy transition, but none has yet fully stabilised its use of alternative fuels other than LNG.

The trajectory is gradual, experimental and highly dependent on shipowners.

... And key differences:

- Marseille–Fos
 - Most advanced port in operational terms
 - Strong LNG momentum driven by CMA CGM
 - Captive customer → infrastructure' logic
- Le Havre
 - Strategic national position
 - Highly structured approach (master plans, long-term forecasting)
 - High expectations for a stable regulatory framework
- Nantes–Saint-Nazaire
 - Cautious and safety-focused approach

The transition is not uniform. It is progressing where a leading shipowner secures volumes of alternatives energies.

3.4.2. Convergences and divergences by alternative energy source

For LNG:

- Marseille: mature, structured, profitable
- Le Havre: controlled but cautious
- Saint-Nazaire: mixed feedback (lack of maturity)

LNG = transitional energy, but not unanimously considered a long-term solution.

For methanol:

Strong consensus on:

- Rapid arrival
- Moderate but real toxicity
- Bunkering as a critical issue
- Le Havre / Marseille ports are under active observation

Methanol is the next realistic step, but requires safety measures and training to be put in place.

For Ammonia:

- Negative consensus

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- 1) Extreme toxicity
 - 2) Major societal risk (toxic cloud)
 - 3) Very low acceptability
- Saint-Nazaire: clearly identified as a feared scenario
 - Marseille / Le Havre: only considered in the very long term

Ammonia = operational red line at this stage.

For hydrogen

- Very long term (>2030)
- Projects linked to renewable energy sources
- Significant challenges in terms of storage, safety and costs

Hydrogen = a technological gamble, not a short/medium-term solution.

For batteries

- Underestimated risk
- Unclear regulations
- Fires that are difficult to manage

An emerging issue that is riskier than perceived, especially in ro-ro areas.

3.4.3. Risks

Bunkering is considered the most critical phase.

Why:

- It is a mobile installation.
- It has multiple interfaces.
- It is dependent on human factors.
- It has a high probability of failure.

Other shared observations:

- Fixed storage is better controlled.
- Ship manoeuvres are considered secondary.
- The real risk = combination of errors. (procedures + context)

The human factor is the critical link.

3.4.4. Governance and role of ports

The fundamental point that is common to all is that ports do not position themselves as energy operators, but as:

- safety authorities
- regulators
- producers of local rules

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The key roles identified are:

- Approval of operators
- Audits and inspections
- Shutdown of operations in case of danger
- Interface with SDIS / Prefecture

The port is the coordinator ensuring safety, not an energy producer.

3.4.5. Regulatory framework

The unanimous conclusion is that the RPM does not cover alternative fuels (excluding LNG). Ports:

- Are developing their own local regulations
- Are relying on international guidelines (IAPH, etc.)

The identified risks would lead to

- National heterogeneity
- Legal uncertainty
- Increased liability for port authorities

There is a clear need for a structured national framework.

3.4.6. Infrastructure: targeted, not massive, development

The shared approach is not to embark on major immediate infrastructure changes, but rather to focus on:

- gradual adaptation
- safety
- modular solutions

Common requirements are:

- installation of specific fixed detectors (methanol, ammonia)
- appropriate firefighting equipment (batteries)
- a robust warning system
- more precise studies of potential impact zones

3.4.7. Skills and safety culture: a key issue

There is a shared consensus that success depends less on technology than on:

- training
- understanding of phenomena
- shared feedback

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The needs identified relate to:

- dedicated training in new energies
- simple operational guides
- incident databases
- community of national port infrastructure stakeholders

3.4.8. Overall strategic elements

The opportunities identified relate to the need for:

- Real decarbonization of maritime transport
- Strengthening the strategic role of ports
- Enhanced inter-port cooperation

The main obstacles are:

- A lack of a clear regulatory framework
- Dependence on shipowners
- Difficulty in gaining societal acceptance (ammonia)
- Time-consuming skills development

In conclusion, the port energy transition is not only a technological issue, but rather a matter of governance, safety, and collective maturity.

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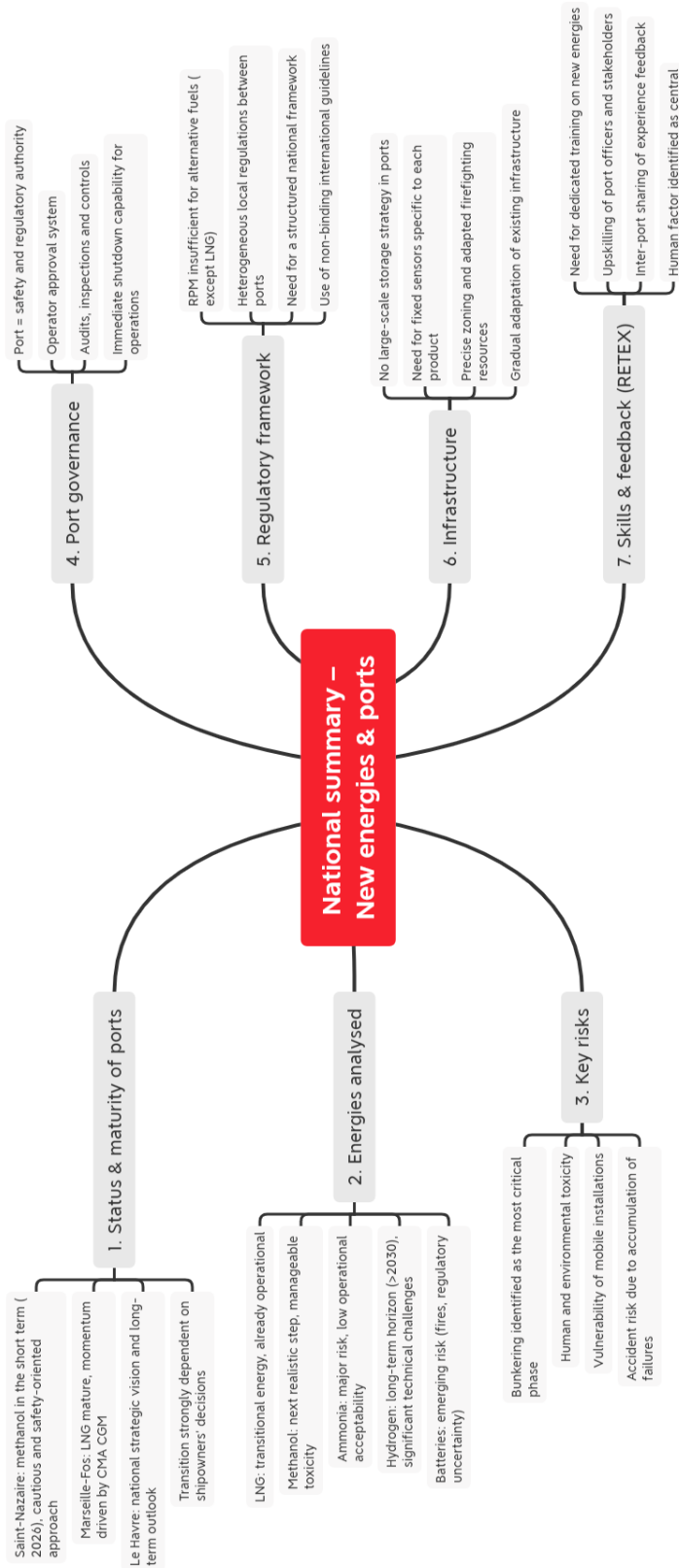


Figure 4. Cross-analyses of the three-port interviews

4. Analysis of collected data with sending questionnaire

Stakeholders were consulted at European level, relying on the contacts of the partners of the MANIFESTS *Genius* project and using the questionnaire set out in section 2.2. Fourteen responses were received from France, Belgium, the UK, Spain and Portugal. All the responses are analysed later in this section 4.

4.1.1. Respondent Profile and Port Typology

The two first questions allow to specify who respond to this questionnaire and what are the main activities of port infrastructure.

On the base of the reading of figure 5, we can say that respondents mainly hold operational or risk-management roles (port authorities, safety departments, harbour master's offices).

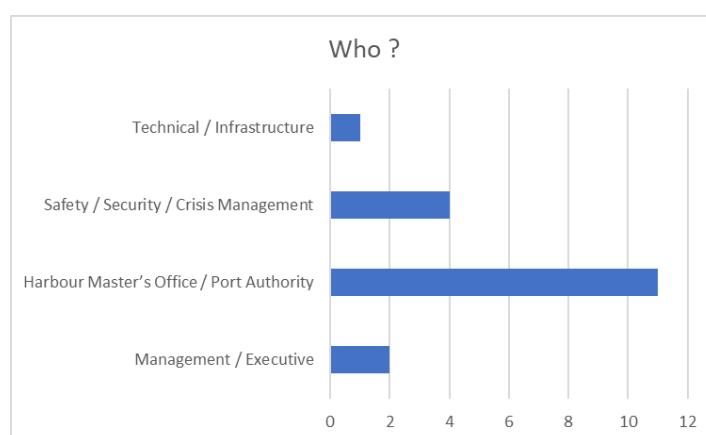


Figure 5. Who respond to the questionnaire

The ports represented display strong industrial profiles (figure 6):

- presence of SEVESO-type facilities
- activities related to liquid and gas bulk cargo
- diversified logistics operations

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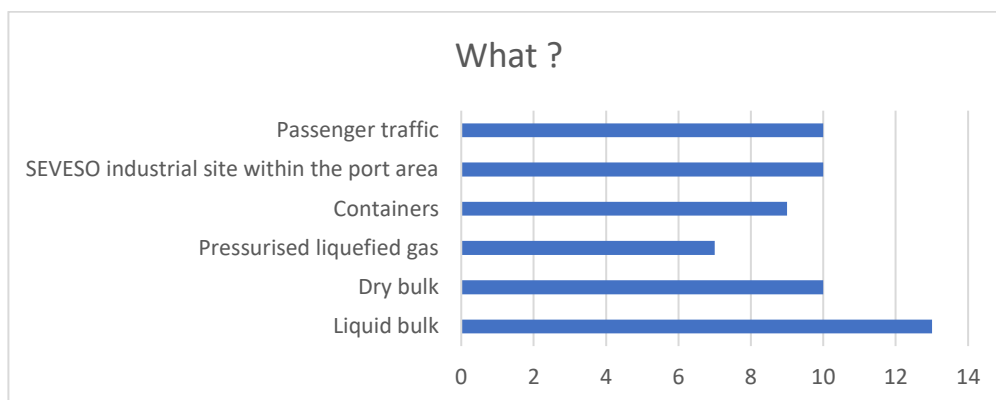


Figure 6. What are the main activities of the port

This indicates that responses come from stakeholders directly confronted with industrial safety challenges.

4.1.2. Level of Deployment of New Energies

On the base of the reading of figures 7 and 8, a clear hierarchy of maturity emerges:

- LNG: widely integrated into port operations
- Methanol: present but still limited
- Hydrogen and ammonia: mostly at pilot or project stage
- Batteries / electrification: occasional presence

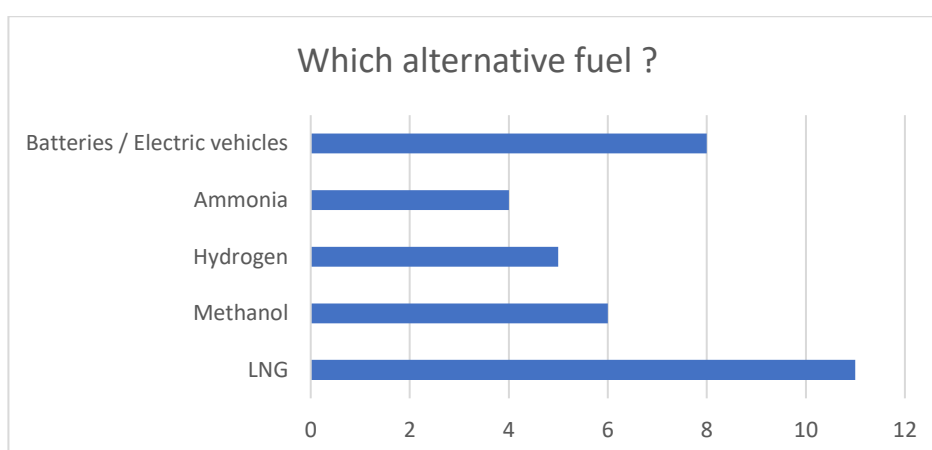


Figure 7. Which alternative fuel is used?

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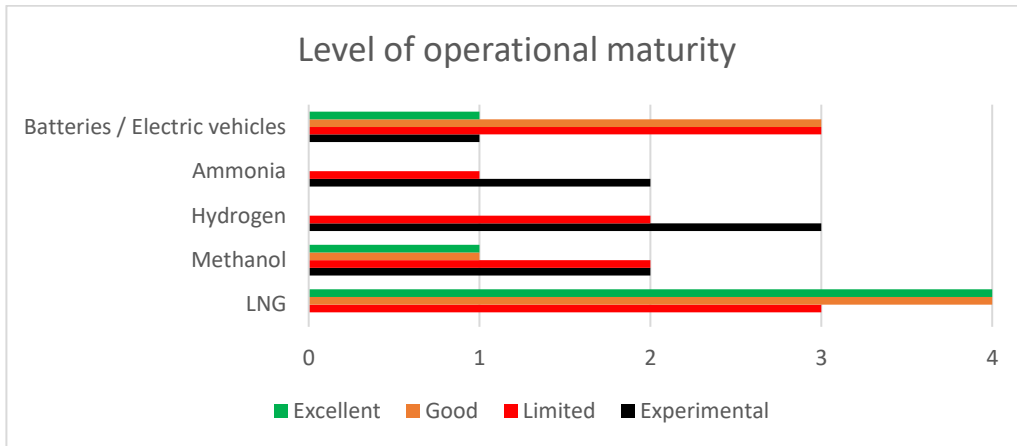


Figure 8. Level of operational maturity for new energies

The main uses of these concern (figure 9):

- bunkering
- storage
- Infrastructure projects

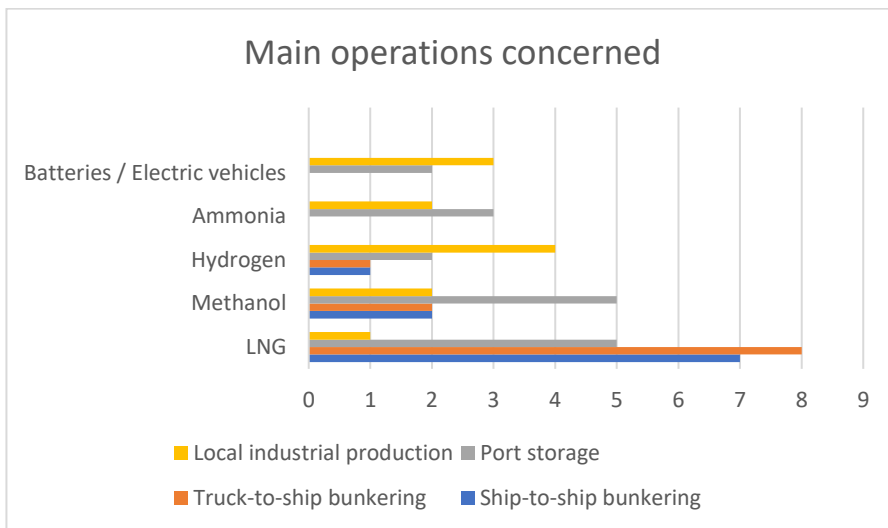


Figure 9. Main operations concerned for new energies

This reflects the classic energy transition pattern:

- LNG is considered as a transitional solution
- Hydrogen/ammonia are emerging solutions with high uncertainty

It suggests that ports are entering a phase where multiple fuels coexist, increasing risk-management complexity.

4.1.3. Analysis of Perceived Risks

On the base of the reading of figure 10, relative to the perceived risk, it shows that

- Ammonia and Hydrogen are considered as the most hazardous
- LNG and methanol are considered as a moderate risk

And nearly of them haven't a shared emergency plan with local rescue services (figure 11).

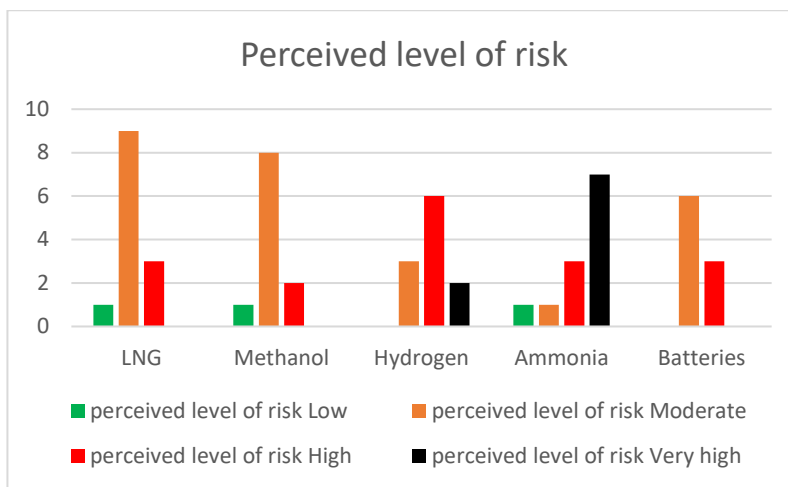


Figure 10. Main operations concerned for new energies

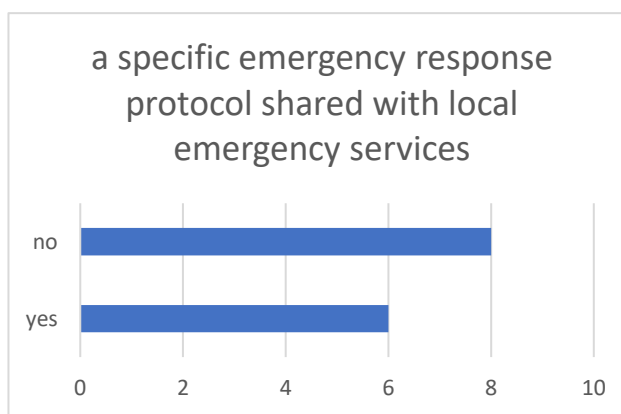


Figure 11. Shared emergency response plan

In Figure 12, the bunkering phase clearly emerges as the most critical. Implicit reasons mentioned include:

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- product handling
- ship-shore interfaces
- multiplicity of stakeholders

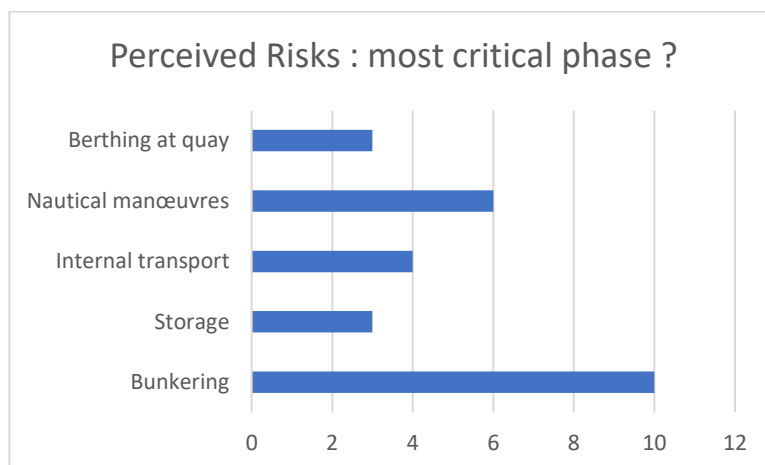


Figure 12. Most critical phase

Nevertheless, the number of reported incidents remains low (figure 13).

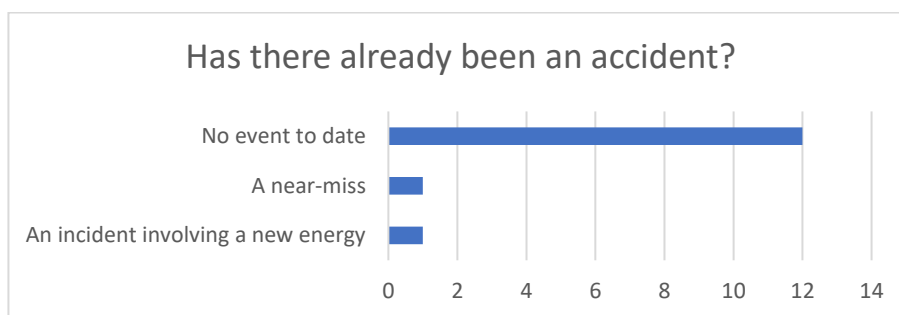


Figure 13. Existing accidents

Energy transfer operations, particularly bunkering, are identified as the main point of vulnerability, more on the basis of anticipation than extensive feedback.

4.1.4. Level of Preparedness and Capabilities

On the base of the reading of figure 14 and 15, ports report that the level of preparedness is mainly 'under development' or 'satisfactory' to a lesser extent.

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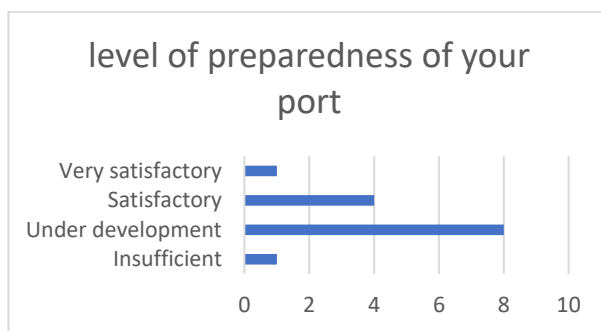


Figure 14. Level of preparedness

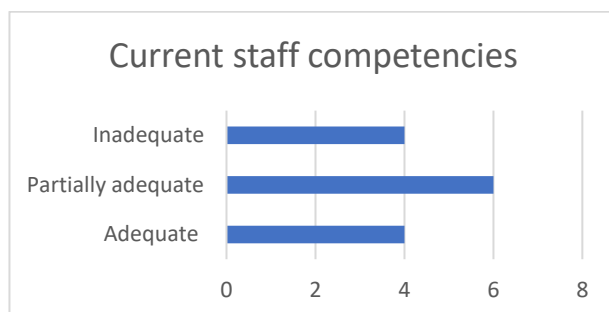


Figure 15. Current staff competencies

The figure 16 shows:

- existence of specific procedures in some cases
- variable detection and protection equipment
- training programmes under development partially adapted

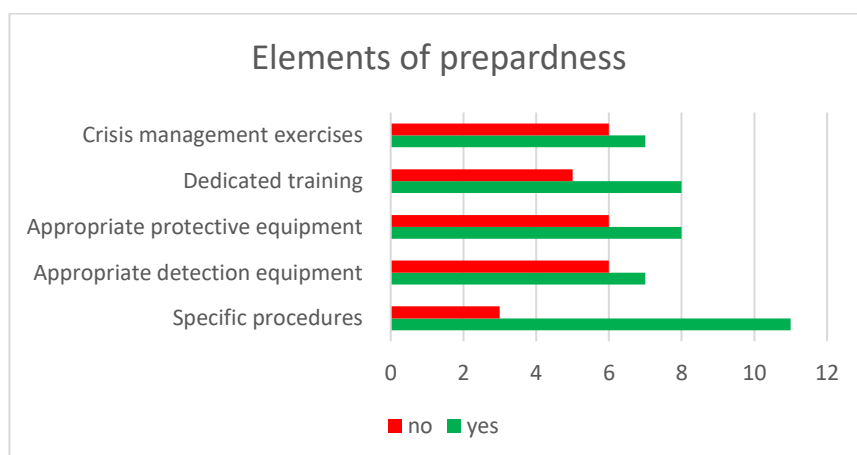


Figure 16. Elements of preparedness

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This indicates a phase of organisational transition, ports are building capabilities as new energies are introduced. It reflects the classic time lag between technological innovation and adaptation of safety systems.

Preparedness capacities appear to be globally in the process of structuring, reflecting gradual organisational adaptation to emerging risks.

4.1.5. Perception of the Regulatory Framework

On the base of the reading of figure 17, the framework is largely perceived as:

- partially adapted
- fragmented
- requiring clarification

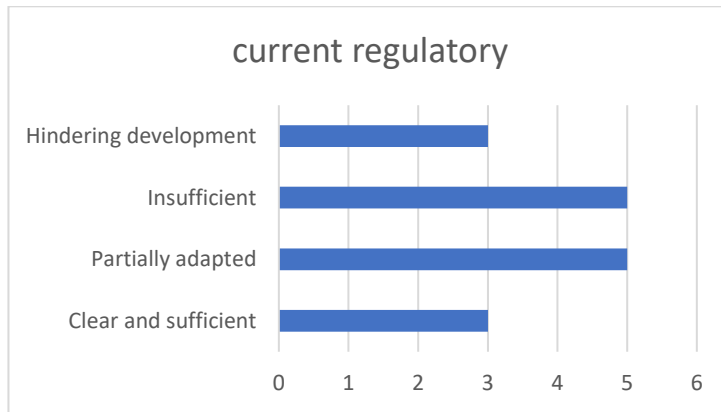


Figure 17. Assessment of current regulatory

Key needs identified are (figure 18):

- regulatory harmonisation
- clarification of responsibilities
- specific integration of new fuels

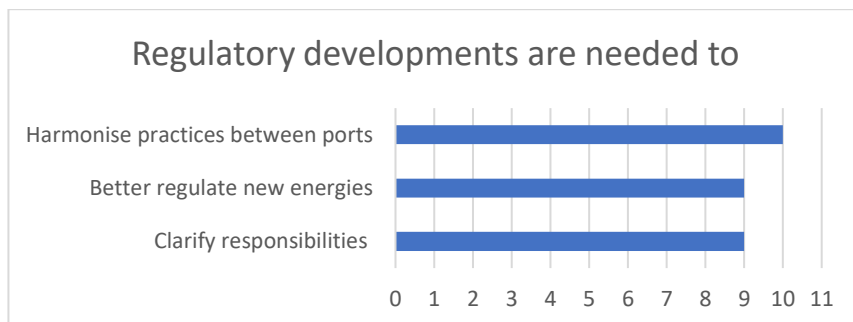


Figure 18. Needs for regulation development

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Regulation appears both as a key safety enabler and a source of uncertainty. This reflects the gap between the pace of technological innovation and regulatory evolution.

Respondents emphasise the need for a more harmonised and clarified regulatory framework to effectively support the development of new energies.

4.1.6. Forward-Looking Vision and Barriers

On the base of the reading of figure 19, infrastructure is generally considered adaptable with investment. The main barriers:

- administrative complexity and technological uncertainty for the most part
- investment costs and social constraints for more than 50% of them.

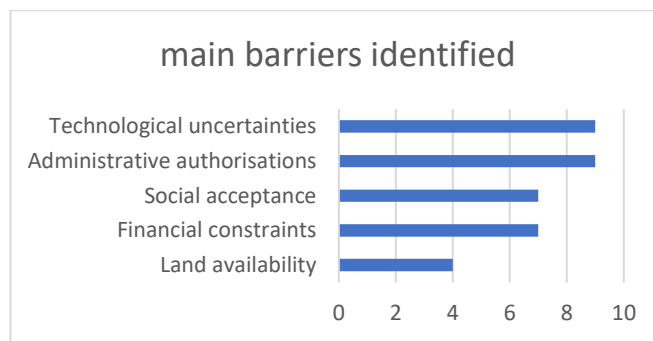


Figure 19. Main barriers identified for the development of new energies uses

Overall perception remains largely positive (opportunity) in figure 20.

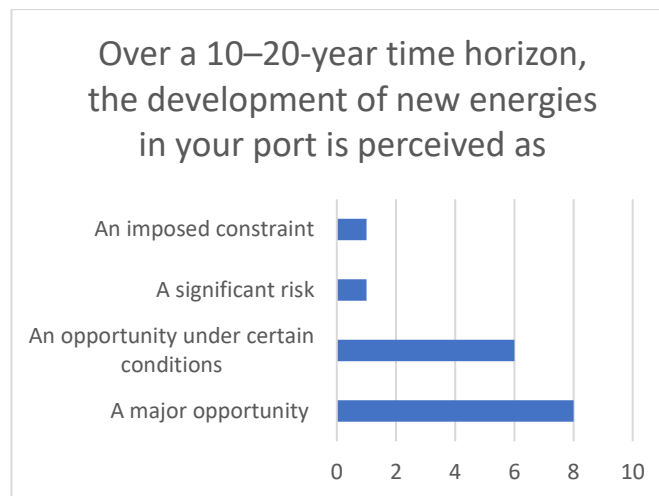


Figure 20. Perception of the development of new energies uses

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Ports position themselves in a logic of adaptation rather than resistance. The transition is perceived as inevitable but conditioned by economic and institutional factors.

Despite financial and administrative constraints, new energies are largely perceived as a strategic opportunity for ports in the medium and long term.

5. Summary and key recommendations

Overall, the results show that ports are already engaged in the energy transition, but with very different maturity levels depending on the fuels. Risks are mainly identified at the level of transfer operations, particularly bunkering, while operational feedback remains limited. Port organisations appear to be in a phase of gradual adaptation, with a strong need for regulatory clarification and capacity building. Finally, despite economic and administrative constraints, the development of new energies is largely perceived as a strategic long-term opportunity.

From all the analyses presented in this report, it is possible to highlight some key recommendations:

- Create a shared national framework for alternative fuels
- Share risk analyses and feedback from different ports
- Develop common training modules (officers, decision-makers)
- Provide decision-making tools for crisis situations (guides, scenarios)
- Give priority to the security of bunkering and transitional phases
- Strengthen cooperation between ports, fire and rescue services and industry

There are many challenges to overcome but it is a real opportunity in the coming years.

6. Conclusion

In conclusion, the energy transition of ports, through the integration of new propulsion energies for maritime transport, emerges as a major challenge encompassing environmental, industrial, and organizational dimensions. The analysis conducted, based on in-depth interviews with French port authorities as well as a broader European survey, has made it possible to address the initial research question by highlighting current dynamics, associated risks, and the conditions required for the effective adaptation of port infrastructures.

First, the findings demonstrate that European ports are already engaged in this transition with varying levels of maturity. Liquefied Natural Gas (LNG) currently stands out as the most developed alternative energy source, benefiting from a relatively well-structured operational framework and substantial feedback from experience. On the other hand, other energy sources such as methanol, hydrogen, and ammonia remain at exploratory or pilot stages, characterized by significant technological and regulatory uncertainties. The coexistence of multiple energy vectors, in the absence of a clearly dominant standard in the short term, considerably complicates risk management and investment decision-making for port authorities.

One of the key contributions of this study lies in the clear identification of critical phases in terms of safety. There is a strong consensus among port authorities that transfer operations, particularly bunkering, represent the main point of vulnerability. This phase involves multiple technical and human interfaces, thereby increasing the probability of incidents. More generally, the analysis highlights that risk does not solely result from the intrinsic hazard properties of these new energies, but rather from the gap between technological innovation and the operational capacity of organizations to effectively manage its implications.

Furthermore, the results underline that port infrastructure development follows a logic of gradual adaptation rather than radical transformation. Ports tend to prioritize flexible solutions, including the adjustment of existing facilities, the development of specific procedures, and the integration of new detection and crisis management tools. This pragmatic approach is largely explained by uncertainties surrounding long-term energy pathways, as well as by the land-use, economic, and societal constraints affecting port areas.

However, this transition also reveals several structural limitations. First, the regulatory framework appears largely insufficient to encompass the full range of emerging energy sources, with the exception of LNG. This situation leads to heterogeneous practices between ports, increased legal uncertainty, and greater responsibility for local authorities. Second, the need for enhanced skills and training constitutes a central issue: the rise of new energies requires a significant evolution of technical and operational

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competencies. Finally, the lack of shared feedback and inter-port coordination limits the collective ability to anticipate and effectively manage emerging risks.

In this context, several perspectives can be envisaged. Strengthening regulatory harmonization at both national and European levels appears essential to secure the development of these new energy sectors. Similarly, the establishment of experience-sharing mechanisms, incident databases, and cooperative networks between ports would represent a major lever for improving practices. In addition, investment in training, decision-support tools, and monitoring technologies (such as sensors, drones, and information systems) is crucial to support this transformation.

Finally, beyond technical considerations, this study highlights that the energy transition of ports should be understood as a systemic transformation. It implies not only technological developments but also significant changes in governance, safety culture, and cooperation between public and private stakeholders. While the risks are tangible—particularly for certain energy sources such as ammonia—the opportunities in terms of decarbonization and the strategic repositioning of ports are considerable.