FUEL SAFETY FRAMEWORKS
Ammonia

Ammonia Process Safety Management Maturity Self-Assessment Tool

User Guide

Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

The Decarb Hub LR

Disclaimer

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Ammonia as Fuel Competencies and Training (2025)

- Project Summary Report
- Competencies and Training Proposed Overall Framework
- Detailed Competency & Training Operational, Maintenance and Emergency Response Scenario Evaluations

Ammonia Competency and Training Practitioners Handbooks (2026)

- Emergency Response
- Maintenance
- Leak Detection, Management, Isolation and Repair

Ammonia Process Safety Management Maturity Self-Assessment Tool (2026)

- User Guide
- Element Maturity Tables
- Assessment Template

Executive summary

Why use this tool?

The adoption of alternative fuels in shipping, for the purpose of lowering greenhouse gas (GHG) emissions, will entail significant changes in maritime safety management. Ammonia has received particular attention as a high-potential route to maritime decarbonisation that – in its deployment – also requires a careful re-evaluation of maritime safety practices. While the general need for this re-evaluation is clear, our understanding of the particular character of the required changes is less settled. Vessel owners, operators and managers contemplating use of ammonia as a fuel are confronted with important safety management questions for which there are few ready answers: 'where do we begin?', 'what aspects of our operation should we focus on when implementing change?', 'how can we be confident that our operation is ammonia-ready?'.

This tool provides a basis for developing initial answers to these questions. It is grounded in a belief that the maritime industry can learn from other safety-critical industries that have track-records of safely handling hazardous molecules like ammonia. Specifically, it describes how the process safety management (PSM) approach to managing safety – well-established in sectors such as chemical engineering and oil and gas – can be applied in the maritime context to help orient the industry to the safety management requirements of an ammonia-powered future.

Who is this tool for?

The primary audiences for this tool are those vessel owners, operators and managers who are in the process of adopting ammonia as a marine fuel, or considering doing so. This includes both shore-based and sea-going vessel management. For these audiences, this tool provides a mechanism for evaluating present safety management arrangements against a PSM framework, and for identifying the aspects of these arrangements that may require improvement.

In addition to these primary audiences, this tool may also be of interest to stakeholders with a more general interest in assuring safe maritime operations, including seafarers, operators using fuels other than ammonia, regulators and training establishments. While the development of this tool has been motivated by the challenge of assuring the safe deployment of ammonia as a marine fuel, there may nevertheless be value in maritime stakeholders who are not (or not yet) considering adopting ammonia as a fuel evaluating their activities through the lens provided by PSM. We welcome engagement from this extended audience as part of the wider dialogue supporting continuous improvement in maritime safety outcomes.

Structure

For ease of use, the tool is separated into 3 documents that should be used together when performing self-assessments. These are:

- The **User Guide**
- The **Element Maturity Tables**
- The **Assessment Template** (click here to download the editable template)

Feedback

We are keen that this publication – and future work – is as relevant and useful to industry as possible. To this end, we welcome feedback on this tool using the following QR code or click here.

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1. Introduction to the PSM maturity self-assessment tool

1.1. Concept

This tool has been developed to support operator self-assessments of their safety management maturity. As the best practices for managing ammonia safety are still emerging, these assessments should not be thought of as 'pass/ fail' tests or audits. Rather, they are open but structured explorations aimed at constructive evaluation of the safety management activities associated with the use of ammonia as a marine fuel.

This tool is intended as a flexible, practical reference applicable to a range of contexts. To facilitate this use, it has a modular structure that enables users to prioritise engagement with the sections of the content that are of most value to them. While this flexibility has advantages, a key strength of the PSM approach to safety management is that it is holistic and integrative – its scope covers design, technical assurance and operations, and it is an approach that is explicitly concerned with ensuring that safety management activities across these domains function as a whole. As such – where feasible – users are encouraged to engage with the totality of the information presented in this publication, and indeed with the wider PSM literature.

1.2. Structure

For ease of use, this tool is divided into three parts:

- **The User Guide:** This provides the starting point for engaging with this self-assessment tool. Following this introductory section:
  - Sections 2 and 3 respectively introduce the background that led to this point, and the conceptual foundations of the tool;
  - Sections 4 and 5 respectively provide guidance on use of the tool, and on next steps following an assessment;
  - Section 6 highlights selected reference materials; and
  - Two short appendices provide additional guidance on assessment strategies and evidence gathering.
- **The PSM Element Maturity Tables:** This is the 'main body' of the tool. It consists in a set of PSM 'elements' (categories of practice), divided into maturity bands and specific performance criteria. This part provides the technical substance that enables assessment of PSM maturity for ammonia as a marine fuel.
- **The Assessment Template:** This template is used to record findings. It is provided as a stand-alone document for convenience and is also provided as an Excel spreadsheet for circumstances where the PDF version is restrictive.

While we recommend that users read Sections 2 and 3 of this **User Guide** to baseline their understanding of the background to this tool, it is possible for users well-acquainted with PSM and capability maturity assessment to skip directly to Section 4.

Sections 4 and 5 of this **User Guide** are required reading for anyone seeking to practically implement the tool.

2. Introduction

2.1. Why process safety management matters for ammonia as a marine fuel

While all marine fuels possess hazard attributes that must be controlled, the use of ammonia as a marine fuel represents a new challenge for the maritime industry. Most existing maritime safety management practices have evolved in the context of hydrocarbon fuels that are flammable, and may be explosive, but whose hazards are well-understood and addressed through mature design standards and operating practices. In contrast, the hazard attributes of ammonia are less well addressed by current practices. Most notably, ammonia is toxic and can form hazardous vapour clouds following loss of containment. But ammonia is also corrosive, can present a cold hazard and may also – under certain circumstances – form explosive atmospheres/ ignite. These hazard attributes carry important implications for safety management:

- **Loss of ammonia containment is more likely to present as an operational crisis rather than a contained technical failure.** Given its toxicity, even relatively small ammonia leaks can rapidly escalate in consequence potential if detection, containment or response arrangements are ineffective. As a result, control of ammonia hazards requires greater emphasis on the reliable effectiveness of safety barriers – particularly those associated with design integrity, leak detection and operational discipline.

- **Ammonia operations are less tolerant of latent weaknesses in management systems.** Operational lapses that may be tolerable for conventional fuels – for example, informal procedure deviations, reliance on individual expertise, or deferred resolution of 'temporary changes' – are far more likely to undermine safety when applied to ammonia systems. The margin for degraded performance is narrower, and the consequences of error or delay can be more severe.

- **Ammonia changes the human dimension of operations.** Crew exposure is a key vector for harm from ammonia hazards, while operational discipline and a strong safety culture are crucial risk mitigations. Effective control of hazards therefore depends not only on technical integrity, but on effective integration of the human element.

While current approaches to maritime safety management have resulted in significant improvements in the safety of maritime operations, and remain essential, they are unproven in the context of managing the hazards that ammonia presents as a fuel. In particular, experience from other safety-critical industries shows that managing these hazards requires explicit attention to how technical systems, human performance and organisational controls interact to prevent loss of containment and incident escalation. This kind of integrated thinking is not always apparent in current approaches to maritime safety management.

In this context, it is our view that the safe introduction of ammonia as a marine fuel will require more than the incremental adaptation of existing maritime safety management arrangements; it will require a holistic and integrated approach to maintaining control of hazards over time. PSM offers such an approach.

2.2. The ammonia PSM maturity self-assessment tool

Phase 2 of the joint MMMCZCS and Decarb Hub work on ammonia safety identified PSM as a key domain from which the maritime industry could learn lessons applicable to the safe adoption of ammonia as a marine fuel. This tool takes the next step, offering an elaboration of how PSM can help vessel operators[1] adjust to the requirements of an ammonia-powered future. It translates proven PSM concepts into safety expectations that are meaningful, applicable and proportionate in the maritime context, and invites vessel operators to review their existing safety management arrangements against these expectations. In this way, it provides practical support to operators considering whether their existing systems, practices and safety culture are capable of managing the hazards associated with using ammonia as a fuel, and – where gaps exist – initial guidance on what needs to improve.

This tool is intended to help vessel operators think clearly and consistently about their preparedness for managing the hazards associated with ammonia as a marine fuel. It is not intended to replace the mechanisms for safety management that already exist within the maritime industry (e.g. regulatory demands[2], class requirements/ risk assessments). Rather, it **contextualises**, **integrates** and **augments** these within the major hazard control framework provided by PSM.

- **Contextualises:** PSM provides a structured safety management framework, within which it is possible to locate the activities of current safety management practice;
- **Integrates:** PSM describes how safety management activities relate to and support one-another within this structured framework; and
- **Augments:** PSM enriches maritime safety management, by strengthening concepts such as management of change and process knowledge management.

The PSM framework is extensive, and has been developed over decades of reflection on practical experience. As such, this tool cannot hope to provide a fully comprehensive account of its applicability to shipping. Instead, this tool is best thought of as offering:

1. A practical 'entry point', supporting development of an initial understanding of what effective PSM looks like in the context of ammonia-fuelled shipping operations; and
2. A high-level reference that can inform discussion of ammonia fuel readiness gaps and priorities for improvement.

The essential idea that underpins the tool is simple: shipping operations that exhibit greater PSM maturity are more likely to be effective in controlling the hazards associated with use of ammonia as a marine fuel. Assessing the PSM maturity of an operation therefore offers useful insight into present 'ammonia-readiness', and into what might need to change to improve this readiness.

1 For conciseness, this tool uses the term 'operator' as a general descriptor for vessel owners, operators and managers.

2 In this connection, the Maritime Technologies Forum has recently issued a useful reference: Guidelines for developing and implementing a safety management system for ammonia-fuelled vessels, MTF (2025).

2.3. Over to you

Buy-in from organisational leadership and management is essential for improving safety outcomes. The success of efforts to safely adopt novel fuel types, such as ammonia, rely on the vision, energy and determination of maritime professionals working together – at sea and ashore – to develop the technical infrastructures and operational competences required to safely control the associated hazards. This tool is provided to support these professionals – you – with useful and accessible guidance that makes the task of managing ammonia hazards a little easier. Ultimately, however, it is your work and commitment that underpins the success of efforts to decarbonise our industry. This work remains essential.

In developing this tool, we have incorporated a wide range of credible expertise in assembling what we hope is an informative, grounded and useful tool for evaluating safety management practices. This has included several review rounds and testing with owners and operators of vessels. We recognise, however, that shipping is a diverse industry in which there is no monopoly on expertise – particularly in the fast-moving context of the adoption of alternative fuels. As such, feedback regarding both the form and content of this tool is welcomed and may be submitted via the link/ QR code provided in the executive summary.

3. Conceptual foundations

Before turning to the use of this tool – It is helpful to clarify three foundational, 'framing' concepts that underpin its design: process safety, process safety management (PSM) and the Capability Maturity Model (CMM).
It ensures that assessments made using the tool proceed from a shared conceptual base and will help avoid misunderstandings later.

3.1. Process safety

To meaningfully consider the application of PSM in the maritime context, we should first identify what we mean by 'process safety'. Several credible definitions are available. The Center for Chemical Process Safety (CCPS) opts for the comprehensive:

> *'A disciplined framework for managing the integrity of operating systems and processes handling hazardous substances by applying good design principles, engineering, and operating practices. It deals with the prevention and control of incidents that have the potential to release hazardous materials or energy. Such incidents can cause toxic effects, fire or explosion and could ultimately result in serious injuries, property damage, lost production and environmental impact.'*[3]

The Society for Gas as a Marine Fuel (SGMF) has more pithily defined process safety as:

> *'The control of hazards that can give rise to major accidents involving the release of potentially dangerous materials, release of energy (such as fire or explosion) or both.'*

More pithily still, process safety has colloquially been described as:

> *'Keeping the process in the pipe.'*

While these definitions vary in range and in emphasis, they are all, for our purposes, accurate: they describe **control** of the safety of 'socio-technical **systems**'[4] involving hazardous substances, where – by the nature of the **hazardous substance** managed – system failure (and, in particular, **loss of containment**) could result in **major harm**.

3 Guidelines for Risk Based Process Safety, CCPS (2007)

4 "Socio-technical systems comprise people, technologies, and organisational arrangements, whose interactions determine system performance." Nancy G. Leveson, *Engineering a Safer World* (2011)

3.2. Process safety management

Given this understanding of process safety, how should we think about 'Process Safety *Management*'?

While not a definition as such, SGMF elaborates the character of PSM in a 'propellor' concept – illustrated in Figure 1 below. Here PSM is formulated as concerned with activity assuring four intersecting classes of system integrity: design, technical, operational and leadership.

This propellor concept has been useful in the course of developing this tool, as it highlights the **holistic** and **integrative** attributes of PSM as an approach that connects all the major classes of management activity associated with socio-technical systems involving hazardous substances (i.e. activities directed towards assuring design, technical, operational and leadership integrity), through time (i.e. from system design through to operations, maintenance and decommissioning). It is these attributes of PSM that most clearly differentiate it from the conventional approaches to maritime safety management, which can be somewhat 'siloed' in comparison.

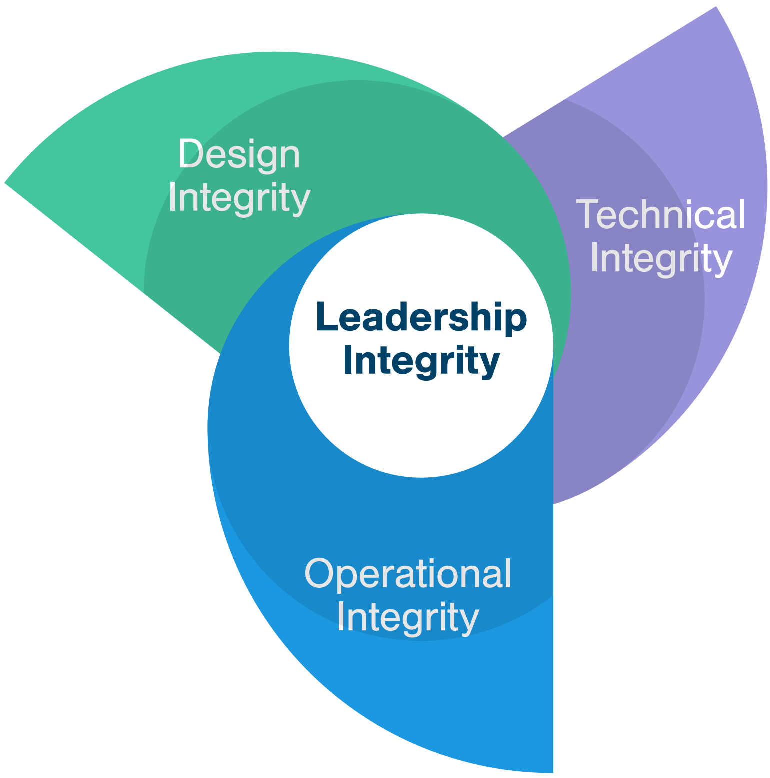

Figure 1 – SGMF Process Safety Concept (figure adapted with permission)

The main PSM framework referenced in this tool, however – and one of the most widely-used PSM frameworks globally – is the Risk-Based Process Safety Management (RBPSM) framework issued by the CCPS. This framework consists in 20 elements, divided across 4 categories, that collectively scope the range of management activities required to assure process safety. This CCPS framework is illustrated in Figure 2 below.

The CCPS defines PSM as:

> *'A management system that is focused on prevention of, preparedness for, mitigation of, response to and restoration from catastrophic releases of chemicals or energy from a process...'*[5]

Accepting that even smaller uncontrolled loss of ammonia containment events could, if sustained, have major consequences, we can think of PSM as a **structured set** of **safety management activities** – spanning design, technical, operational and leadership integrity – that assures the **control of hazards** associated with an operation; in our case the hazards associated with the use of ammonia as a marine fuel.

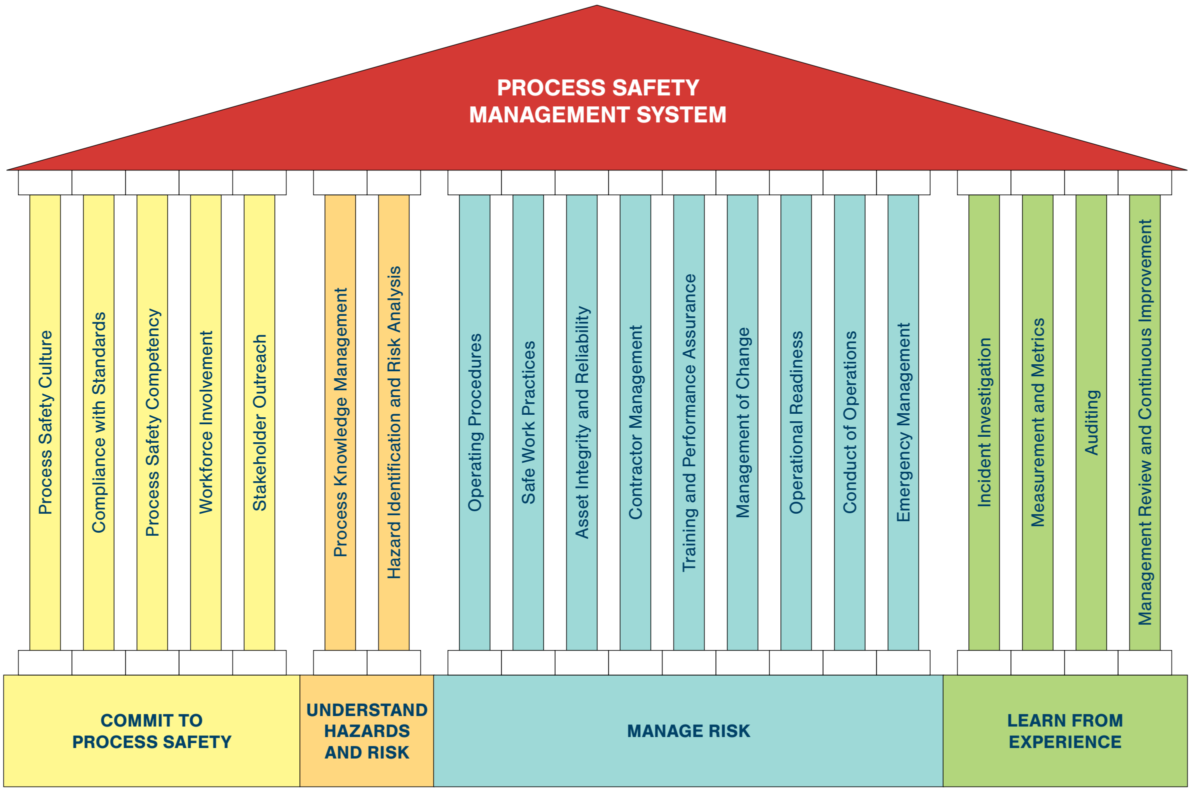

Figure 2 – The CCPS Risk-Based PSM Framework

Used with permission of CCPS, from A summary of risk based process safety management approach as detailed in Guidelines for Risk Based Process Safety, 2007; permission conveyed through Copyright Clearance Center, Inc.

5 Guidelines for Risk Based Process Safety, CCPS (2007)

3.3. The Capability Maturity Model

Where the CCPS RBPSM Framework provides the basis for establishing the scope of this tool, the Capability Maturity Model (CMM) provides the basis for evaluating the degree of maturity of safety management arrangements assessed within this scope.

Originating in the mid-1980s in software engineering, the CMM has since found wide application in sectors ranging from rail to chemical engineering to defence. While formulations of the CMM vary – and the formulation used here is not strictly canonical – it is typically comprised of five maturity bands, which describe progressively more mature levels of organisational control. The maturity bands presented here are not drawn from the CMM alone - the ladder's framing also reflects the safety-culture maturity work of Parker, Lawrie and Hudson which offers a conceptual scaffold complementary to the CMM[6]. For our purposes, the five bands, from lowest to highest maturity level, are:

Ad-hoc

Reactive

Standardised

Proactive

Generative

These bands are not 'scores' or 'targets' – rather, they are 'indicative descriptors' of different qualities of control maturity[7]. Using the CMM to evaluate control helps sharpen our focus on the mechanisms underpinning how safety management works in practice, so grounding the notion of 'control maturity' (which can seem abstract) in concrete safety management actions. Specific, concrete descriptors of PSM maturity at each CMM band form the main substance of the tool presented in the **Element Tables**.

3.4. Summary

Taken together, the three concepts described in this section provide the conceptual scaffolding for this tool. Process safety frames the problem: the need to reliably control hazards associated with ammonia systems, where loss of containment could result in major harm. PSM describes the means by which that control is achieved in practice, through an integrated system of design, technical and operational activities, underpinned by strong leadership commitment. The CMM provides the framework against which the maturity of those activities is evaluated.

The unifying idea across all three concepts is **control**. We are interested not only in the presence of hazard control systems and procedures, but also their quality, consistency and resilience.

The remainder of this **User Guide** sets out how – through this tool – these foundational concepts can be used to support the development of safety management regimes that are fit to handle the hazards posed by ammonia as a marine fuel.

6 Parker D, Lawrie M, Hudson P. "A framework for understanding the development of organisational safety culture." Safety Science 2006;44(6):551–562.

7 As such, the accounts of *Ad-hoc* and *Reactive* levels of maturity included in this tool are not endorsements of the acceptability or feasibility of performance at these levels; they are analytic devices provided purely to support evaluation.

4. How to use this tool

4.1. Understanding the structure of the tool

This tool offers a mechanism for evaluating the PSM maturity of a shipping operation against 16 PSM 'elements', so informing an assessment of the readiness of that operation for using ammonia as a marine fuel. Each element is associated with an overall goal statement (see Table 1 below). The PSM elements that frame this mechanism are taken from the CCPS Risk-Based Process Safety Management framework (RBPSM). The 5 maturity bands are adapted from the Capability Maturity Model (CMM) and the safety-culture maturity work of Parker, Lawrie and Hudson, as described above.

For the purposes of applying this tool, it may be helpful to conceive of the PSM elements as falling into two categories: 'enabling elements' and 'delivery elements'.

1. Enabling elements: Those falling under the categories of 'Commit to Process Safety' and 'Understand Hazards and Risks' – are concerned with establishing the conditions for PSM success.

2. Delivery elements: Associated with the categories 'Manage Risk' and 'Learn from Experience' – address the procedures that more directly give effect to hazard control and which assure this control in practice.

Note on elements excluded from this tool

Four elements from the CCPS framework are excluded from the scope of this tool: Stakeholder outreach, Contractor Management, Operational Readiness and Incident Investigation.

This is not because these elements are unimportant or irrelevant to PSM of ammonia as a marine fuel – the reverse is true. Rather it is because it has not been possible to effectively address these elements through the framework provided by the present tool. In the absence of guidance here, operators are encouraged to address these elements independently. This could, for instance, take the form of a focused gap analysis against these elements using CCPS guidance and a company's management systems, followed by integration of identified gaps into existing processes such as pre-start-up safety review (PSSR), contractor oversight, incident investigation systems, and ship shore/ third party engagement. Improvements should be assigned ownership, tracked to closure, and verified through the organisation's assurance framework. Future work may provide further guidance on these points.

Table 1 – Element Goal Descriptions

Commit to Process Safety

Element	Element goal
Process Safety Culture	Leadership and workforce consistently prioritise process safety in decision-making and daily behaviour.
Compliance With Standards	All operations demonstrably meet or exceed relevant codes, standards and legal requirements.
Process Safety Competency	Organisational processes and resources support the maintenance and application of effective process safety knowledge and practices (technical and non-technical).
Workforce Involvement	Personnel from across the organisation actively participate in developing, improving and assuring integrated PSM.

Understand Hazards & Risks

Element	Element goal
Process Knowledge Management	Accurate, accessible and current process safety information is maintained and used to enable effective risk-based decision-making.
Hazard Identification and Risk Analysis	Hazards and associated risks are systematically identified and assessed to enable control of risks within tolerable limits.

Manage Risk

Element	Element goal
Operating Procedures	Procedures are clear, current, appropriately formulated and dependably followed by trained personnel.
Safe Work Practices	Safety practices for hazardous work are developed and consistently implemented to assure the safety of those affected by the work, as well as the integrity of the assets involved.
Asset Integrity and Reliability	Technical system assets are designed, installed and maintained to operate safely throughout their lifecycle.
Training and Performance Assurance	Adequate training is provided to all persons serving on ammonia-fuelled vessels and shore-side staff managing such vessels. Safe human performance is verified.
Management of Change	Effective change management ensures that neither the quantity, frequency nor the nature of changes (to assets, processes or organisation) adversely affects system safety.
Conduct of Operations	Operations are conducted in a disciplined, controlled and consistent manner that delivers required outputs while maintaining the integrity of systems.
Emergency Management	Emergency situations – including those involving ammonia hazards – are anticipated and adequately prepared for, with resources and practiced plans available to support effective response to emergencies.

Learn from Experience

Element	Element goal
Measurement and Metrics	Performance indicators track leading and lagging safety indicators and are used to guide risk management decisions and continuous improvement.
Auditing	Regular audits confirm that PSM systems are functioning as intended and identify areas for improvement.
Management Review and Continuous Improvement	Leadership/ management reviews ensure that organisation-level policies, strategies and plans remain appropriate and effective over time.

The elements in the **Element Maturity Tables** follow the same general structure:

- At the top of each element, the goal statements (described in Table 1) are restated. These describe – in simple terms – what the element seeks to achieve, and provide a reference point for understanding the more detailed maturity descriptions that follow.

- A brief explanatory paragraph then outlines why the element matters for PSM of ammonia-fuelled maritime operations and the types of activity within the element that contribute to controlling major accident hazards.

- Finally, elements are expanded into tables describing the types of activities that are associated with each of the five CMM maturity bands within that element. These descriptions are deliberately formulated – so far as has been practicable – with reference to explicit, verifiable activities that could plausibly be 'checked' through a review of an operation, rather than more vague or abstract attributes.

  The maturity bands are broken down into four themes that group the types of activities associated with an element. These themes describe classes of mechanisms through which control of operations is established, applied and sustained in practice. While these themes vary by element, they typically address:

  - Governance, ownership and expectations;
  - Development or design of controls;
  - Implementation of controls in day-to-day operations; and
  - Review, learning and improvement.

Using a common set of themes within each element allows the different bands within an element to be compared more easily and highlights how progress between bands can occur.

Some assessors may wish to work with the **Element Tables** in hard copy. To support such use, the tables contain space for notes and a 'Fit' column provided to allow users to mark the activity descriptions that seem to best fit their organisations.

4.2. Understanding the maturity bands

This tool provides a structured way of describing how organisational capability can develop from informal and inconsistent practices to disciplined, reliable and continuously improving controls. This is achieved through use of five maturity bands – adapted from the CMM and the safety-culture maturity work of Parker, Lawrie and Hudson – that describe progressively more mature forms of organisational control. These are:

- **Ad-hoc** Activity controls are informal. Control depends heavily on individual efforts, experience or goodwill, and outcomes are variable. Systems are poorly defined, and loss of control is likely, particularly under abnormal or time-pressured conditions.
- **Reactive** Basic systems and procedures for effecting control exist, but these are applied inconsistently. Safety management activity is often driven by incidents, audits or external pressures. Control can be achieved in favourable conditions, but it is fragile and prone to break down.
- **Standardised** At this level, control mechanisms are defined, documented and reliably followed. Expectations are clear and applied consistently across the organisation. This level of maturity provides a credible baseline for managing major accident hazards, though performance may still rely on compliance rather than active risk awareness.
- **Proactive** Controls are applied proactively based on risk, not just compliance requirements. Human performance, operational variability and interfaces are understood and effectively managed. 'Weak signals' suggestive of deteriorating control are identified and addressed before incidents occur.
- **Generative** At this level of maturity, hazard control assurance is integral to the design, planning and performance of technical and operational activities. The organisational safety culture is strong and learning and improvement are continuous, driven by insights from 'front line' operations as well as by engagement with wider industry practices.

Note on maturity

The nature of change between maturity bands differs as an organisation progresses through the maturity bands. From *Ad-hoc* through *Reactive* to *Standardised*, maturity develops progressively. Informal and inconsistent practices are replaced by defined and reliably applied controls. At a *Standardised* level of maturity, *Ad-hoc* and *Reactive* modes of working should no longer be relied upon to maintain control. Beyond *Standardised*, further progress to *Proactive* and *Generative*, however, maturity becomes additive. The activities associated with higher maturity are expected to occur in addition to the controls already in place at *Standardised*. In short, increasing maturity to *Standardised* replaces earlier practices; increasing maturity beyond *Standardised* builds on them. Figure 3, on page 18, illustrates this point.

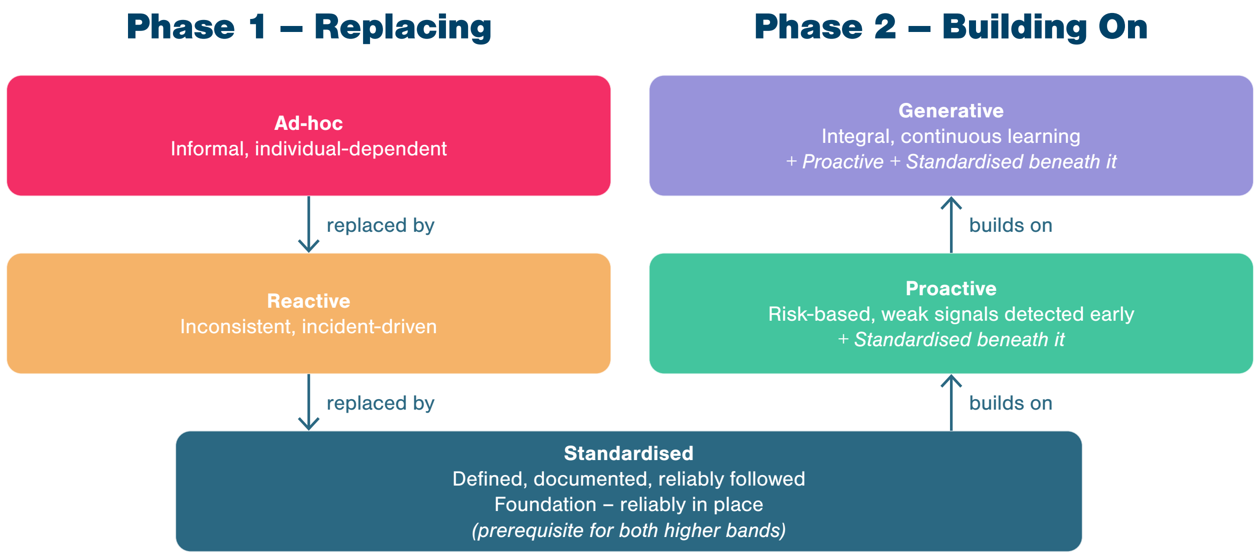

Figure 3 – Maturity Progression Concept

When using this tool, the maturity bands should be treated as 'indicative descriptors', rather than as 'scores'. While maturity band descriptions are written to be explicit, observable and verifiable, users will still need to exercise judgement when assigning the band that best reflects their organisation's current maturity level for a given element.

In cases of doubt regarding whether current practices meet the level of control implied by a higher maturity band, the lower band should normally be assigned and the gaps in performance noted as opportunities for improvement.

Organisational maturity is not an 'average across elements', and it should not be assumed that strengths in some areas compensate for weaknesses in others. A better approach is to view a safety management organisation as only as mature as the weakest of the elements on which control of its major hazards depends. Weaknesses in risk-critical elements should therefore be given particular weight, even where maturity is stronger elsewhere.

4.3. Assessment process/ strategies

This tool is designed to support assessments at various levels of granularity, and also to allow that the effort associated with undertaking maturity assessments need not be overly onerous. To this end, this tool offers three assessment strategies to help users parse the information provided with an order and level of detail that make sense for their circumstances. These strategies are elaborated in Appendix A, and address three use cases:

1. **Maritime baseline:** This strategy is addressed to operators coming from the mainstream of commercial shipping, where operations are compliant to regulatory requirements and adhere to the baseline safety management norms of shipping.

2. **PSM conversion:** This strategy is addressed to operators coming from shipping sectors where safety management norms are more mature than the mainstream (e.g. OCIMF-compliant tanker operators, gas-carriers) and the focus is therefore more tightly addressed to the specific hazard control changes required by ammonia-fuelled ops.

3. **Risk-based triage:** This strategy is a flexible option that allows operators to self-direct their engagement with the materials provided here in a risk-informed manner.

Irrespective of the strategy adopted, the general process of performing an assessment essentially consists of four steps:

1. Review element descriptions, as detailed in the **Element Tables**;

2. Compile and evaluate evidence regarding an organisation's performance against assessed elements;

3. Assign an organisation's current level of maturity within assessed elements and record this in the **Template**, alongside an indication of the type of evidence used to support the assessment; and

4. Record the opportunities to improve implied by the higher maturity bands for those elements.

Each of these steps may be undertaken with more or less rigour and resource. A quick pass through the elements, based on an assessor's own understanding of an operation and resulting in 'pencilled-in' conclusions, may take a matter of minutes. A more detailed evaluation of each element might take several hours or several days, depending on the degree of evidence gathered and the number of stakeholders involved. Some users may find that they transcend this tool altogether and enter into longer-term change programmes informed by wider PSM practice/ literature.

Each of these approaches and combinations of them can be valid. Different users and shipping organisations have different needs and resources, and the 'right' approach to using this tool is the approach that allows an organisation to make progress in improving safety, given its constraints.

For more detail on the assessment strategies, see Appendix A.

4.4. Assessment quality and evidence

As this tool supports a variety of approaches to assessment, it follows that not all assessments resulting from its use will be of equivalent quality. Appendix B provides high-level guidance on the factors affecting the quality of assessments using this tool, as well as general guidance on how assessments should be conducted to ensure that they provide the most useful findings, given the inevitable constraints.

In summary, however, the quality of an assessment may be thought of as governed by a 'triad' of interrelated factors:

1. The **credibility of the expertise** deployed to support the assessment;
2. The **evidence** base that informs the assessment; and
3. The **time** afforded to the process.

It is the combination of these components that determines assessment quality. Weakness in any component can have a large adverse effect on the overall strength of an assessment. Figure 4, below, illustrates this point.

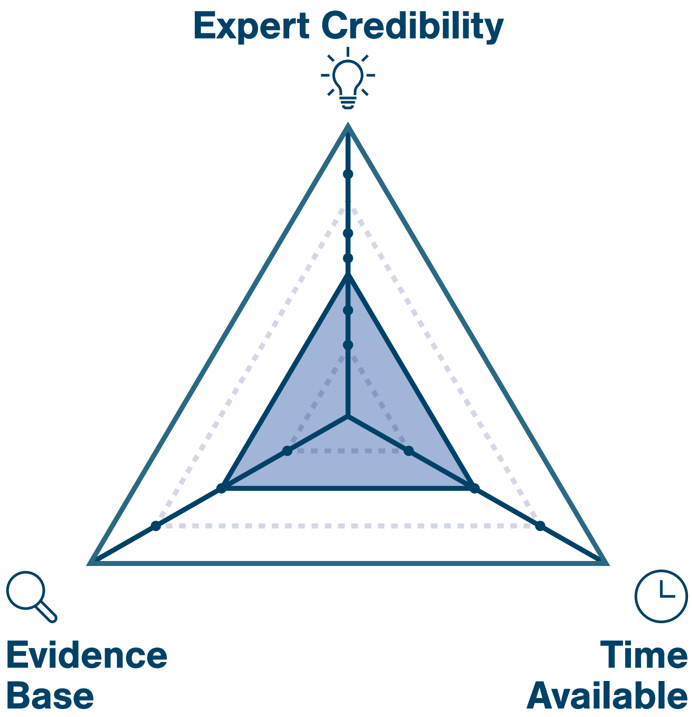

Figure 4 – The Assessment Quality Triad

5. We have completed an assessment – what now?

5.1. Evaluating assessment findings

Having completed an assessment with this tool, you will have developed:

- A structured view of the current PSM maturity of your operation's safety management arrangements as they relate to ammonia-fuelled systems across up to 16 PSM elements; and
- An indication of the activities associated with improved maturity in each element assessed.

These findings should be reflected in your completed **Template**.

As a general 'rule of thumb', we regard evidence of a *Standardised* level of PSM maturity across all elements as a minimum starting point for operators seeking to demonstrate effective control of the hazards associated with ammonia-fuelled operations. However, even *Standardised* maturity may not always be sufficient to provide for adequate control of these hazards, particularly where operators are confronting novel or dynamic contexts. Assessors must be mindful of the specific requirements of their circumstances when evaluating the adequacy of hazard controls, and a conservative approach to evaluating the efficacy of ammonia safety management is advised.

The presence of *Ad-hoc* maturity in any element indicates that an organisation is not yet ready to operate ammonia-fuelled systems (indeed, this level of performance is typically below current minimum regulatory norms for conventionally-fuelled vessels). *Reactive* performance is unlikely to be tolerable on any continuing basis in an organisation that seeks to control ammonia hazards.

5.2. Next actions

Having reviewed findings, the next step is to translate this new understanding into specific actions that improve safety management in practice. Here, it may be helpful to keep four points in mind:

First, focus on the aspects of your maturity profile that are likely to be priority limiting factors for ammonia operations. Although the tool gives equal space to all 16 elements, not all elements are equally important. In general, we assess that shortcomings in the elements Hazard Identification and Risk Analysis, Asset Integrity and Reliability, Management of Change and Emergency Management will have disproportionate influence on the likelihood and consequences of ammonia major hazard events. Where weaknesses are indicated in these domains, they should usually be treated as priorities.

Second, build a concise, usable improvement plan to which your organisation will hold itself accountable. In most cases, this should include: a set of prioritised actions; a named owner for each action; the evidence that will demonstrate the action has taken effect; and a review date. Where the assessment findings have highlighted uncertainty, disagreement, or weak evidence, it may be helpful to prioritise verification activities first before committing to changes. To be clear, the objective when effecting improvements is not to 'close out' assessment findings, but to increase the reliability with which hazards are controlled both during routine operations and when conditions are degraded.

Third, engage with the wider universe of PSM/ safety management resources (some of which are provided in the 'Selected references' section, below) to deepen analyses and strengthen improvement planning. This tool is designed to orient and prioritise. Where assessments indicate material uncertainty, weak performance, or high consequence exposure, operators should expect to draw on the wider PSM/ ammonia safety literature and practice to inform deeper work. For example:

- Where the hazard picture is uncertain or contested, structured hazard evaluation methods (for example, HAZID and HAZOP) can be used to test scenarios, assumptions and safeguards systematically. The Maritime Technologies Forum has issued guidance on these methods (available here).
- Where the adequacy of claimed safeguards is uncertain, PSM approaches such as Layer of Protection Analysis (LOPA) can be used to examine whether protection layers are independent, effective and sufficient for the scenarios that matter most.
- The CCPS Risk Based Process Safety Management framework and implementation guidance provides more detailed advice for diagnosing which elements require strengthening and how to sequence change.
- Where learning and feedback are underdeveloped, process safety metrics guidance can be used to establish leading and lagging indicators that reflect barrier health and management system performance, supporting evaluation of whether improvements are taking effect over time.
- For practical reasons, this tool has not been able to attend to the PSM elements Stakeholder outreach, Contractor Management, Operational Readiness and Incident Investigation. These elements remain important to effective ammonia PSM, however, and merit further investigation as described in the box on page 14.

Finally, plan for reassessment. Use of this tool need not be a one-off exercise, and it may be helpful to revisit the maturity assessment after major changes, key operational milestones and following audits, exercises or events that provide new evidence about hazard control performance. Such reassessments serve to validate the continuing accuracy of previous conclusions, confirm that intended improvements have taken effect and provide a basis for updated priorities as operational experience with ammonia increases.

The scope of this tool – while wide-ranging – is not fully comprehensive. While it offers insight into the maturity of an operator's safety management arrangements, it cannot provide complete or definitive assurance of ammonia readiness. Ultimate responsibility for determining the adequacy of safety management arrangements remains as specified within the applicable regulatory codes.

5.3. Get in touch

We welcome feedback to ensure that this new tool is as relevant and useful to the industry as possible. Please submit your feedback on the tool's format and/ or content via the link/ QR code provided in the executive summary.

6. Selected references

Maritime Technologies Forum. (2025). Guidelines for conducting qualitative risk assessments for alternative-fuelled ships: HAZID and HAZOP. Available from MTF website.

Maritime Technologies Forum. (2025). Guidelines for developing and implementing a safety management system for ammonia-fuelled vessels. Available from MTF website.

Center for Chemical Process Safety. (2007). Guidelines for Risk Based Process Safety. Hoboken, NJ: John Wiley & Sons.

Center for Chemical Process Safety. (2001). Layer of protection analysis: Simplified process risk assessment. Hoboken, NJ: John Wiley & Sons.

Center for Chemical Process Safety. (2011). Guidelines for auditing process safety management systems (2nd ed.). Hoboken, NJ: John Wiley & Sons.

Center for Chemical Process Safety. (2016). Guidelines for implementing process safety management (2nd ed.). Hoboken, NJ: John Wiley & Sons.

Center for Chemical Process Safety. (2022). Process safety metrics guide for leading and lagging indicators (Version 4.1). New York, NY: American Institute of Chemical Engineers.

Appendix A

Assessment strategies

This section presents three assessment strategies, provided to help users engage with the tool elements in a manner calibrated to their particular circumstances and objectives. These strategies frame the elements for different operator contexts: 'maritime baseline', for vessel operators complying with basic maritime safety management norms, 'PSM conversion' for operators with more advanced safety management practices, and a flexible 'triage' route. Use of these strategies is not mandated, but they illustrate logical, manageable and defensible 'on-ramps' for engaging with the tool elements.

A.1 Strategy 1 – Maritime Baseline

Target audience
Operators whose safety management arrangements are broadly compliant with baseline maritime safety management norms, but who are new to PSM/ safety management maturity self-assessment approaches.

Logic
This strategy reflects how PSM capability tends to develop. It prioritises establishing enabling conditions for reliable control, then defining the hazard and barrier picture. These actions provide 'groundwork' for subsequent work developing the more delivery-oriented PSM elements.

Example use case(s)
When first considering ammonia adoption, or when seeking an initial, baseline view of PSM maturity and improvement priorities.

Tier	Elements	Focus
Primary focuses	Process Safety Culture	Assure/ build enabling conditions for reliable control, then establish a credible hazard picture and safety intent.
	Compliance with Standards	
	Process Safety Competency	
	Workforce Involvement	
	Process Knowledge Management	
	Hazard Identification and Risk Analysis	
Secondary focuses	Operating Procedures	Translate intent into dependable operations, then sustain control through asset integrity maintenance, change management and emergency preparedness.
	Safe Work Practices	
	Asset Integrity and Reliability	
	Training and Performance Assurance	
	Management of Change	
	Conduct of Operations	
	Emergency Management	
Consider as able	Measurement and Metrics	Verify performance and drive continuous improvement.
	Auditing	
	Management Review and Continuous Improvement	

A.2 Strategy 2 – PSM Conversion

Target audience
Operators whose safety management practices are already well-structured and disciplined (e.g. OCIMF SIRE-compliant), and who are seeking to adapt these arrangements for ammonia operations.

Logic
This route assumes a broadly '*Standardised*' baseline across most elements. Priority is given to the elements most sensitive to the ammonia hazard profile. Follow-on checks confirm that practices and assurance remain calibrated to revised control requirements.

Example use case(s)
When an operator already demonstrates disciplined practice in control of hazards and the objective is to identify what must change for ammonia-fuelled operations.

Tier	Elements	Focus
Primary focuses	Hazard Identification and Risk Analysis	Revalidate hazard understanding and control logic, manage change, assure safety barrier performance, and validate human performance assumptions.
	Process Knowledge Management	
	Management of Change	
	Asset Integrity and Reliability	
	Emergency Management	
	Training and Performance Assurance	
Secondary focuses	Process Safety Culture	Confirm that day-to-day discipline, procedures and control of work are calibrated to ammonia scenarios and interfaces.
	Operating Procedures	
	Safe Work Practices	
	Conduct of Operations	
Consider as able	Compliance with Standards	Confirm that assurance systems will detect drift, skill fade and barrier degradation as experience accumulates.
	Process Safety Competency	
	Workforce Involvement	
	Measurement and Metrics	
	Auditing	
	Management Review and Continuous Improvement	

A.3 Strategy 3 – Risk-based triage

Target audience
Any operator wishing to tailor engagement with the appendices in a proportionate and defensible manner.

Logic
This route does not prescribe a fixed priority order. It provides a method for operators to determine their own priorities based on a risk-informed reading of the elements. The resulting strategy should be transparent in its bases and proportionate to available resources.

Example use case(s)
When time or resources require selective engagement, or where fleet diversity and/ or operational contexts imply atypical priorities.

The approach

1. **Define your operational context:** Evaluate and record the features of your operation that shape potential ammonia hazard exposure and controls (e.g. operations, interfaces, workforce factors).
2. **Perform an initial triage across all elements:** Using only the **Template**, perform a 'quick-pass', conservative assessment of all elements, in the light of the conclusions of Step 1, to identify any elements where either:
   a. Confidence that safety management is at '*Standardised*' level or above is low; or
   b. You lack the confidence to make even an initial assessment.
3. **Select a priority element set to review based on weaknesses and consequences:** From the triage, identify the elements that are most likely to be limiting factors for safe ammonia operations. The objective is to reduce material weaknesses first, not to perfect every element. As a general guide, prioritise elements that feature:
   a. Credible contribution to major hazard risk if weak; and/ or
   b. Evidence of '*Ad-hoc*' or '*Reactive*' characteristics, or low confidence in the assessment.
4. **Consider the enablers of your priorities:** For each priority selected from within the 'delivery element' ('Manage Risk' and 'Learn from Experience') categories of elements, confirm that the 'enabling elements' ('Commit to Process Safety' and 'Understand Hazards and Risks') basis required for reliable implementation is credible. Where enabling conditions are weak or questionable, findings in the delivery elements should be held with reduced confidence, and consideration should generally be given to elevating the priority of relevant enabling elements.
5. **Evaluate final priority element set in depth:** Review the full maturity descriptors (see **Element Tables**) for the priority elements, gather proportionate evidence and record maturity and evidence type in the **Template**. Where uncertainty exists between two bands, assign the lower band and note the implied improvement opportunities.
6. **State confidence explicitly:** Record the assessment bases, including expertise involved, evidence strength and time invested. This calibration of confidence is central to defensible use of the tool and to subsequent risk-based action.

Appendix B

Guidance on evidence quality

B.1 Credibility of expertise

PSM is an explicitly *integrative* approach to safety management, that insists that effective management of hazards requires the coordination of safe design, technical integrity assurance and prudently executed operations. In this context, the credibility of an assessment is strongly predicated on the technical credibility of those performing an assessment across each of these domains of integrity.

Generally, this means that a highly credible assessment should be performed by a team of experts who collectively possess the knowledge and experience required to evaluate the safety management arrangements in question from the range of perspectives relevant to those arrangements. While a single assessor – or a limited group – can perform assessments (and such assessments may be a sensible, pragmatic place to start), confidence in the conclusions drawn – particularly with respect to matters concerning any disciplines not represented among assessors – should be caveated accordingly.

In addition to expertise pertaining to the operation, specific expertise in process safety management, functional safety and human factors should also be incorporated in teams seeking to perform a maximally credible assessment.

Finally, while this tool is intended for self-assessment use, the credibility of assessments may be generally related to the independence of the team performing the assessment from the operation being assessed. 'Marking one's own homework' is best avoided.

B.2 Evidence

The confidence with which conclusions pertaining to an operation are drawn is a function of the quality of the supporting evidence. To this end, the PSM elements in the **Element Tables** are deliberately written to allow for explicit and unambiguous assessments of maturity based on observable safety management practices that can be evidenced as occurring (or not).

To allow for a diverse range of applications, however, this tool is deliberately non-prescriptive about 'what counts as evidence'. This recognises that different operators may deploy different levels of resource to gathering and compiling evidence (ranging, for example, from a single expert conducting a quick-pass assessment based on their own experience to a multi-disciplinary team taking several days or weeks to sample safety management practices and assembling dossiers of evidence obtained in the process).

This does not mean, however, that it is not possible to discriminate between better and worse evidential bases. The general rules applicable here are that better evidence is:

- **Objective:** Good evidence is typically grounded in observable/ verifiable states of an operation, not more subjective opinions;
- **Traceable:** From a practical perspective, specific evidence that can be documented and traced to a particular set of circumstances tends to provide a more useful basis for supporting safety management activities than more abstract, general observations where provenance is less clear;

- **Representative:** Good evidence should reflect the typical performance of the operation. Assessors should be alert to the risk that evidence gathered from a narrow sample – whether of assets, time periods, or operational conditions – may present a misleading picture, and should qualify conclusions accordingly; and

- **Succinct:** The temptation to gather large volumes of data simply because it is available should be resisted, except where this contributes meaningful additional value to an assessment.

An approach that may be useful when gathering evidence is the employment of 'objective tests'. These tests pose specific, observable conditions that should hold if a given level of maturity is genuinely present, rather than relying solely on document review or the self-reporting of those being assessed. For example, if an organisation genuinely operates at a mature level of process safety culture, one would expect that asking three different people who is accountable for a given process safety decision would produce a consistent answer. If it does not, this is a meaningful signal regardless of what documentation suggests. Assessors are encouraged to develop their own objective tests of this kind, tailored to the specific context of the operation being assessed, as a practical means of grounding their conclusions.

The general approach to evidence-gathering presented here has two key implications:

1. **Proportionality:** While lower-quality evidence implies that conclusions should be held with lower confidence, this does not mean that they are invalid. A 'quick-pass' may be an acceptable 'place to start' when using this tool and – in the context of limited resources – it may be reasonable to triage the aspects of the safety management organisation that get the most attention.

2. **Transparency:** It is, however, important that an evaluation is transparent with respect to its evidential bases, as this helps users and external parties maintain an appropriate orientation with respect to the integrity of assessments made.

To this end, the **Template** contains a column for indicating the type of evidence that supports an assessment. Entries to this column may be as simple as 'Professional opinion – [Assessor's Name], [Date]', but can be expanded to reference multidisciplinary workshop minutes/ conclusions, or dossiers of evidence gathered (etc.), depending on the circumstances.

B.3 Time

The time afforded to an assessment has an obvious and direct bearing on the depth of expertise that can be engaged and the breadth of evidence that can be gathered; it is an enabler/ constraint on the other two components of the 'evidence quality triad'. A rapid assessment conducted by a single expert will typically rest on a narrower evidential base than one conducted by a multidisciplinary team over several days, and confidence in conclusions should be calibrated accordingly.

As with evidence quality, however, this is not to say that time-constrained assessments are without value. A time-limited assessment that is transparent about its constraints may still offer a reasonable starting point, particularly where the primary purpose is to identify areas meriting closer attention, rather than to produce a definitive assessment of maturity. The key discipline is that the time invested in an assessment should be proportionate to the confidence placed in its conclusions, and that where time has been limited, this is clearly recorded as a qualification on those conclusions.

Terms and Abbreviations

Abbreviation	Expansion
AFSS	Ammonia fuel supply system
CCPS	Center for Chemical Process Safety
CMM	Capability Maturity Model
D&A	Drug and alcohol
FMEA	Failure mode and effects analysis
GHG	Greenhouse gas
HAZID	Hazard identification
HAZOP	Hazard and operability study
HIRA	Hazard identification and risk analysis
IMO	The International Maritime Organization
ISM Code	The International Safety Management Code
LOPA	Layer of protection analysis
LOTO	Lock out, tag out
MoC	Management of change
P&I	Protection and indemnity
P&ID	Piping and instrumentation diagram
PDCA	Plan–Do–Check–Act
PFD	Process flow diagram
PKM	Process knowledge management
PMS	Planned maintenance system
PPE	Personal protective equipment
PSM	Process safety management
PSSR	Pre-start-up safety review
PTW	Permit to work
QRA	Quantitative risk assessment
RBPSM	Risk-based process safety management
SGMF	The Society for Gas as a Marine Fuel
SIMOPS	Simultaneous operations (e.g. bunkering while loading cargo)
SMS	Safety management system
SOP	Standard operating procedure
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

Fonden Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping is real climate action. We are a not-for-profit, independent research and development center established to accelerate the transition towards a net-zero future for the maritime industry. Together with our partners, we enable and inform the development and implementation of new technologies, build confidence in new concepts, and mature viable pathways to support the systemic and regulatory changes required to decarbonize global shipping.

As an independent and neutral platform for cross-sector collaboration, the Center brings together industry leaders, researchers, policymakers and public institutions to address some of the most complex challenges facing maritime decarbonization. Our work is grounded in scientific integrity, transparency and responsible governance, and is designed to facilitate trusted collaboration while respecting the independent decision-making of all participants.

The Center does not direct, coordinate or endorse commercial behaviour, market strategies or competitive outcomes. Instead, we provide fact-based research, analysis and insights that stakeholders may independently assess and apply within their own organisations and decision-making processes. We are committed to presenting our findings neutrally and transparently, including through clear methodologies and defined scopes of work, in order to support informed dialogue, innovation and evidence-based policymaking across the maritime ecosystem.

Through applied research, partnerships and industry-wide engagement, we aim to accelerate scalable solutions that support a safe, sustainable and commercially viable transition for the global maritime industry.

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The Decarb Hub

The Lloyd's Register Maritime Decarbonisation Hub (commonly known as the Decarb Hub) is an independent, non-profit initiative established through a partnership between Lloyd's Register Foundation — a global charity with a mission to engineer a safer world — and Lloyd's Register Group, a global provider of maritime professional services with over 260 years of heritage.

This partnership brings together the Foundation's public benefit mandate and focus on societal resilience, with the Group's deep technical expertise and trusted relationships across the maritime industry. Positioned at the intersection of these two organisations, the Hub is uniquely equipped to accelerate the safe, sustainable, and human-centric decarbonisation of global shipping — combining neutrality with influence, and research with real-world application.

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