

Navigating the Green Transition: The Urgent Need for Competence-Based VET in Alternative Marine Fuels

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Abstract

The maritime sector is undergoing a rapid and unprecedented transition toward alternative marine fuels, driven by stringent European and international climate and decarbonization objectives. While technological advancements and regulatory frameworks are progressing at an accelerated pace, workforce skills and training systems remain inadequately prepared to support safe and effective implementation. This paper addresses the critical mismatch between labor-market needs and the current provision of maritime Vocational Education and Training (VET). Existing programs are predominantly designed around conventional fossil fuels, lacking structured, competence-based curricula tailored to the unique operational, safety, and emergency-response requirements of novel fuels such as ammonia, methanol, hydrogen, and biofuels. Consequently, there is an urgent need to strengthen safety-related competencies among both seagoing and shore-side professionals. By synthesizing current literature, industry guidelines, and risk assessments, this paper highlights the hazards associated with alternative fuel bunkering and handling, and proposes strategic recommendations for modernizing maritime VET to ensure a safe, sustainable, and skilled workforce.

1. Introduction

The global maritime industry is under immense pressure to decarbonize. With the International Maritime Organization (IMO) setting ambitious targets for net-zero greenhouse gas (GHG) emissions by or around 2050, and the European Union implementing stringent measures under the European Green Deal such as the inclusion of shipping in the Emissions Trading System (ETS) the transition from conventional fossil fuels to alternative marine fuels is accelerating rapidly.

While the industry is witnessing significant progress in engine technologies, vessel design, and overarching regulatory frameworks, a hidden crisis is emerging: the human element. The workforce's skills and the existing training systems are not evolving at the same pace as the technology. Current maritime VET programs are still largely optimized for the handling of heavy fuel oil (HFO) and marine diesel. They do not sufficiently address the highly specific, and often

more dangerous, characteristics of zero- and near-zero emission fuels. This creates a critical mismatch between labor-market requirements and training provision, inevitably increasing operational and environmental risks.

2. The Landscape and Hazards of Alternative Marine Fuels

To understand the training gap, it is essential to recognize the distinct operational and safety profiles of the alternative fuels currently entering the maritime market. Unlike conventional fuels, these alternatives introduce severe toxicity, extreme flammability, and cryogenic hazards.

- **Ammonia:** While offering a zero-carbon profile, ammonia is highly toxic and corrosive. Safe bunkering requires rigorous control of dispersion risks and the establishment of extensive safety zones. Crew members must be trained in the use of specialized Personal Protective Equipment (PPE) and rapid emergency response in the event of a leak.
- **Methanol:** As a liquid at ambient temperature, methanol is easier to store than cryogenic fuels but is highly flammable, toxic, and burns with an invisible flame. Safe maritime decarbonization using methanol relies heavily on advanced fire safety barriers, double-walled piping, and specialized vapor management systems.
- **Hydrogen:** Liquid hydrogen offers high energy density but poses extreme cryogenic and explosive risks. The bunkering infrastructure for liquid hydrogen is highly susceptible to Natural Hazard-Triggered Technological Disasters (Natech), requiring shore-side and seagoing personnel to possess advanced risk assessment and crisis coordination skills.
- **Liquefied Natural Gas (LNG):** While already in use as a transitional fuel, LNG Ship-to-Ship (STS) bunkering operations remain complex. Risk assessments utilizing models like Fuzzy Failure Mode and Effect Analysis (FMEA) demonstrate that human error during connection, transfer, and disconnection phases represents a critical vulnerability.
- **Biofuels:** Drop-in biofuels present a more immediate decarbonization pathway. However, as outlined by the European Maritime Safety Agency (EMSA), safe bunkering of biofuels still requires strict adherence to new checklists and operational procedures to mitigate risks related to fuel stability, microbial growth, and compatibility.

3. The Widening Gap in Maritime VET

A primary need in the current maritime education landscape is the establishment of structured, competence-based VET for alternative marine fuels.

Currently, human safety and operational training are largely governed by the STCW (Standards of Training, Certification and Watchkeeping) Convention. However, training related to new fuels is often treated informally, implemented merely as awareness-raising activities rather than rigorous, competence-based education. There is a lack of clear learning outcomes, standardized assessment criteria, and direct links to professional practice for these emerging technologies.

When personnel are forced to rely on outdated practices or insufficient theoretical knowledge, the likelihood of catastrophic failure during safety-critical operations such as bunkering or

emergency response increases exponentially. The absence of modernized VET creates a bottleneck in the green transition, as shipowners may hesitate to adopt new technologies if they cannot guarantee a competent crew to operate them safely.

4. Strengthening Safety-Related Competencies

The transition to alternative fuels is not solely a seafarer issue; it demands a holistic upgrade of competencies across both seagoing and shore-side professionals.

4.1. Bunkering and Fuel Handling

Bunkering alternative fuels requires precise coordination between the vessel and the terminal or bunkering ship. Personnel must understand the specific properties of the fuel being transferred. For instance, the EMSA guidance on biofuel bunkering emphasizes the need for comprehensive pre-bunkering, connection, transfer, and disconnection checklists. Similarly, handling ammonia or hydrogen requires Shore-to-Ship synchronization to manage emergency shutdown (ESD) systems and prevent toxic or explosive releases.

4.2. Emergency Response and Decision-Making

Alternative fuels shrink the margin for human error. A methanol leak or an ammonia spill requires immediate, specific, and coordinated responses that differ entirely from an HFO spill. VET programs must prioritize advanced decision-making skills, ensuring that crews can assess dynamic risks in real-time and coordinate effectively with shore-based emergency services.

4.3. Regulatory and Industry Initiatives

Recognizing this gap, international bodies are beginning to act. The IMO has issued interim training guidelines for seafarers on ships using alternative fuels, aiming to integrate these requirements into the broader STCW framework. Additionally, industry-led initiatives, such as the Training Standard for Handling Alternative Fuels (Ammonia, Methanol, and Hydrogen) recently published by The Nautical Institute, provide a much-needed baseline for trainers and training managers to develop specialized courses. Organizations like ISCC are also establishing sustainability certification markets, ensuring the entire supply chain is regulated. However, these guidelines must be rapidly translated into mandatory, actionable VET curricula.

5. Strategic Recommendations

To bridge the gap between technological advancement and workforce readiness, the following strategic actions are recommended:

1. **Develop Competence-Based Curricula:** VET providers must transition from theoretical awareness to competence-based training. Curricula must include hands-on simulator training for alternative fuel bunkering, leak containment, and specific fire-fighting techniques.
2. **Integrate Shore-Side and Seagoing Training:** Safe operations require seamless

communication. Joint training modules involving both ship crews and port/terminal operators should be developed to ensure standardized emergency response and bunkering protocols.

3. **Standardize Assessment Criteria:** European maritime authorities should collaborate to establish unified assessment and certification standards for alternative fuels, building upon guidelines from the IMO and The Nautical Institute to ensure cross-border recognition of competencies.
4. **Continuous Professional Development (CPD):** Because alternative fuel technologies are still evolving, training cannot be a one-time event. VET frameworks must mandate regular refresher courses to keep personnel updated on the latest operational and safety procedures.

6. Conclusion

The rapid transition towards alternative marine fuels is an environmental imperative, but its success relies entirely on the people managing the technology. Currently, maritime VET systems are lagging behind technological and regulatory advancements, leaving seagoing and shore-side personnel underequipped to handle the complex safety demands of fuels like ammonia, methanol, hydrogen, and biofuels. By urgently reforming VET programs to focus on structured, competence-based training, the European maritime sector can mitigate operational risks, protect its workforce and the environment, and successfully navigate the transition to a zero-carbon future.

References

- Argus Media. *Alternative Marine Fuels: Topical Market Themes*.
- Bunker Index. *IMO issues training guidelines for seafarers on alternative fuels*.
- ClassNK. (2025). *Guidelines for Safety Operation for Ammonia-Fueled Vessels*.
- DNV GL. (2019). *Comparison of Alternative Marine Fuels*. Report No. 2019-0567.
- Duong, P.A., et al. (2023). Safety Assessment of the Ammonia Bunkering Process in the Maritime Sector: A Review. *Energies*, 16, 4019.
- European Maritime Safety Agency (EMSA). (2024). *Guidance for Safe Bunkering of Biofuel*.
- European Maritime Safety Agency (EMSA). *Sustainable Shipping: Alternative Fuels*.
- Feng, W., et al. (2025). Ship-to-Ship Liquefied Natural Gas Bunkering Risk Assessment by Integrating Fuzzy Failure Mode and Effect Analysis. *Journal of Marine Science and Engineering*, 13, 710.
- International Sustainability & Carbon Certification (ISCC). *Alternative Marine Fuels*.
- Ismail, A.M., et al. (2025). Towards Safe Maritime Decarbonization: Safety Barriers of Methanol Fuel. *Sustainability*, 17, 4896.
- Istanbul & Marmara Chamber of Shipping. (2025). *Alternative Fuels and Bunkering Operations (Biofuels)*.
- Tamburini, F., et al. (2025). Evaluating Natech Risks in the Liquid Hydrogen Maritime Bunkering Infrastructure. *Proceedings of the ASME 2025 OMAE*.
- The Nautical Institute. (2024). *Training Standard for Handling Alternative Fuels in the*

Maritime Sector: Ammonia, Methanol, and Hydrogen.

- University of Piraeus. (2024). *Alternative Fuels and Bunkering Operation*. Master's Dissertation.