DARE2X

Decentralised Ammonia production from Renewable Energy utilising novel sorption-enhanced plasma-catalytic Power-to-X technology

D7.3- ROADMAP FOR STANDARDISATION AND CERTIFICATION

Lead beneficiary: Lomartov SL

Author(s): Jan Klenner, Alba Lafarga, Francisco J. Astorga, Patricia Monzó, Isaac Herraiz

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Executive summary: This report summarises the work in T7.4 on standardisation and certification, with the objective of aligning the DARE2X technology development with current and future requirements, and thereby facilitating a faster successful market uptake of the project's technology. First, an overview of the current legal and standardisation landscape is provided. This is based on extensive database search, external services, and the focus on thematic clusters of safety, production & quality, green ammonia, and various applications. Second, this report summarises current gaps in this landscape and provides recommendations for actions to pursue to meet all requirements. Recommendations, also given with an approximate timing, are to i) comply with existing, relevant safety standards in development and production, ii) comply with existing, relevant ammonia quality and production standards, iii) evaluate participation in standardisation committees for DARE2X technology, iv) ensure alignment with green ammonia and energy efficiency standards, v) comply with sector specific requirements and standards and vi) acquire certifications that are of strategic importance.

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[1] R: Document, report; DEM: Demonstrator, pilot, prototype; DEC: Website, video etc., DATA: Data sets; DMP: Data management plan; ETHICS; SECURITY; Other: Software, technical diagram, algorithms, models etc.

[2] PU: Public, fully open; SEN: Sensitive.

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ABBREVIATIONS AND ACRONYMS

Abbreviation	Full expression
ASME	American Society of Mechanical Engineers
CBAM	Carbon Border Adjustment Mechanism
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
ETS	Emission Trading Scheme
ETSI	European Telecommunications Standards Institute
EU	European Union
GA	Grant Agreement
GHG	Greenhouse gas
H2	Hydrogen
IMO	International Maritime Organisation
ISO	International Standardisation Organisation
NH3	Ammonia
NTP	Non-thermal plasma
PSA	Pressure-swing absorption
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RED	Renewable Energy Directive
RFNBO	Renewable Fuel of Non Biological Origin
SC	Subcommittee
TC	Technical Committee
TRL	Technology Readiness Level
US	United States of America

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Introduction

NH_3 is key chemical in today's economies due to its importance for the production of nitrogen fertilisers (Lim et al., 2021). In addition, NH_3 is considered as a Renewable Fuel of Non-Biological Origin (RFNBO) – if produced with renewable energy – that could be employed in a wide range of applications, from shipping to stationary power (Chai et al., 2021; Valera-Medina et al., 2018). Nevertheless, currently NH_3 is produced almost exclusively with the Haber-Bosch process using fossil, natural gas. Thus, current NH_3 production contributes about 1.3% to global anthropogenic CO_2 emissions (International Energy Agency, 2021). This motivates the development of alternative production technologies such as in the DARE2X project with the ambition to align future NH_3 production with the sustainable development goal (SDG) 13: *Climate Action* (Valera-Medina et al., 2018).

Particularly, the DARE2X project proposes an alternative pathway for ammonia (NH_3) production that combines a non-thermal plasma (NTP) reactor with in-situ or post-reactor novel sorption materials to produce a pure NH_3 stream. The approach promises environmental benefits using renewable electricity as power source.

One of DARE2X project objectives is to increase the technology readiness level (TRL) of related technologies. **To reach commercial application** (a TRL of 9), **the adherence to and compliance of international regulations and standards is necessary**. This is particularly relevant in the case of DARE2X, as NH_3 is known to be inflammable, toxic for humans and the environment, and corrosive (Valera-Medina et al., 2018).

This report summarises the analysis of the **regulatory and standardisation landscape** relevant for the DARE2X project. The adherence to some specifications covered by standards is mandatory by law, but compliance with non-mandatory standards can also increase the value of the solution. Certifications are related, as they communicate a third-party proven adherence to specific standards.

Standards can ensure compatibility and interoperability of products and processes, improve their safety, prepare them for public procurement in the future and de-risk investments and reduce (financing) cost (European Clean Hydrogen Alliance, 2023). In the development stage, awareness and/or compliance to standards can also help to make aware of best-practices in the field, streamline the innovation process, potentially enable innovation (HSbooster.eu, 2022). Findings of relevance can also be channelled into input to a new or existing standardisation process. Furthermore, gaps in the current standardisation landscape can be addressed by actively participating in the standardisation process. In fact, the need for updating regulations and standards to enable new technologies and markets for NH_3 has been highlighted previously (Mission Possible Partnership, 2022; van't Noordende et al., 2024).

The motivation for this report is to increase the awareness of project partners about:

1. Relevant, **current** standards and certifications.
2. Relevant standards and certifications **in development**.
3. Opportunities to shape future developments by participating in the process.

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The ambition of this report is to serve as a starting point for further activities regarding standardisation. It summarises information and indicates relevant sources regarding the topic. Furthermore, a **roadmap** is presented that indicates which activities may be prioritised in the next development stages.

As the author team, we focus on those standards and certifications we deem most relevant for a successful commercialisation of the DARE2X technology. Consequently, not all standards are considered in detail, in particular, highly specific technical standards are not the focus. Spatially, this deliverable focuses on the commercialisation on the European market. In some cases, additional information for extra-European markets is provided.

The remainder of the report is structured as follows *Chapter 1* draws a picture of the current standardisation landscape, provides a working definition for a standard, and describes typical processes for standards generation. *Chapter 2* contains an overview of the DARE2X technology and what aspects are potentially relevant for standardisation. *Chapter 3* contains a summary of the methodology applied to identify relevant standards for the DARE2X project. The results of applying this methodology are presented, grouped into thematic clusters, in *Chapter 4*. *Chapter 5* focuses on gaps in the current standardisation landscape and provides a roadmap with suggestions regarding standardisation of DARE2X technology towards its commercialisation. A short conclusion is provided in *Chapter 6*.

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1. Standard definition, actors, and creation processes

This chapter provides a short overview of the status-quo of the standardisation landscape and a rough outline of different stakeholders and their role. This chapter can facilitate a better understanding of the requirements for the DARE2X solution and a potential roadmap. First, the working definition of a standard is provided and two main pathways for standards creation are outlined. In this context, different standardisation bodies are introduced. Lastly, the role of certification entities is described.

The definition of the term standard (as a synonym for technical standard), in the words of the International Standardisation Organisation (ISO), is:

[…] A standard provides rules, guidelines or characteristics for activities or for their results, aimed at achieving the optimum degree of order in a given context. It can take many forms. Apart from product standards, other examples include: test methods, codes of practice, guideline standards and management systems standards.[3]

A standard by itself can be followed but compliance is not mandatory. However, in many cases adhering to standards is de-facto mandatory as they often are in agreement with existing legislation.

In contrast to a standard, a regulation or law is a rule that establishes specific requirements that actors must comply with. Legislation by the European Union (Commission and Parliament) is made via directives, regulations, and decisions. While directives define goals and the individual member states are free to enact specific laws to achieve them, regulations are directly binding for all member states[4]. In the EU, there is a close link between standardisation and legislation.

1.1 Two pathways for standard creation

Two pathways for standard creation in the EU are distinguished here. The first involves the creation of a standard in response to new or updated legislation, while the second can be characterised by the voluntary efforts by a group of stakeholders to increase the degree of standardisation within their area of interest.

The **first pathway** is exemplified by the example of the "New Approach" in the EU. It is a way of splitting responsibilities between the legislation and the more technical-oriented standardisation bodies. The "New approach" from 1985 builds on the following four blocks:

1. **Legislative Harmonization through Essential Requirements**

   EU Directives establish essential safety and general interest requirements. These directives ensure that products placed on the market conform to these requirements, facilitating their free movement throughout the European Union.

[3] Link: *https://www.iso.org/deliverables-all.html* (accessed 20/05/2025)
[4] Link: https://european-union.europa.eu/institutions-law-budget/law/types-legislation_en (accessed 20/05/2025)

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2. **Delegation of Technical Specification Development**

   The detailed technical specifications required for products to meet the essential requirements set out in the directives are developed by competent standardisation organizations. In the European Union, only three standardisation bodies are accepted to fulfil this role, namely the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), and the European Telecommunications Standards Institute (ETSI).

3. **Voluntary Nature of Harmonised Standards**

   The technical specifications, or harmonised standards, created by these standardisation bodies are not mandatory. They maintain their status as voluntary standards, providing manufacturers with flexibility in their production processes.

4. **Presumption of Conformity and Obligations of Proof**

   Products that adhere to harmonised standards are presumed to comply with the essential requirements established by the relevant directives (presumption of conformity). However, manufacturers are not obligated to use these harmonised standards; they can choose alternative methods to demonstrate that their products meet the essential requirements. In such cases, the burden of proof lies with the manufacturers to show compliance with the directives.[5]

In the US, the approach is different. There, regulatory authorities can recognise multiple national, regional and/or international standards as compliant with legislation. Simultaneously, standards development is less legislation driven and rather follows the second, (industry) stakeholder-driven pathway[6],[7].

The **second pathway** can also be considered the classical way of standards development. A single or group of stakeholders, often private companies, come forward with an idea of increasing the degree of standardisation regarding a product or process.

Reasons, as described earlier, can include improved compatibility and interoperability of products and processes, improved safety, and de-risking investments and reduced (financing) cost (European Clean Hydrogen Alliance, 2023). Furthermore, economic interests and the advantage of being involved in the standard setting can be further motives.

Once established the need or desire to establish a new standard, often a well-defined process is initiated. An example for this process at the ISO is visualised in Figure 1. The full process of

[5] Link: https://boss.cen.eu/reference-material/guidancedoc/pages/newapproach/ (accessed 28/02/2025)
[6] Link: https://www.transatlantic.org/wp-content/uploads/2022/03/TTC-tech-standards-January-2021.pdf (accessed 20/05/2025)
[7] Link: https://osha.europa.eu/en/european-standards (accessed 20/05/2025)

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standard development (TC/SC Route in figure) often takes various years and includes consensus building and formal checks.

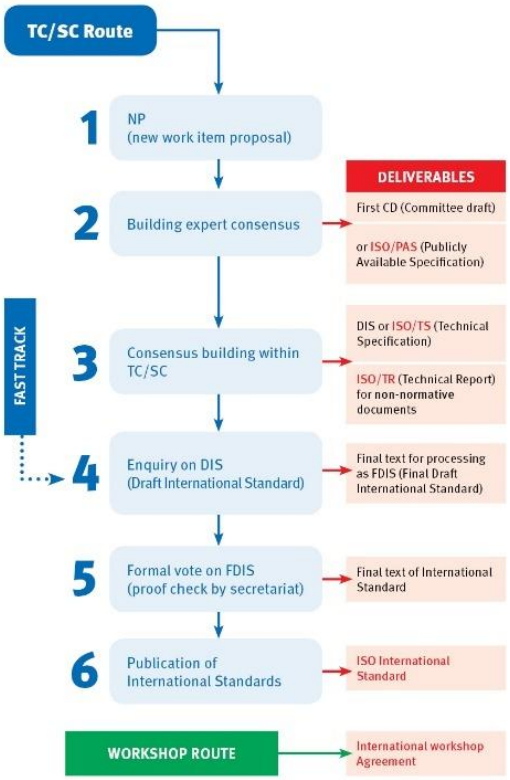

Figure 1. Schematic representation of the standard development process at the International Standardisation Organisation for an ordinary standard or an International Workshop Agreement.

Yet, there are also intermediate results such as workshop agreements that are much faster to achieve and can provide first public results while, in parallel, the development of a full standard may be ongoing. Workshop agreements can be published relatively quickly and offer therefore the opportunity to influence the standardisation landscape in a potentially faster manner[8].

1.2 Certification and certification bodies

Certification is a voluntary procedure by which conformity or adherence to one or several standards is expressed. This conformity is assured by an independent, third party, called a certification body. Certification is a means of communication with other parties as it demonstrates that the product / process adheres to specific standards, and thereby often to applicable legislation.[9] In some cases, certification is not based on any existing, applicable standard.

[8] Link: https://www.iso.org/deliverables-all.html (accessed 28/02/2025)
[9] Link: https://www.fao.org/4/y5136e/y5136e07.htm (accessed 28/02/2025)

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1.3 Relevant institutions

In the European context, the hierarchy of relevant institutions for the standardisation landscape can be summarised as in Figure 2. United Nations organisations, such as the International Maritime Organization (IMO), can be considered one level above, as they may propose international treaties that establish global, international laws. Legislative bodies of the EU (European Commission, European Parliament, Council of the European Union) establish directives and regulations that are mandatory within the EU. In addition, national regulation applies. However, in our analysis of the legal situation, European legislation appeared consolidated with regards to aspects relevant to DARE2X.

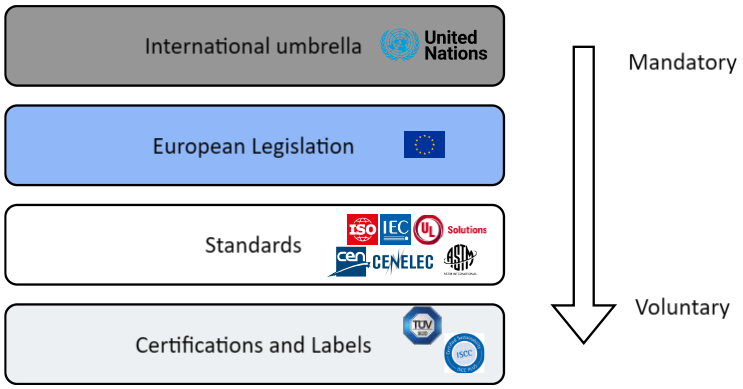

Figure 2. Hierarchy and overview of relevant institutions and organisations considered relevant for the standardisation and certification roadmap for DARE2X technology.

Standardisation bodies can, as described above, create standards that ensure compliance of these directives or create standards for other reasons. Examples for public standardisation organisations are the CEN, CENELEC and ETSI, or national standardisation bodies (often contributing towards CEN and ISO) such as the German “Deutsches Institut für Normung” (DIN) or Danish “Dansk Standard” (DS). Important private standardisation institutions are the ISO and the American Society of Mechanical Engineers (ASME),

Various certification bodies exist. They are usually private companies, as for example TÜV SÜD, CertifHY, ISCC, and UL, and offer different certifications, for example, related to safety and environmental standards.

1.4 Chapter summary

The standardisation landscape in which DARE2X is situated hosts different actors. Legislative institutions at global, European and national level may enact relevant directives and regulations. These may be adapted by public or private standardisation organisations to provide technical guidance that ensures the compliance to current laws. In addition, other, independently developed standards by industry or other stakeholders may apply. Certification bodies can provide third-party verifications that express that standards are fulfilled.

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2. Aspects of DARE2X solution relevant for the deliverable

This chapter briefly outlines the DARE2X solution and highlights aspects that are deemed as highly relevant for the standardisation roadmap.

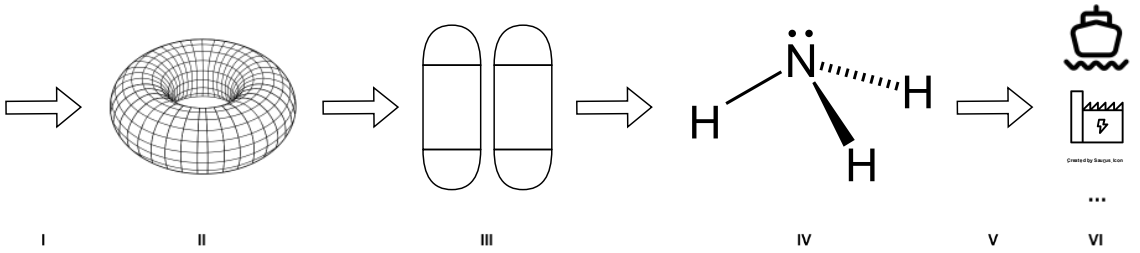

Figure 3. DARE2X technology and potential supply chain to key applications. I: Production of H_2 and N_2, II: Non-thermal plasma reactor for NH_3 synthesis using novel catalysts, III: Pressure-Swing-Adsorption with novel adsorption materials (assuming a two-stage solution), IV: Ammonia as the main product, subject to potential impurities, V: Ammonia transport, VI: Key applications (maritime fuel, stationary fuel, others).

The outline of the DARE2X key components in the NH_3 production and full supply chain are presented in Figure 3. Hydrogen (H_2) and nitrogen (N_2), produced with electrolysis and pressure swing adsorption (PSA), respectively, and hence potentially with renewable electricity, are input feedstock to a NTP reactor (Figure 3, element II). There, innovative catalysts are used to further enhance the economics of the NH_3 synthesis by lowering the energy demand and increasing the reaction speed. Two design options are considered. A reactor with integrated NH_3 sorption or a two-stage solution with subsequent NH_3 separation using a PSA unit with novel sorption materials. Reactor and adsorption are used to produce a pure NH_3 stream (Figure 3, element III, IV). A key promise of the DARE2X technology is to produce NH_3 at smaller, decentralised plants compared to thermal processes, such as electric Haber-Bosch synthesis. From the plant NH_3 can then be transported to envisioned end-uses, e.g., NH_3 as a fuel for maritime sector and stationary power (Figure 3, element V, VI).

Regulations, standards, and certifications may apply and affect the design of the system at all these stages. Standards related to catalysts, and general production standards including aspects of **safety** are especially relevant in step II and III. Standards related to the **properties and quality** of the product apply in step IV and subsequent steps. In the steps V and VI, **safety and emissions** may be of special importance.

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3. Methodology

This chapter explains briefly the approach and resources used for the analysis of the standardisation landscape and the development of a roadmap. First, standards were identified by screening potentially relevant standardisation bodies, using search engines and databases, the external HSBooster service, asking for feedback from project partners, and contacting local regulation bodies. Then, identified standards were scanned for potential relevance and a short-list of standards is presented in Chapter 4, clustered into thematic groups. In addition, related regulations and directives, and certifications were collected. An evaluation of importance and priorities, and an analysis of potential gaps led to the formulation of a roadmap for standardisation (Chapter 5).

3.1 Identification of standards

Different sources are used to screen the landscape and to create an initial list of potentially relevant standards (existing or in development).

3.1.1 Working groups search and direct search

Inspecting the standardisation bodies

ISO, CEN, IEC, DIN, Standard Norge, Danish Standards, British Standards Institute, EAGLE, UL, ASME, ANSI,

potentially relevant working groups (technical committees etc.) were identified. All standards (published, in development, planned, superseded) prepared by relevant working groups of these organisations were extracted and subsequently screened for relevance to the DARE2X project considering the title and abstract.

In addition, direct keyword search for the keywords

(Ammonia OR NH_3 *OR hydrogen) AND (safety OR air quality OR emissions OR green OR stationary OR quality OR purity OR catalyst OR plasma)*

was performed on the standardisation bodies search engines and databases (e.g., genorma.com).

Additional literature search on previous project deliverables was realised and used to confirm above choices. Iteratively, the list of working groups was expanded with newly identified standards from the keyword search and the search in additional material.

3.1.2 HSbooster

In addition, the external expert service HSbooster was used. The self-description of HSbooster is: *HSbooster.eu offers a consultancy service to EU-funded projects seeking guidance on standardisation-related aspects of their research projects. Our aim is to assist projects in effectively navigating the standardisation landscape, ensuring their work aligns with relevant standards and maximising their impact in the market.* (https://www.hsbooster.eu/how-booster-works-standards-experts).

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The service provided a shortlist of **41 standards**, some grouped in the categories testing for quality, storage, and hydrogen. These shortlisted standards were used in the analysis of working groups and relevant standards.

3.1.3 Contact with local regulation bodies and project partners

Recommended by the experts of HSbooster.eu, the Spanish standardisation organisation UNE was contacted. They provided valuable insights on the general standardisation landscape (reflected in Chapter 1) and pointed towards some external references that were used to identify additional standards.

Additionally, the project partners were actively invited to provide input to the deliverable. In a first step, a couple of survey questions were sent out to partners as a part of the stakeholder survey. In a second step, the created shortlist of standards and roadmap was presented and valuable feedback gathered.

3.2 Classification and prioritisation framework for standards and certifications

To structure the shortlisted standards, thematic groups were identified and used to analyse the current standardisation landscape (Figure 4). The thematic **cluster of safety** applies to the entire DARE2X supply chain. Likewise, the **cluster of green NH_3** concerns all production stages, inputs, and applications as the related life-cycle philosophy implies that emissions along the entire supply chain (Scope 3 emissions in the EU framework) are of relevance. More technology specific standards and NH_3 quality standards are grouped into the **cluster of NH_3 production technology and quality** and concern the NTP reactor, PSA for NH_3 production and the final product leaving the DARE2X plant, as impurities may be present. In addition, standards for **maritime applications** and other applications are considered. In the case of overlap, standards are presented in the most specific group, e.g., safety standards that apply to the production process are listed in the production cluster. However, in most cases, safety standards are framed more generally explaining that the safety category contains the largest number of standards.

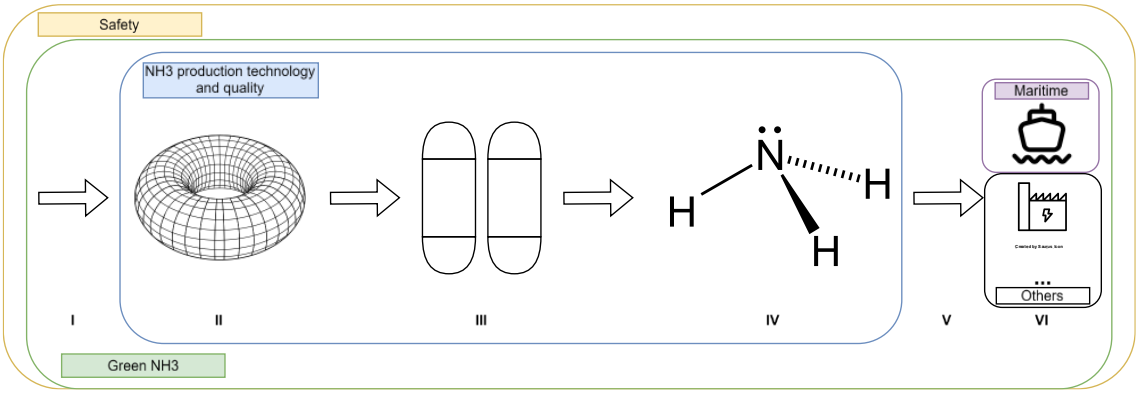

Figure 4. Classification framework for standards and certifications differentiated by thematic area and in relation to DARE2X potential supply chain. Thematic clusters are safety (yellow), green NH_3 (green), production technology and quality (blue), maritime applications (purple) and other applications (black).

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In the process of shortlisting the most relevant standards, a qualitative, expert judgement approach was chosen. Criteria and examples for classification of all collected standards into one of four categories of importance are summarised in Table 1. Mandatory and de-factor mandatory standards for commercial NH_3 applications were given the highest priority. Then optional standards with direct relevance to DARE2X key innovations are shortlisted. Identified standards that are of no relevance to the DARE2X supply chain or highly general are not shortlisted and assigned the lowest priority level.

Table 1: Prioritisation criteria applied to identified standards.

Category	Description and examples
High relevance	Mandatory by law at continental of global scale. Often used certification applicable to the product. Applicable to H_2 or NH_3 as products of DARE2X solution.
Medium relevance	Adherence of all current technologies to these standards, applies to core technologies of DARE2X. Optional standard applicable to technologies not at the centre of development, e.g., to electrolysers or NH_3 storage
No relevance	Evaluation shows no relevance for DARE2X solution. Also, standards that apply to all organisations (e.g., general quality management) fall into this category.

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4. Standards, certifications and regulations for DARE2X

In total, more than one hundred standards were identified as relevant for DARE2X technology using the previously described methodology. The standards are categorised and ranked for relevance in different thematic clusters, namely: safety; green ammonia; ammonia production, catalysts, and quality; maritime applications; and other applications. The largest group of shortlisted standards concerns safety of NH_3 production, storage, and handling. Standards related to production and quality of NH_3 are also frequent, followed in quantity by standards related to environmental-friendly, green ammonia. Less standards are shortlisted for maritime and other applications of DARE2X and NH_3. The most frequently occurring terms in relevant standards are shown in Figure 5. The reader is reminded of the exclusion of very general standards that are not specific to NH_3 or DARE2X, e.g., general standards on company-wide quality management. Before the detailed overview of the thematic clusters, the importance of different regulatory and standardisation bodies and their working groups for different thematic clusters is presented.

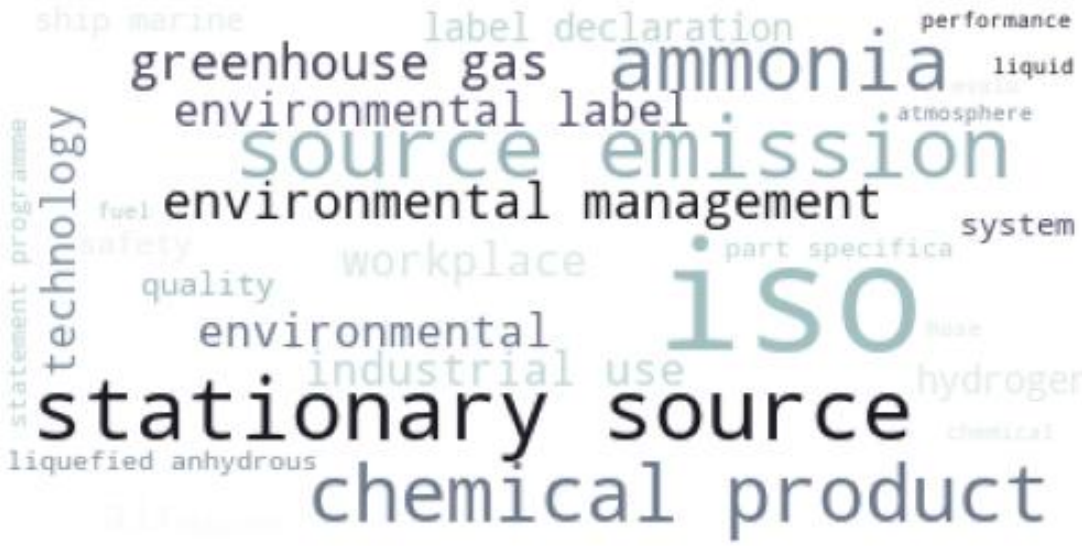

Figure 5: Wordcloud summary of most frequently mentioned terms in the shortlisted standards using titles and abstracts.

4.1 Mapping of Institutions and DARE2X relevance

Regulatory bodies identified that enacted relevant legislation regarding DARE2X technology comprise the EU Commission and EU Parliament, and the International Maritime Organization (IMO) (Figure 6). Additionally, the EU Occupational Safety and Health Administration is involved in the regulatory work in the EU but does not have a legislative mandate. US entities are mentioned here, but the focus of this deliverable is on the EU market.

ISO and CEN are the two standardisation bodies with most relevant working groups and standards identified (Figure 6). They have published standards of all thematic clusters

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considered. Other standardisation bodies of relevance are IEC, CGA, ASME, UL, AGS, NACE, EAGLE and ASTM.

Some examples of certification bodies are TÜV SÜD, CertifHy, UL, ISCC, Smart Energy, and LLoydRegister. These entities offer several certifications related to green ammonia, safety, and maritime handling.

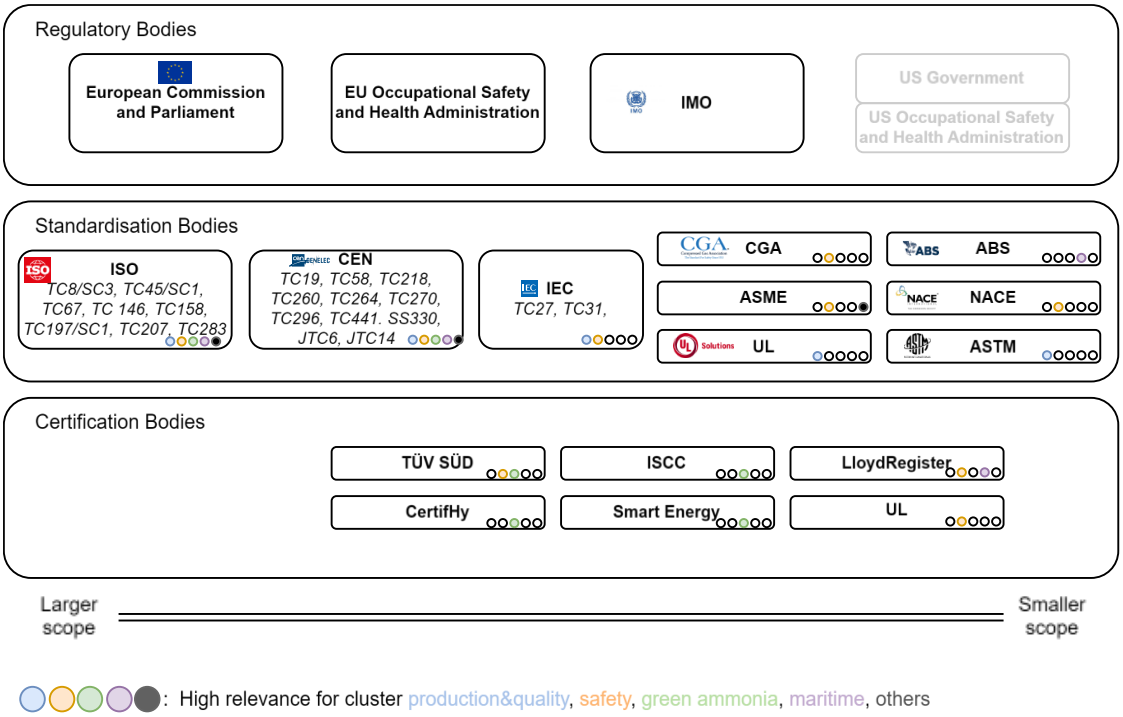

Figure 6. Mapping of DARE2X thematic clusters to regulatory, standardisation and certification bodies. Coloured circles for standardisation and certification bodies indicate which thematic clusters are addressed by the respective body. Blue: Production and Quality; Yellow: Safety; Green: Green ammonia; Purple: Maritime applications; Grey: Others.

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4.2 Safety cluster

The first thematic group of regulations and standards inspected is related to the topic of safety. NH_3, being toxic to humans and the environment, corrosive, and explosive (in gaseous, anhydrous state), requires controlled handling.[10] Further, safety is a critical aspect in the process of social acceptance of NH_3 according to stakeholder consultations and studies (Bennani et al., 2016; Guati Rojo, 2021).

4.2.1 Legislation: Safety directives and regulations

Table 2 contains an overview and short description of directives and regulations identified as relevant to DARE2X in the topical cluster of safety. The directives cover topics of classification of chemicals as hazardous, and their occupational exposure, handling, transport, environmental protection, and labelling. Also, more general topics of worker safety are treated.

Table 2. European safety legislation relevant for DARE2X technology.

Short name	***Title***
Directive 98/24/EC	***Directive 98/24/EC - risks related to chemical agents at work***
Description	The Directive aims to protect workers from risks to their safety and health arising, or likely to arise, from the effects of chemical agents that are present at the workplace or as a result of any work activity involving chemical agents. It places obligations on the employers to determine whether any hazardous chemical agents are present at the workplace and to take steps to assess (and reduce) any risk to the safety and health of workers arising from the presence of those chemical agents.
Directive 2000/39/EC	***Directive 2000/39/EC - indicative occupational exposure limit values***
Description	The directive provides a list of indicative occupational exposure limit values for different chemicals, including ammonia. The list is based on Council Directive 98/24/EC concerning the protection of the health and safety of workers from the risks related to chemical agents in the workplace. Indicative occupational exposure limit values (IOELV) are health-based, non-binding values, derived from the most recent scientific data available and the availability of reliable measurement techniques. Member States are required to establish a national occupational exposure limit value, taking into account the EU limit value when determining the national limit. The indicative values by the EU are: Time-Weighted Average exposure limits over 8 hours: 20 parts per million (ppm) or 14 milligrams per cubic meter (mg/m³) and Short-Term Exposure Limit over 15 minutes: 50 ppm or 36 mg/ m³.
CLP Directive	***Regulation (EC) No 1272/2008 - classification, labelling and packaging of substances and mixtures (CLP)***
Description	The purpose of this Regulation is to harmonise the criteria for classification of substances and mixtures, and the rules on labelling and packaging for hazardous substances and mixtures. It also aims at establishing a classification and labelling inventory of substances. This Regulation shall not apply to the transport of dangerous goods by air, sea, road, rail or inland waterways except for labelling of outer packaging, inner packaging and single packaging. It sets general obligations to manufacturers, importers and downstream users to classify, label and package substances or mixtures. It orders that packaging has to be strong and solid enough to endure general handling and defines competent authorities for enforcement.

[10] Link: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.028.760 (accessed 30/10/2024)

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Short name	*Title*
Directive 2008/68/EC	***Directive 2008/68/EC - inland transport of dangerous goods***
Description	The Directive establishes a common regime for all aspects of the inland transport of dangerous goods, by road, rail, and inland waterway. Transport of dangerous goods between Member States, and between Member States and third countries, must comply with the requirements. This Directive does not apply to the transport of dangerous goods by the armed forces, by seagoing vessels on maritime waterways, or by ferries crossing an inland waterway.
REACH	***Regulation (EC) No 1907/2006 - Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)***
Description	Directive concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and establishing a European Chemicals Agency for the purpose of this regulation is to ensure a high level of protection of human health and the environment. The directive applies to all substances which are produced in quantities of one tonne or more per year and intended to be released under normal or reasonably foreseeable conditions of use. These have been registered in accordance with the relevant provisions where this is required. A chemical safety assessment shall be performed and a chemical safety report completed for all substances subject to registration in quantities of 10 tonnes or more per year per registrant. A chemical safety assessment of a substance shall include the following steps: human health hazard assessment, physicochemical hazard assessment, environmental hazard assessment, persistent, bioaccumulative and toxic (PBT) and very persistent and very bioaccumulative (vPvB) assessment.
ATEX	***Directive 2014/34/EU - harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast)***
Description	The ATEX Directive 2014/34/EU covers equipment and protective systems intended for use in potentially explosive atmospheres. The directive defines the essential health and safety requirements and conformity assessment procedures, to be applied before products are placed on the EU market. It is aligned with the new legislative framework policy, and it is applicable from 20 April 2016, replacing the previous Directive 94/9/EC. It is understood that the DARE2X technology will involve explosive atmospheres and hence be subject to the directive.
Directive 89/391 EEC	***Directive* 89/391 EEC- introduction of measures to encourage improvements in the safety and health of workers at work**
Description	This Directive contains general principles concerning the prevention of occupational risks, the protection of safety and health, the elimination of risk and accident factors, the informing, consultation, balanced participation in accordance with national laws and/ or practices and training of workers and their representatives, as well as general guidelines for the implementation of the said principles.

In the United States, similar legislation is in place. A short overview of identified directives is provided in the Annex.

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4.2.2 Safety standards – current and in development

Standards collected for with relevance to safety aspects of NH_3 production, handling and storage are provided in Table 3. Some standards focus on the technical specifications of implementing safe NH_3 infrastructure. Other standards describe the occupational health and safety systems including maximum exposure values. Further topics addressed include the signalling and communication of NH_3, testing of air quality, and testing exposure levels.

Table 3. Safety standards identified relevant for DARE2X technology. Grey background for standards with highest priority within the cluster.

Short name	Title	Working group
CGA G-2.1-2023	Requirements for the Storage and Handling of Anhydrous Ammonia - 7th Edition.	CGA
ISO/TS 19883:2017	Safety of pressure swing adsorption systems for hydrogen separation and purification.	ISO TC 197
ISO 45004:2024	Occupational health and safety management — Guidelines on performance evaluation.	ISO/TC 283
OSHA 1910.119	Process safety management of highly hazardous chemicals.	OSHA
NACE TR5A192-2021	Guidelines for Maintaining Integrity of Equipment in Anhydrous Ammonia Storage and Handling.	NACE
IEC 60079:2024 Series	Explosive atmospheres – All Parts.	IEC TC 31
IEC 80097-34	Explosive atmospheres - Part 34: Application of quality management systems for Ex Product manufacture.	IEC TC 31
EN 17346:2020	Ambient air - Standard method for the determination of the concentration of ammonia using diffusive samplers.	CEN/TC 264
ISO/AWI TS 15916	Hydrogen technologies — Basic considerations for the safety of hydrogen systems.	ISO/TR 15916:2015
OSHA 1910.111	Storage and handling of anhydrous ammonia.	OSHA
ASME B31.4 - 2022	Pipeline Transportation Systems for Liquids and Slurries.	ASME
UL 125 Ed. 10-2020	ANSI/CAN/UL/ULC Standard for Flow Control Valves for Anhydrous Ammonia and LP-Gas.	UL
UL 119 Ed. 5-2021	Outline of Investigation for Adapters, Fittings and Couplings for Anhydrous Ammonia and Fuel Gases.	UL
ISO/AWI 45001	Occupational health and safety management systems — Requirements with guidance for use.	ISO/TC 283
ISO 11014:2009	Safety data sheet for chemical products — Content and order of sections.	ISO/TC 47
ISO 11057:2011	Air quality — Test method for filtration characterization of cleanable filter media.	ISO/TC 146/SC 1
ISO 14004:2016	Environmental management systems — General guidelines on implementation.	ISO/TC 207/SC 1
ISO 15259:2023	Air quality — Measurement of stationary source emissions — Requirements for measurement sections and sites and for the measurement objective, plan and report.	ISO/TC 146/SC 1
ISO 20581:2016	Workplace air — General requirements for the performance of procedures for the measurement of chemical agents	ISO/TC 146/SC 2
ISO 21258:2010	Stationary source emissions — Determination of the mass concentration of dinitrogen monoxide (N_2O) — Reference method: Non-dispersive infrared method.	ISO/TC 146/SC 1
ISO 22734:2019	Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications.	ISO/TC 197
ISO 23861:2022	Workplace air — Chemical agent present as a mixture of airborne particles and vapour — Requirements for evaluation of measuring procedures using samplers.	ISO/TC 146/SC 2

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Short name	Title	Working group
ISO 3165:1976	Sampling of chemical products for industrial use — Safety in sampling.	ISO/TC 47
ISO 7103:1982	Liquefied anhydrous ammonia for industrial use — Sampling — Taking a laboratory sample.	ISO/TC 47
ISO/TR 15916:2015	Basic considerations for the safety of hydrogen systems.	ISO/TR 15916:2015
ISO/WD 13977	Workplace atmospheres – Assessment of dermal exposure — Part 1: Framework for Dermal exposure assessment.	ISO/TC 146/SC 2
EN 12115:2021	Rubber and thermoplastics hoses and hose assemblies for liquid or gaseous chemicals – Specification.	CEN/TC 218
EN 13765:2018	Thermoplastic multi-layer (non-vulcanized) hoses and hose assemblies for the transfer of hydrocarbons, solvents and chemicals – Specification.	CEN/TC 218
EN 14412:2004	Indoor air quality - Diffusive samplers for the determination of concentrations of gases and vapours - Guide for selection, use and maintenance.	CEN/TC 264
EN 13528-2:2002	Ambient air quality - Diffusive samplers for the determination of concentrations of gases and vapours - Requirements and test methods - Part 2: Specific requirements and test methods.	CEN/TC 264
EN 15267-2:2023	Air quality - Assessment of air quality monitoring equipment - Part 2: Initial assessment of the manufacturer's quality management system and post certification surveillance for the manufacturing process.	CEN/TC 264
EN 13528-1:2002	Ambient air quality - Diffusive samplers for the determination of concentrations of gases and vapours - Requirements and test methods - Part 1: General requirements.	CEN/TC 264
EN 15267-3:2023	Air quality - Assessment of air quality monitoring equipment - Part 3: Performance criteria and test procedures for stationary automated measuring systems for continuous monitoring of emissions from stationary sources.	CEN/TC 264
EN 13611:2019/AC:2021	Safety and control devices for burners and appliances burning gaseous and/or liquid fuels - General requirements.	CEN/TC 58
ISO 45002:2023	Occupational health and safety management systems — General guidelines for the implementation of ISO 45001:2018.	ISO/TC 283

4.2.3 Certifications related to ammonia safety

European "CE" marking would be applicable to DARE2X technology if sold on the European market. The CE marking shows that a product has been evaluated by the manufacturer and is considered to comply with the EU's safety, health, and environmental protection standards, among others the ATEX directive. [11]

Two certification schemes are identified, both accrediting compliance with the EU Directive 2014/34/EU, the ATEX directive, which covers equipment and protective systems intended for use in potentially explosive atmospheres.

Outside the European market, the IECEx certification scheme can be considered the equivalent to the ATEX certification, but without the legally binding nature. All these certification schemes are compiled in Table 4.

[11] Link: https://europa.eu/youreurope/business/product-requirements/labels-markings/ce-marking/index_en.htm (accessed 30/10/2024)

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Table 4. Certifications identified related to DARE2X safety. Columns contain the names of the certifications, related standards and regulations, and a short description.

Name	Related standard/regulation
EU CE marking	***EU safety, health and environmental legislation***
Short description	CE marking indicates that a product has been assessed by the manufacturer and deemed to meet EU safety, health and environmental protection requirements. It is required for products manufactured anywhere in the world that are then marketed in the EU.[11]
TÜV SÜD ATEX certification	***Directive 2014/34/EU***
Short description	Equipment, components and protective systems in a potentially explosive environment can only be placed on the market if essential health and safety requirements according to the ATEX Directive 2014/34/EU have been met, and the required conformity assessment procedures for your category of equipment have been successfully completed. If you manufacture or sell equipment and systems of this nature, TÜV SÜD can ensure you conform to the relevant ATEX Directives and entitle you to feature the CE mark.[12]
TÜV SÜD IECEx certification	***IECEx certification scheme, e.g., IEC 60079:2024 Series, IEC 80097-34***
Short description	TÜV SÜD provides all the necessary guidance and support to comply with the IECEx scheme standards. This includes experts conduct testing, on-site inspection and conformity assessment of equipment operating in potentially explosive atmospheres. [13]
UL ATEX, IECEx certification	***Directive 2014/34/EU, IEC 60079:2024 Series, IEC 80097-34***
Short description	UL is one of the top issuers of global ATEX and IECEx certifications. This supports acceptance of your UL-issued certificates, test reports and quality audits for local country marks around the globe. [14]

[12] Link: https://www.tuvsud.com/en-us/services/product-certification/atex-directive-2014-34-eu (accessed 30/10/2024)

[13] Link: https://www.tuvsud.com/en/industries/manufacturing/components-and-equipment/explosion-protection/iecex---global-scheme (accessed 30/10/2024)

[14] Link: https://www.ul.com/services/atex-certification-european-union (accessed 30/10/2024)

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4.3 Renewable and green ammonia

A key ambition of DARE2X is to advance a technology that can produce a renewable fuel of non-biological origin (RFNBO). The term green ammonia can also be used for NH_3 produced from renewable energy sources. The use of renewable energy promises NH_3 production with low associated GHG equivalent emissions (abbreviated with "low carbon footprint"). Several regulations and standards related to the definition of green processes, fuels, and NH_3 are presented here.

Low carbon footprint and green production of NH_3 is subject to several measures from the *EU Fit for 55* package, such as the *European Emission Trading Scheme (EU ETS)*, *Carbon Border Adjustment Mechanism (CBAM)*, and the *Renewable energy directive (RED)*. The EU directives also present explicit methodologies for the mechanisms basing themselves on life cycle perspectives. Standards related to environmental reporting by the ISO describe in detail how to apply the life cycle perspective and environmental accounting. The inclusion of NH_3 (fuel) into the RED framework occurred recently in the RED III directive. At the time of writing, the first certification schemes for RED III compliance have been recognised, and more are expected soon.

4.3.1 Legislation: Relevant environmental legislation in the EU

The EU has a strong ambition to reduce GHG emissions of its economy. The Green Deal, presented in 2019, is a major initiative to achieve growth and climate-neutrality in the EU by 2050. The "Fit for 55" package can be understood as a collection of different main directives that all aim at achieving the climate neutrality target. This entails legislation on alternative fuels, emission control, and reduction. NH_3 and DARE2X technology are (or will be) subject to various of these directives. A visual summary of the components of the EU Fit for 55 package is provided in Figure 7.

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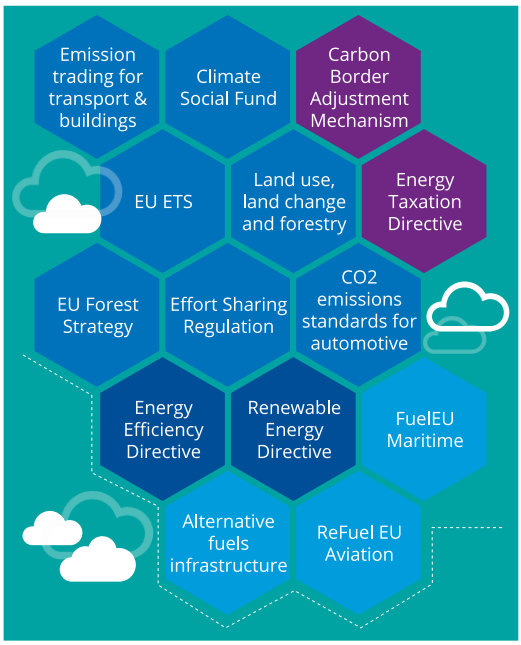

Figure 7. EU Fit for 55 legislative components. Source: https://kpmg.com/xx/en/home/insights/2021/11/european-green-deal-policy-guide.html (accessed 11.02.2025).

A list of most relevant legislation related to green ammonia is provided in Table 5. Firstly, the NH_3 production (industry) is subject to the EU Emission Trading Scheme (ETS), and thereby also to the Carbon Border Adjustment Mechanism (CBAM). In practice, this translates to the need to report GHG emissions during NH_3 production on an annual basis, if NH_3 is produced within or imported into the EU at larger quantities.

The RED II and RED III directives are other highly relevant directives as they set out objectives for the uptake of alternative fuels and guidelines for qualifying fuels as renewable. These guidelines assume a life cycle perspective and provide calculation approaches and default values for specific inputs.

The Fuel EU Maritime directive explicitly addresses the decarbonisation of maritime fuel and establishes the need for some technical specifications in the handling of NH_3 fuel for shipping.

Table 5. Legislation regarding environmental concerns related to ammonia and low emission ammonia in the EU.

Short name	***Title***
EU Fit for 55	-
Description	The 'fit for 55' package of July and December 2021 was designed to realise the European Climate Law objectives: climate neutrality by 2050 and a 55 % reduction of net greenhouse gas (GHG) emissions by 2030, compared with 1990 levels. It consisted of 13 interlinked proposals to revise existing EU climate and energy laws, and six new legislative proposals. All proposals, except the Energy Taxation Directive, have been adopted or agreed by the European Parliament and the Council of the EU. The package seeks to accelerate emissions reductions in the sectors covered by the EU emissions trading system (ETS) and those covered by the Effort-sharing Regulation, and to increase carbon removals in the land use, land-use change and forestry (LULUCF) sector.

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Short name	*Title*
EU ETS	***Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and amending Council Directive 96/61/EC, and later amendments. Latest amendment is REGULATION (EU) 2024/795.***
Description	The EU ETS is a key instrument to reduce GHG emissions in the EU. In essence, emitters have to acquire permits to release GHGs into the environment. These permits can be traded, thereby trusting in the market to find optimal GHG reduction strategies. Generally, only emitters that surpass a certain threshold are subject to the EU ETS regulation. In recent years, the scope of industries and sectors that are subject to the ETS has been amplified and will soon cover, among others, **NH_3 production**, and operational emissions from shipping and intra-EU aviation. Until 2034, the last free permissions for ammonia producers will be phased out. Additionally, by 2025 producers of renewable H_2 and derivatives will be granted free permits that can be sold on the market.
EU CBAM	***Carbon Border Adjustment Mechanism***
Description	The EU's Carbon Border Adjustment Mechanism (CBAM) is the EU's tool to put a fair price on the carbon emitted during the production of carbon intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries. By confirming that a price has been paid for the embedded carbon emissions generated in the production of certain goods imported into the EU, the CBAM will ensure the carbon price of imports is equivalent to the carbon price of domestic production, and that the EU's climate objectives are not undermined. The CBAM is designed to be compatible with WTO-rules. CBAM will apply in its definitive regime from 2026, while the current transitional phase lasts between 2023 and 2025. This gradual introduction of the CBAM is aligned with the phase-out of the allocation of free allowances under the EU Emissions Trading System (ETS) to support the decarbonisation of EU industry.
FuelEU Maritime	***Regulation (EU) 2023/1805 on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC***
Description	The main objective of the FuelEU maritime initiative, as a key part of the EU's Fit for 55 package, is to increase the demand for and consistent use of renewable and low-carbon fuels and reduce the GHG emissions from the shipping sector, while ensuring the smooth operation of maritime traffic and avoiding distortions in the internal market. It is understood that ammonia is one of the candidate fuels covered in the category renewable fuels of non-biological origin (RFNBO).
RED II	***Directive (EU) 2018/2001, Renewable Energy – Recast to 2030***
Description	In the RED II, the EU target for renewable energy use by 2030 was set at 32%. Additionally, a specific minimum target (14%) is set for the road and rail sector, which is to be enforced by the EU member states. The directive further specifies sustainability criteria for bioliquids (while excluding non-bio liquids such as ammonia and hydrogen) and a methodology for calculating GHG emissions that also recognises and considers ILUC as a potential major source of emissions by biofuels. Additionally, maximum volumes (caps) are introduced for specific biofuels.[15]
RED III	***Directive (EU) 2023/2413 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652 (RED III)***

[15] Link: https://joint-research-centre.ec.europa.eu/welcome-jec-website/reference-regulatory-framework/renewable-energy-recast-2030-red-ii_en (accessed 18/02/2025)

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Short name	*Title*
Description	It introduces strong measures to ensure that all possibilities for the further development and uptake of renewables are fully utilised. In addition to the new headline target to double the existing share of renewable energy sources compared to RED II, a strong policy framework will facilitate electrification in different sectors, with new increased sector-specific targets for renewables in heating and cooling, transport, industry, buildings and district heating/cooling, but also with a framework promoting electric vehicles and smart recharging. To support renewables uptake in transport and heating and cooling, it converts into EU law some of the concepts outlined in the energy system integration and H_2 strategies, published in 2020. These concepts aim at creating an energy-efficient, circular and renewable energy system that facilitates renewables-based electrification and promotes the use of renewable fuels, including ammonia, in sectors like transport or industry where electrification is not yet a feasible option.
Regulation (EU) 2023/1184	***Commission Delegated Regulation (EU) 2023/1184 supplementing Directive (EU) 2018/2001 establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin***
Description	This regulation establishes detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin.
Alternative Fuels Infrastructure Regulation	***Regulation (EU) 2023/1804 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU***
Description	This Regulation establishes mandatory national targets leading to the deployment of sufficient alternative fuels infrastructure in the Union for road vehicles, trains, vessels and stationary aircraft. It lays down common technical specifications and requirements on user information, data provision and payment requirements for alternative fuels infrastructure. The specific targets address road, air, and maritime transport. While charging (road), shore-side electricity (maritime), ground support electricity (air), and hydrogen supply infrastructure (road) are addressed, NH_3 is not. However, ammonia is included in the definition of alternative fuels, and requirements for technical specification for maritime infrastructure. [16]
Directive 2010/75/EU	***Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control)***
Descriptio	The directive is about minimising pollution from various industrial sources throughout the European Union. Operators of industrial installations operating activities covered by Annex I of the IED have to obtain a license from the authorities in the EU countries. More than 50.000 installations are covered by the IED.
Directive (EU) 2016/2284	***Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC***

[16] Link: https://www.consilium.europa.eu/en/press/press-releases/2023/07/25/alternative-fuels-infrastructure-council-adopts-new-law-for-more-recharging-and-refuelling-stations-across-europe/ (accessed 18/02/2025)

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Short name	*Title*
Descriptio	To avoid significant negative impacts on and risks to human health and the environment, this Directive establishes the emission reduction commitments for the Member States' anthropogenic atmospheric emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), ammonia (NH_3) and fine particulate matter ($PM_{2.5}$).

4.3.2 Renewable and green ammonia standards

Standards related to environmental management, emissions and the assessment of life cycle impacts as the basis for qualifying the NH_3 produced with DARE2X technology as low-carbon or green are summarised below (Table 6).

Identified standards are not specific to NH_3. Instead, they describe more general rules and approaches to measure, report and communicate emissions and the environmental performance of products and production.

Table 6. Environmental standards of relevance for DARE2X technology. Grey background for standards with highest priority within the cluster.

Short name	Title	Working group
ISO 14044:2006	Environmental management — Life cycle assessment — Requirements and guidelines	ISO/TC 207/SC 5
ISO 14040:2006	Environmental management — Life cycle assessment — Principles and framework	ISO/TC 207/SC 5
ISO 14067:2018	Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification	ISO/TC 207/SC 7
ISO 14026:2017	Environmental labels and declarations — Principles, requirements and guidelines for communication of footprint information	ISO/TC 207/SC 3
ISO 14064-1:2018	Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals	ISO/TC 207/SC 7
ISO 14064-2:2019	Greenhouse gases — Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements	ISO/TC 207/SC 7
ISO 14064-3:2019	Greenhouse gases — Part 3: Specification with guidance for the verification and validation of greenhouse gas statements	ISO/TC 207/SC 7
ISO/CD 19870-1	Hydrogen technologies — Methodology for determining the greenhouse gas emissions — Part 1: Emissions associated with the production of hydrogen up to production gate (under development)	ISO/TC 197/SC 1
ISO 14030-2:2021	Environmental performance evaluation — Green debt instruments — Part 2: Process for green loans	ISO/TC 207/SC 4
ISO 14030-3:2022	Environmental performance evaluation — Green debt instruments — Part 3: Taxonomy	ISO/TC 207/SC 4
ISO 14083:2023	Greenhouse gases — Quantification and reporting of greenhouse gas emissions arising from transport chain operations	ISO/TC 207/SC 7
ISO 14097:2021	Greenhouse gas management and related activities — Framework including principles and requirements for assessing and reporting investments and financing activities related to climate change	ISO/TC 207/SC 7
ISO/CD 14002:3	Environmental management systems — Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area — Part 3: Climate *(under development)*	ISO/TC 207/SC 1
ISO 14021:2016	Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling)	ISO/TC 207/SC 3

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Short name	Title	Working group
ISO 14026:2017	Environmental labels and declarations — Principles, requirements and guidelines for communication of footprint information	ISO/TC 207/SC 3
ISO 14031:2021	Environmental management — Environmental performance evaluation — Guidelines	ISO/TC 207/SC 4
ISO 14002-1:2019	Environmental management systems — Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area — Part 1: General	ISO/TC 207/SC 1
ISO 14002-2:2023	Environmental management systems — Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area — Part 2: Water	ISO/TC 207/SC 1
ISO 14024:2018	Environmental labels and declarations — Type I environmental labelling — Principles and procedures	ISO/TC 207/SC 3
ISO 14025:2006	Environmental labels and declarations — Type III environmental declarations — Principles and procedures	ISO/TC 207/SC 3
ISO 14066:2023	Validating and verifying environmental information — Competence requirements for teams	ISO/TC 207/SC 7
IWA 42:2022	Net zero guidelines	ISO/TC 207/SC 7
ISO/AWI 14060	Net Zero Aligned Organizations	ISO/TC 207/SC 7
ISO/TS 14027:2017	Environmental labels and declarations — Development of product category rules	ISO/TC 207/SC 3

4.3.3 Renewable and green ammonia certifications

Currently, there are 17 (voluntary) certification schemes approved by the European Commission that affirm compliance with the RED II directive (where H_2 and NH_3 were not included in the list of renewable fuels).[17]

Three providers of these certification (see Table 7) have, status quo, also been certified for an extension of their certification schemes to the scope of RFNBOs including NH_3, as set out in the RED III directive. At least three more certification schemes have filed an application for recognition to the European Commission. There are also the CertifHy or the ISCC+ certifications that are both certifications for green hydrogen. Additionally, they also certify alignment with the ISO14044 and ISO 14067 standards on life cycle assessment and carbon footprinting.

Table 7. Renewable and green ammonia certification schemes in the EU. Columns contain the names of the certifications, related standards and regulations, and a short description.

Name	Related standard/directive	Short description
ISCC EU	RED III, RED II, (EU) 2023/1184	The RED III Certificates confirm the alignment of fuels with RED III criteria to qualify as a RFNBO and be eligible for potential benefits.

[17] Link: https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/voluntary-schemes_en (accessed 11/02/2025)

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REDcert 	RED III, RED II, (EU) 2023/1184	
CertifHy 	RED III, RED II, (EU) 2023/1184	

4.4 Ammonia production, catalysts, and quality

In the context of NH_3 production, catalysts, and quality, no specific legislation was identified. However, several standards are shortlisted (Table 8). Standards concern the assessment of the quality and properties of the process output. For example, several standards describe different aspects of gas analysis. Further, some standards for catalyst terminology, efficiency, and testing are listed as catalysts are used in the DARE2X NTP and PSA steps.

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Table 8. Standards for DARE2X ammonia production technology. Grey background for standards with highest priority within the cluster.

Identifier	Title	Working group
IEC TS 60680:2008	Test methods of plasma equipment for electro heat and electrochemical applications.	IEC TC 27
ASTM D4222-20	Standard Test Method for Determination of Nitrogen Adsorption and Desorption Isotherms of Catalysts and Catalyst Carriers by Static Volumetric Measurements.	ASTM
ISO 7108:1985	Ammonia solution for industrial use — Determination of ammonia content — Titrimetric method.	ISO/TC 47
ISO 7109:1985	Ammonia solution for industrial use — Determination of residue after evaporation at 105 degrees C — Gravimetric method	ISO/TC 47
ASTM D3766-24a	Standard Terminology Relating to Catalysts and Catalysis	ASTM
ASTM D4365-19	Standard Test Method for Determining Micropore Volume and Zeolite Area of a Catalyst	ASTM
ASTM D3663-20	Standard Test Method for Surface Area of Catalysts and Catalyst Carriers	ASTM
ASTM D7085-04:2018	Standard Guide for Determination of Chemical Elements in Fluid Catalytic Cracking Catalysts by X-ray Fluorescence Spectrometry (XRF)	ASTM
ISO 5771:2024	Rubber hoses and hose assemblies for transferring anhydrous ammonia — Specification	ISO/TC 45/SC 1
ISO 7105:1985	Liquefied anhydrous ammonia for industrial use — Determination of water content — Karl Fischer method	ISO/TC 47
ISO 7106:1985	Liquefied anhydrous ammonia for industrial use — Determination of oil content — Gravimetric and infra-red spectrometric methods	ISO/TC 47
ISO 6141:2015	Gas analysis — Contents of certificates for calibration gas mixtures	ISO/TC 158
ASTM D4926-20	Standard Test Method for Gamma Alumina Content in Catalysts and Catalyst Carriers Containing Silica and Alumina by X-ray Powder Diffraction	ASTM
ASTM D4567-19	Standard Test Method for Single-Point Determination of Specific Surface Area of Catalysts and Catalyst Carriers Using Nitrogen Adsorption by Continuous Flow Method	ASTM
ASTM D4641-17	Standard Practice for Calculation of Pore Size Distributions of Catalysts and Catalyst Carriers from Nitrogen Desorption Isotherms	ASTM
ASTM D4284-12:2017 e1	Standard Test Method for Determining Pore Volume Distribution of Catalysts and Catalyst Carriers by Mercury Intrusion Porosimetry	ASTM
ASTM D8393-21	Standard Guide for Determination of Pore Volume of Powdered Catalysts and Catalyst Carriers by Water Adsorption	ASTM
ASTM D4780-23	Standard Test Method for Determination of Low Surface Area of Catalysts and Catalyst Carriers by Multipoint Krypton Adsorption	ASTM
ASTM D4824-24	Standard Test Method for Determination of Catalyst Acidity by Ammonia Chemisorption	ASTM
ASTM D3907/D3907M-19	Standard Test Method for Testing Fluid Catalytic Cracking (FCC) Catalysts by Microactivity Test	ASTM
ASTM D5154/D5154M-18	Standard Test Method for Determining Activity and Selectivity of Fluid Catalytic Cracking (FCC) Catalysts by Microactivity Test	ASTM
ASTM D7206/D7206M-19	Standard Guide for Cyclic Deactivation of Fluid Catalytic Cracking (FCC) Catalysts with Metals	ASTM
ASTM D7964/D7964M-19	Standard Test Method for Determining Activity of Fluid Catalytic Cracking (FCC) Catalysts in a Fluidized Bed	ASTM
ASTM D3907-92	Standard Method for Testing Fluid Catalytic Cracking (FCC) Catalysts by Microactivity Test (Withdrawn 2001)	ASTM
ASTM D7442-22	Standard Practice for Sample Preparation of Fluid Catalytic Cracking Catalysts, Catalytic Materials, and Zeolites for Elemental Analysis by Inductively Coupled Plasma Optical Emission Spectroscopy	ASTM

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Identifier	Title	Working group
ASTM D4481-21	Standard Test Method for Total Nickel in Fresh Al-Base Catalysts	ASTM
ASTM D4782-10:2016	Standard Test Method for Palladium in Molecular Sieve Catalyst by Wet Chemistry	ASTM
ASTM D4642-04:2016	Standard Test Method for Platinum in Reforming Catalysts by Wet Chemistry	ASTM
ISO 1392:1977	Determination of crystallizing point — General method	ISO/TC 47
ISO 18158:2016	Workplace air — Terminology	ISO/TC146/SC 2
ISO 2211:1973	Liquid chemical products — Measurement of colour in Hazen units (platinum-cobalt scale)	ISO/TC 47
ISO 3165:1976	Sampling of chemical products for industrial use — Safety in sampling	ISO/TC 47
ISO 6206:1979	Chemical products for industrial use — Sampling — Vocabulary	ISO/TC 47
ISO 6228:1980	Chemical products for industrial use — General method for determination of traces of sulphur compounds, as sulphate, by reduction and titrimetric	ISO/TC 47
ISO 758:1976	Liquid chemical products for industrial use — Determination of density at 20 degrees C	ISO/TC 47
UL 51 Ed. 11-2023	Power-Operated Pumps and Bypass Valves for Anhydrous Ammonia, LP-Gas, and Propylene	UL
ISO/TR 17737:2012	Workplace atmospheres — Guidelines for selecting analytical methods for sampling and analysing isocyanates in air	ISO/TR 17737:2012
ISO 12963:2017	Gas analysis — Comparison methods for the determination of the composition of gas mixtures based on one- and two-point calibration	ISO/TC 158
ISO 14167:2018	Gas analysis — General quality aspects and metrological traceability of calibration gas mixtures	ISO/TC 158
ISO 14912:2003	Gas analysis — Conversion of gas mixture composition data	ISO/TC 158
ISO 15796:2005	Gas analysis — Investigation and treatment of analytical bias	ISO/TC 158
ISO 16664:2017	Gas analysis — Handling of calibration gases and gas mixtures — Guidelines	ISO/TC 158
ISO 19229:2019	Gas analysis — Purity analysis and the treatment of purity data	ISO/TC 158
ISO 19230:2020	Gas analysis — Sampling guidelines	ISO/TC 158
ISO 21087:2019	Gas analysis — Analytical methods for hydrogen fuel — Proton exchange membrane (PEM) fuel cell applications for road vehicles	ISO/TC 158
ISO 6144:2003	Gas analysis — Preparation of calibration gas mixtures — Static volumetric method	ISO/TC 158
ISO 6145:x	Group of ISO 6145:2019 - Gas analysis — Preparation of calibration gas mixtures using dynamic methods	ISO/TC 158
ISO 7504:2015	Gas analysis — Vocabulary	ISO/TC 158
EN 16913:2017	Ambient air - Standard method for measurement of NO_3^-, SO_4^{2-}, Cl^-, NH_4+, Na+, K+, Mg^2+, Ca^2+ in $PM_{2.5}$ as deposited on filters	CEN/TC 264
EN 16841-1:2016	Ambient air - Determination of odour in ambient air by using field inspection - Part 1: Grid method	CEN/TC 264
EN 17628:2022	Fugitive and diffuse emissions of common concern to industry sectors - Standard method to determine diffuse emissions of volatile organic compounds into the atmosphere	CEN/TC 264
EN 14564:2019	Tanks for transport of dangerous goods - Terminology	CEN/TC 296
EN 15900:2010	Energy efficiency services - Definitions and requirements	CEN/CLC/JTC 14
EN 16247-1:2022	Energy audits - Part 1: General requirements	CEN/CLC/JTC 18
EN 16247-3:2022	Energy audits - Part 3: Processes	CEN/CLC/JTC 15
EN 16247-4:2022	Energy audits - Part 4: Transport	CEN/CLC/JTC 16
EN 14620	Design and manufacture of site built, vertical, cylindrical, flat-bottomed tank systems for the storage of refrigerated, liquefied	CEN/TC 265

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Identifier	Title	Working group
	gases with operating temperatures between 0 °C and -196 °C - Part 1: General	

4.5 Maritime applications

While the transport of NH_3 by chemical carrier ships is already current practice, the use of NH_3 as a ship fuel is, so far, in its infant stage. Nonetheless, there are relevant regulations by the IMO and EU, and standards by the ISO, CEN and EAGLE that would apply to the case of using DARE2X fuel for maritime transport.

4.5.1 Legislation: Regulations relevant for maritime applications of ammonia

Several global conventions and treaties regulate aspects of safety and emissions of shipping in general. In addition, the Fuel EU Maritime regulation, current under development, would likely set important targets and incentives for the use of non-fossil shipping fuels. An overview of the potentially most relevant regulations is provided in Table 9. Additional, less relevant regulations are summarised by the European Maritime Safety Agency.[18]

Table 9. Most relevant regulations for ammonia in maritime applications.

Short name	***Title***
MARPOL	***International Convention for the Prevention of Pollution from Ships***
Descriptio	The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes.
IMO CII	***IMO Carbon Intensity Indicator***
Descriptio	The CII determines the annual reduction factor needed to ensure continuous improvement of a ship's operational carbon intensity within a specific rating level. The actual annual operational CII achieved must be documented and verified against the required annual operational CII. This enables the operational carbon intensity rating to be determined.[19]
IMO SOLAS	***IMO Safety of Life at Sea***
Description	The main objective of the SOLAS Convention is to specify minimum standards for the construction, equipment and operation of ships, compatible with their safety. Flag States are responsible for ensuring that ships under their flag comply with its requirements, and a number of certificates are prescribed in the Convention as proof that this has been done. Control provisions also allow Contracting Governments to inspect ships of other Contracting States if there are clear grounds for believing that the ship and its equipment do not substantially comply with the requirements of the Convention - this procedure is known as port State control.[20]

[18] Link: https://www.emsa.europa.eu/publications/legislative-texts.html?start=10 (accessed 11/02/2025)
[19] Link: https://www.imo.org/en/MediaCentre/HotTopics/Pages/EEXI-CII-FAQ.aspx
[20] Link: https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx

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Short name	*Title*
Fuel EU Maritime	***Fuel EU Maritime***
Description	The regulation is currently under development. The main objective of the FuelEU maritime initiative, as a key part of the EU's Fit for 55 package, is to increase the demand for and consistent use of renewable and low-carbon fuels and reduce the greenhouse gas emissions from the shipping sector, while ensuring the smooth operation of maritime traffic and avoiding distortions in the internal market. One target is to ensure that the greenhouse gas intensity of fuels used by the shipping sector will gradually decrease over time, by 2% in 2025 to as much as 80% by 2050

4.5.2 Standards for maritime ammonia applications

Five standards are shortlisted that are most relevant for NH_3 fuelled maritime vessels (Table 10). Standards cover explicitly the requirements for NH_3 fuelled vessels, terminology, and more general aspects relevant to all maritime fuels.

Table 10. Standards identified as relevant for ammonia in maritime applications.

Short name	Title	Working group
EAGLE 325	Requirements for Ammonia Fueled Vessels	
ISO/WD 23397	ISO/WD 23397 - Ships and marine technology — Ammonia fuel systems for ships — Vocabulary	ISO/TC 8/SC 3
EN 16942:2024	Fuels - Identification of vehicle compatibility - Graphical expression for consumer information	CEN/TC 441
ISO 13613:2011	ISO 13613:2011 - Ships and marine technology — Maintenance and testing to reduce losses in critical systems for propulsion	ISO/TC 8/SC 3
ISO/AWI 24941	ISO/AWI 24941 - Ships and marine technology — Piping and machinery — Safety guidelines for engine rooms of ammonia fuelled vessels	ISO/TC 8/SC 3

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4.6 Other applications

Some additional standards for other applications of NH_3 are presented in Table 11. They cover aspects of NH_3 as a fuel for stationary applications, NH_3 as a key material for synthetic fertiliser production, and the use of NH_3 as a hydrogen vector. Most standards listed here originate from the ISO committee ISO/TC 134 *"Fertilizers, soil conditioners and beneficial substances"* that publishes fertiliser standards.

Table 11. Standards for other applications of ammonia. Grey background for standards with highest priority within the cluster.

Short name	Title	Working group
ISO 14687:2019	Hydrogen fuel quality — Product specification	ISO/TC 197
ISO 17179:2016	Stationary source emissions — Determination of the mass concentration of ammonia in flue gas — Performance characteristics of automated measuring systems	ISO/TC 146/SC 1
ISO 21877:2019	Stationary source emissions— Determination of the mass concentration of ammonia — Manual method	ISO/TC 146/SC 1
ISO 19694:1	Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries — Part 1: General aspects	ISO/TC 207/SC 7
ISO 7851:2022	Fertilizers, soil conditioners and beneficial substances — Classification	ISO/TC 134
ISO 8157:2022	Fertilizers, soil conditioners and beneficial substances — Vocabulary	ISO/TC 134
ISO 7409:2018	Fertilizers — Marking — Presentation and declarations	ISO/TC 134
ISO 10155:1995	Stationary source emissions — Automated monitoring of mass concentrations of particles — Performance characteristics, test methods and specifications	ISO/TC 146/SC 1
ISO 10396:2007	Stationary source emissions — Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems	ISO/TC 146/SC 1
ISO 10780:1994	Stationary source emissions — Measurement of velocity and volume flowrate of gas streams in ducts	ISO/TC 146/SC 1
ISO 19694	Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries — Part 1: General aspects	ISO/TC 207/SC 7
ISO 14385:1	Stationary source emissions — Greenhouse gases — Part 1: Calibration of automated measuring systems	ISO/TC 146/SC 1
CEN/TS 17198:2018	Stationary source emissions - Predictive Emission Monitoring Systems (PEMS) - Applicability, execution and quality assurance	CEN/TC 264
CEN/TS 17337:2019	Stationary source emissions - Determination of mass concentration of multiple gaseous species - Fourier transform infrared spectroscopy	CEN/TC 264
EN 17656:2022	Stationary source emissions - Requirements on proficiency testing schemes for emission measurements	CEN/TC 264
ISO/AWI 25300	Fertilizers, Soil conditioners and Beneficial Substances — Simultaneous Determination of free amino acid content	ISO/TC 134
ISO 14820	Fertilizers and liming materials — Sampling and sample preparation — Part 2: Sample preparation	ISO/TC 134
ISO 15604:2016	Fertilizers — Determination of different forms of nitrogen in the same sample, containing nitrogen as nitric, ammoniacal, urea and cyanamide nitrogen	ISO/TC 134
ISO 25475:2016	Fertilizers — Determination of ammoniacal nitrogen	ISO/TC 134
ISO 7837:1992	Fertilizers — Determination of bulk density (loose) of fine-grained fertilizers	ISO/TC 134
ISO 18644:2016	Fertilizers and soil conditioners — Controlled-release fertilizer — General requirements	ISO/TC 134
ISO 20620:2021	Fertilizers and soil conditioners — Determination of total nitrogen by combustion	ISO/TC 134

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ISO/CD 5314	Fertilizers — Determination of ammoniacal nitrogen content — Titrimetric method after distillation	ISO/TC 134
ISO 14820	ISO 14820-1:2016 - Fertilizers and liming materials — Sampling and sample preparation — Part 1: Sampling	ISO/TC 134
ISO 22862:2021	Fertilizers and soil conditioners — Compound fertilizer — General requirements	ISO/TC 134
ISO/TR 7553:1987	Fertilizers — Sampling — Minimum mass of increment to be taken to be representative of the total sampling unit	ISO/TC 134
ISO 18645:2016	Fertilizers and soil conditioners — Water soluble fertilizer — General requirements	ISO/TC 134
ISO 18642:2016	Fertilizer and soil conditioners — Fertilizer grade urea — General requirements	ISO/TC 134
ISO 5315:1984	Fertilizers — Determination of total nitrogen content — Titrimetric method after distillation	ISO/TC 134
ISO 5306:1983	Fertilizers — Presentation of sampling reports	ISO/TC 134
ISO 7408:1983	Fertilizers — Determination of ammoniacal nitrogen content in the presence of other substances which release ammonia when treated with sodium hydroxide — Titrimetric method	ISO/TC 134
ISO 5314:1981	Fertilizers — Determination of ammoniacal nitrogen content — Titrimetric method after distillation	ISO/TC 134
ISO/TS 20917:2023	Fertilizers, soil conditioners and beneficial substances — Determination of ammonium citrate, disodium-EDTA soluble phosphorus and potassium by ICP-OES in inorganic fertilizers	ISO/TC 134
ISO 5313:1986	High nitrogen content, straight ammonium nitrate fertilizers — Determination or oil retention	ISO/TC 134
ISO 5311:1992	Fertilizers — Determination of bulk density (tapped)	ISO/TC 134

4.7 Chapter summary

In this chapter, legislation, standard, and certification schemes relevant to DARE2X technology and product were presented. More than one hundred standards were listed from several standardisation bodies, with the ISO and CEN being the most often referenced sources. Most standards shortlisted are of the thematic groups “safety” and “green NH_3”, but also standards related to catalysts, NH_3 quality, maritime fuel applications and other applications were presented. Building on the overview provided in this chapter, gaps in the current standardisation landscape regarding the DARE2X solution and a roadmap with important steps in standardisation towards commercialising the DARE2X solution are presented next.

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5. Recommendations and suggested roadmap

Based on the analysis in the previous chapter, we present in this chapter, first, gaps in the landscape of DARE2X related legislation and standardisation and, second, recommendations for standardisation related activities to pursue in parallel to further DARE2X technology development.

5.1 Gaps in standardisation and regulatory framework

There are several areas that can be denominated as gaps in the current regulatory and standardisation framework. Their identification may help to anticipate future developments, either by taking a passive role and being alert for upcoming developments or by taking an active role and trying to steer the developments. To influence standardisation development, it is helpful to understand the process of standards development laid out in Chapter 1. We highlight the following gaps:

1. Interoperability in ammonia supply chain

This refers to the lack of standards and regulation related to potential future NH_3 supply chains that go beyond the use of NH_3 in the chemical and fertilizer industry. For instance, the use of NH_3 as a fuel would require technical standards on the refuelling, storage, and transport. The development of such standards is subject to a continued progress towards alternative uses of NH_3. A first example of a standard following this line of thought is EAGLE 325 (c. Table 10. Standards identified as relevant for ammonia in maritime applications.)

2. Ammonia as energy or hydrogen carrier

There are a few technical, environmental, and safety standards on the use of NH_3 as an energy or hydrogen carrier. These uses go beyond the long-established use of NH_3 in the chemical and fertilizer industry, which may explain the absence of such standards. However, with a growing interest related to the transition of societies, the development of new standards in this field appears likely. This gap is also highlighted by other works (Mission Possible Partnership, 2022).

3. Green ammonia certification

In our view, there is currently a lack of green ammonia certification schemes. This view is also shared by the International Energy Agency (International Energy Agency, 2021). For NH_3 as a fuel, the RED III certification scheme, which covers NH_3 as an RFNBO, is now effective and the number of recognised certificates growing. However, we could not identify any similar, credible schemes that certify the green nature of NH_3 for chemicals or fertilizers.

4. Non-thermal plasma reactors

There are no technical and safety standards available that are specific to non-thermal plasma reactors. Nowadays, non-thermal plasma reactors are used for ozone generation, but standards specific to this type of reactor could not be identified. For DARE2X partners, this may be a suitable area for influencing the standardisation process.

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5.2 Standardisation roadmap for DARE2X technology

The idea of the roadmap is to provide an indication for prioritisation of certain next steps to take with regards to standardisation of the DARE2X technology. As introduced previously, complying with certain standards may be necessary to achieve commercialisation, and considering these early on may reduce the time to market of the technology. The roadmap comprises six recommendations and indicates their approximate sequence, considering the current DARE2X solution with a TRL of 4 to 5. With further development, some activities may be shifted or may become obsolete while others may be added until the commercialisation of DARE2X.

The six steps identified are listed in the roadmap visualised in Figure 8. In the following, each step is described in more detail, related directives and standards listed and a potential timing (expressed in TRL) provided. We further recommend screening the standardisation landscape for updates and novelties, which may be expected in the coming years.

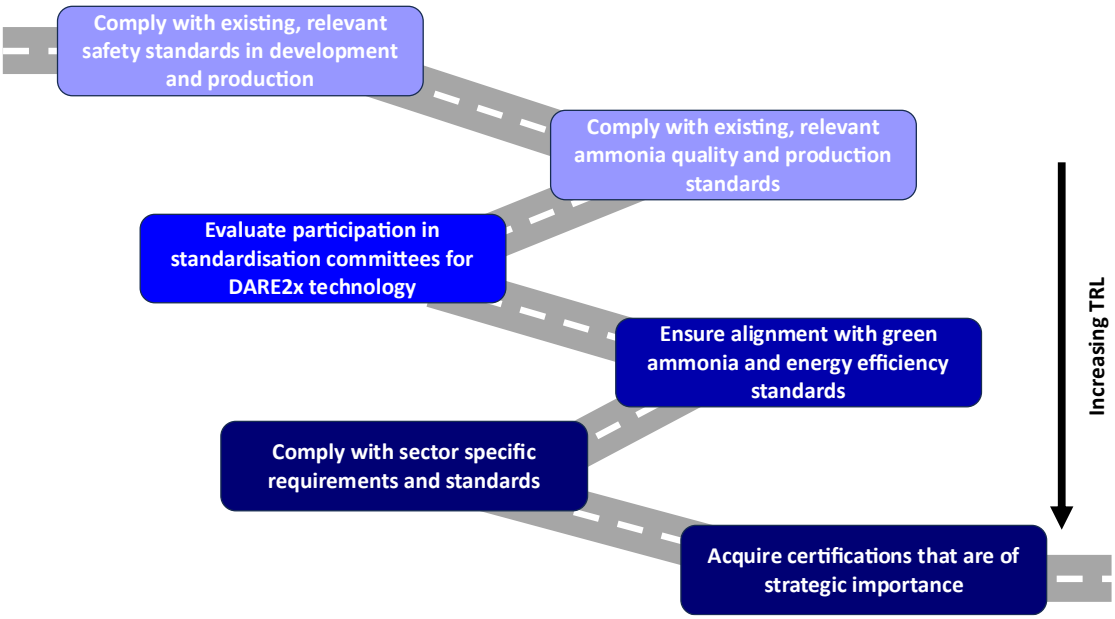

Figure 8. Standardisation roadmap for DARE2X. The roadmap starts out at the development stage (current) and ends with commercial application of the DARE2X technology. The order of future actions may vary and is subject to changes in the standardisation landscape.

TRL 4 – 9

1. Comply with existing, relevant safety standards in development and production

NH_3, with its toxic and hazardous properties, warrants safe practices in handling, production and storage to ensure the safety of workers. This is not only of concern in the industrial production but already during the development of the technology. On the one hand, this ensures that the workers involved are safe. On the other hand, this guarantees that the solution developed meets related standards also at commercial scales. ***Related legislation and standards:*** Regulations and standards identified in the safety cluster in Chapter 4.2.

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TRL 4 – 9	**2. Comply with existing, relevant ammonia quality and production standards** Guaranteeing a high NH_3 purity measured with standardised methods will be key at the moment of commercialization of DARE2X NH_3 and/or related technologies. The suggestion entails applying recommended standards for testing NH_3 purity, implementing standards related to the catalyst and the general production of NH_3 in a preindustrial and industrial environment. ***Related legislation and standards***: All regulations and standards identified in the NH_3 production and quality cluster in Chapter 4.4.
TRL 5 – 9	**3. Evaluate participation in standardisation committees for DARE2x technology** DARE2X technology includes several technological innovations, in particular, the NTP reactor to synthesise NH_3. One potential strategy is to participate in the standardisation process to ensure a fast time-to-market for the DARE2X technology. By shaping future standards, stakeholders can ensure that their own interests are reflected and, additionally, this may help to draw attention to the DARE2X technology. A possible approach to pursue this idea is to approach relevant working groups of international or national standardisation organisations and consider the option of a workshop agreement as a stepping stone to further standardisation activities. ***Related legislation and standards:*** None.
TRL 6 – 9	**4. Ensure alignment with green ammonia and energy efficiency standards** Being able to meet current and future legislation and standards on green / low-carbon fuels and fertilisers may be an important variable in the roll-out of the DARE2X technology. Therefore, DARE2X technology owners should ensure to meet applicable requirements to maintain this strategic advantage compared to alternative NH_3 production technologies. As of now, there is no indication that DARE2X cannot meet these requirements as renewable energy sources can be used for energy intensive processes. ***Related legislation and standards***: Regulations and standards identified in the green cluster in Chapter 4.3.
TRL 8 – 9	**5. Comply with sector specific requirements and standards** DARE2X technology owner may pursue the strategy to target markets that impose specific additional requirements to the production process and the product quality, in particular, purity. At later stages, closer to commercialisation, these should be revisited and ensured that they are met. ***Related legislation and standards***: Those identified in Chapter 4.5 and Chapter 4.6 on maritime and other applications.
TRL 8 – 9	**6. Acquire certifications that are of strategic importance** As introduced above, certifications may signal to potential business partners and buyers that specific requirements are fulfilled by the DARE2X solution. This can both serve for communication with investors and business partners to exploit DARE2X technology. Certification often applies to a narrowly defined process or system. Hence, technology should be mature enough before any certification is considered. Depending on the final target market, certification for the RED III scheme may be

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especially relevant. ***Related legislation and standards:*** For all thematic clusters presented in Chapter 4, certifications may be of interest.

6. Conclusions

This report summarises the work in DARE2X' Task 7.4 on ***standardisation and certification of DARE2X technology***. This report identifies relevant standardisation and certification schemes of the final system(s). Thereby, this report can provide information for further development to facilitate a scale-up and market uptake of the technology. The primary target audience are the project partners. Beyond the project partners, this report can also provide a summary of standardisation landscape to other R&D projects in the field of NH_3 synthesis.

The report provides a comprehensive view on the regulatory, standardisation, and certification landscape for the European single market. The analysis shows an overall consolidated picture in Europe. In other words, the search revealed that global and European regulatory and standardisation organisations published relevant standards, while we did not identify any national deviations of relevance for DARE2X.

We chose to structure our analysis by defining the thematic areas of safety; green ammonia; NH_3 production, catalysts, and quality; maritime applications; and other applications of NH_3. The search was conducted using different search engines, databases, and with the HSbooster service.

Safety and green ammonia regulations are most comprehensive. This is also reflected in the number of available standards to guarantee compliance with existing law. Standards related to final applications of NH_3 are also plentiful. Fewer standards exist that are directly linked to the new production pathway using non-thermal plasma reactors. This was expected given the novelty of this approach to NH_3 synthesis.

In the last chapter, six key recommendations for next steps to regarding standardisation that may be pursued in parallel to further technological development of the DARE2X technologies are presented in a roadmap. They are:

1. Comply with existing, relevant safety standards in development and production.
2. Comply with existing, relevant NH_3 quality and production standards.
3. Evaluate participation in standardisation committees for DARE2x technology.
4. Ensure alignment with green ammonia and energy efficiency standards.
5. Comply with sector specific requirements and standards.
6. Acquire certifications that are of strategic importance.

In short, while there is still standards-related work to be done before a commercialisation of the DARE2X technologies, we are optimistic that all steps can be achieved and that this report provides guidance for the next steps.

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Annex

Legal Framework for Ammonia Safety in the U.S.

Similar to the situation in the EU, ammonia is subject to legislation in the United States (US) aimed at ensuring its safe handling, storage, transport, and emergency preparedness. This framework is defined by multiple federal statutes and regulatory programs, primarily overseen by agencies such as the **EPA**, **OSHA**, and the **Department of Transportation**.

1. Toxic Substances Control Act (TSCA)

Administered by the EPA, the TSCA provides the authority to regulate the manufacture, processing, distribution, and disposal of chemicals, including ammonia. While TSCA focuses broadly on chemical safety, it plays a role in ensuring that risks related to ammonia are assessed and managed throughout ammonia's lifecycle.

2. Pollution Prevention Act (PPA)

The PPA emphasizes reducing the amount of hazardous substances (like ammonia) entering waste streams or being released into the environment. Facilities using ammonia are encouraged to implement safer, more efficient processes that reduce chemical use and emissions at the source.

3. Hazardous Materials Transportation Act

Enforced by the Department of Transportation, this act regulates the safe transport of hazardous materials, including ammonia. It requires proper classification, labelling, packaging, and documentation for ammonia during transport.

4. Emergency Planning and Community Right-to-Know Act

This act mandates facilities to report the storage, use, and releases of hazardous chemicals, including ammonia, to federal, state, and local authorities. The goal is to support community awareness and emergency preparedness.

5. Risk Management Program – Clean Air Act Section 112 (r)

Facilities using large quantities of anhydrous ammonia must develop and submit a Risk Management Plan to the EPA. This includes hazard assessments, accident prevention measures, and emergency response plans.

6. Occupational Safety and Health Administration (OSHA) Regulations

Under **OSHA Standard 29 CFR 1910**, several subparts are relevant to ammonia safety:

- **1910.111** – Storage and handling of anhydrous ammonia.
- **1910.119** – Process Safety Management (PSM) of Highly Hazardous Chemicals; applicable if the facility exceeds the threshold quantity of ammonia (10,000 lbs).

These regulations are mandatory and cover engineering controls, safety systems, employee training and emergency response.

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