North Sea Energy offshore system integration

2.1

North Sea Energy 2020-2022

Standardization

North Sea Energy 2020-2022

Unlock the low-carbon energy potential North Sea with optimal value for society and nature

The North Sea Energy program and its consortium partners aim to identify and assess opportunities for synergies between energy sectors offshore. The program aims to integrate all dominant low-carbon energy developments at the North Sea, including: offshore wind deployment, offshore hydrogen infrastructure, carbon capture, transport and storage, energy hubs, energy interconnections, energy storage and more.

Strategic sector coupling and integration of these low-carbon energy developments provides options to reduce CO2 emissions, enable & accelerate the energy transition and reduce costs. The consortium is a public private partnership consisting of a large number of (international) partners and offers new perspectives regarding the technical, environmental, ecological, safety, societal, legal, regulatory and economic feasibility for these options.

In this fourth phase of the program a particular focus has been placed on the identification of North Sea Energy Hubs where system integration projects could be materialized and advanced. This includes system integration technologies strategically connecting infrastructures and services of electricity, hydrogen, natural gas and CO2. A fit-for-purpose strategy plan per hub and short-term development plan has been developed to fast-track system integration projects, such as: offshore hydrogen production, platform electrification, CO2 transport and storage and energy storage.

The multi-disciplinary work lines and themes are further geared towards analyses on the barriers and drivers from the perspective of society, regulatory framework, standards, safety, integrity and reliability and ecology & environment. Synergies for the operation and maintenance for offshore assets in wind and oil and gas sector are identified. And a new online Atlas has been released to showcase the spatial challenges and opportunities on the North Sea. Finally, a system perspective is presented with an assessment of energy system and market dynamics of introducing offshore system integration and offshore hubs in the North Sea region. Insights from all work lines have been integrated in a Roadmap and Action Agenda for offshore system integration at the North Sea.

The last two years of research has yielded a series of 12 reports on system integration on the North Sea. These reports give new insights and perspectives from different knowledge disciplines. It highlights the dynamics, opportunities and barriers we are going to face in the future. We aim that these perspectives and insights help the offshore sectors and governments in speeding-up the transition.

We wish to thank the consortium partners, executive partners and the sounding board. Without the active involvement from all partners that provided technical or financial support, knowledge, critical feedback and positive energy this result would not have been possible.

North Sea offshore system integration Energy

2.1

North Sea Energy 2020-2022

Standardization

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Executive summary

National, European, and international standards are pivotal for the offshore energy system. Standardization is an important tool to cover aspects on safety, reliability, interoperability, and life-cycle analysis. From a standardization perspective, several aspects governing the NSE project require further analysis. While several national, European (CEN/CENELEC) and international (ISO/IEC) standards are already available, it can be challenging to comprehend which standard applies to which application or process responding to changes due to developments in the energy transition.

To ensure that the value of standards also contributes to innovation in the offshore energy system, it is key that standards that are still needed (i.e., standardization gaps) are brought to the attention of the relevant standardization committees in parallel with market developments. In view of the NSE project, standards are of importance because they:

- enhance the public's awareness on aspects related to safety, reliability and efficiency in the offshore energy system;
- can help to manage risks and opportunities, increase productivity, improve performance, reduce costs and gain access to new markets;
- can support the demonstration of conformity to (statutory) regulations, at lower costs;
- obtain access to the market around the world.

The standardization research question for NSE 4 is:
What standardization is still needed to govern multi-use energy structures in the offshore?

Sub-questions are:

- How can standards support the deployment of an offshore energy system?
- Which relevant national, European and international standards are available, which standards are missing, and which standards form a barrier to the deployment of such an energy system?
- How do (international) standards interact with (international) legislation?

Scope – standardization related topics:

- Platform activities
- Converter station
- PowertoGas (Gas = H2)
- CSS

Mode of transport:

- CCS related pipelines
- H2 and H2 and Natural gas blend (H2NG) pipelines

Additional activities on the platform

- Admixture
- Electrification

Above scope includes continuation of the topics from NSE3 that were not finished to be integrated in the work of NSE4.

Notes regarding scope:
1. The Converter station seemed to be well covered by standardization (see 4.1.1.1) and no further activities needed therefore focus on platform activities related to power to gas.
2. CCS is dealt with as separate item and not included at platform activity item.
3. After the first research activity, CO_2 transportation has been included as one of the CCS topics.
4. Due to time the admixture aspect has been taken less into account.

The main research activities (RA) are:
1. identifying standards and their interaction with legislation (RA1);
2. assessing the impact of (missing) standards – and their interaction with legislation (RA2);
3. formulating recommendations for relevant standardization or governmental bodies to remove barriers or revise/improve (the use of) standards (RA3);
4. disseminating the findings and results (RA4).

The scope of these activities are fed by the specific challenges established for the selected energy hubs in WP 1.

<u>Results of research activities</u>

At first instance it is being looked into which standards are available. The interaction with legislation has not yet been looked into.

Platform and power to gas aspects

In RA1 (paragraph 4.1.1) several standards have been identified that are applicable to the NSE4 project activities. Also actions were defined to get a better understanding of standards needed and if certain standards were applicable. These actions have been dealt with in RA2 (4.2.1). A workshop in January 2022 was organized to discuss the questions with relevant partners and to come with results and recommendations.

At RA3 (4.3.1) clear recommendations for relevant standardization or governmental bodies to remove barriers or revise/improve (the use of) standards, recommendations were formulated. In April 2022 the NSE4 80% meeting was held. At this meeting input was asked in prioritization of the outcome of this study, which is taken into account in the recommendations. Still several recommendations need action to come to a standardisation dissemination action.

At RA4 (4.4.1) the disseminating of the findings and results that can already be performed for standardization actions have been drafted up.

CCS and CO_2 transportation

In RA1 (4.1.2) standards for CCS have been identified that are applicable to the NSE4 project activities. To make the step toward RA2 a better understanding of where the need for standardization could be. Therefore questions for the topics "CCS – CO_2 Injection and storage" and "CCS- CO_2 quantification and verification" have been formulated. These questions were topics for discussion at RA2 in the workshop, January 2022.

For CO_2 transportation an overview of the relevant standards was given in RA1 also key findings and actions were formulated.

In RA2 the following topics have been dealt with, actions have been formulated and results on those actions can be found in paragraph 4.2.2:
1. CO_2 transportation by pipeline
2. CO_2 injection and storage
3. CO_2 quantification & verification

At RA3 clear recommendations for relevant standardization or governmental bodies to remove barriers or revise/improve (the use of) standards (Paragraph 4.3.2) were formulated. For the recommendations the priorities as given after the NSE4 80% meeting were taken into account. Still quite some recommendations need action to come to a standardisation dissemination action.
At RA4 (4.4.2) the disseminating of the findings and results, that can already be performed for standardization actions have been drafted up.
An important national standardization activity is related to the CO2 transportation:

- Participate in preparation amendment to the new edition of NEN 3656 '*Requirements for submarine pipeline systems in steel*, especially Annex Q, that addresses the comments not covered in NEN 3656:2022 (NEN NC 310004)
- Participate in Review NEN 3650-2 '*Requirements for pipeline systems - Part 2: Additional specifications for steel pipelines'*, especially Annex G, to provide suggestions for next edition (NEN NC 310004)

Transportation H2 and H2NG

In RA1 (4.1.3) relevant standards have been identified that are applicable to the NSE4 project activities regarding the transportation of H_2/H_2NG.
In RA2 (4.2.3) actions were formulated for the next steps. An important step was to provide input on NEN 3650-2 '*Requirements for pipeline systems - Part 2: Additional specifications for steel pipelines'* and the revision of the NEN 3656 '*Requirements for submarine steel pipeline systems'* which was published in March 2022. These standards are a part of the Dutch legal framework.

The recommendations (RA3 4.3.3) and recommendations for dissemination (RA4 4.4.3) are very straight forward; input/involvement to be given to NEN 3656 '*Requirements for submarine steel pipeline Systems'* and NEN 3650-2 '*Requirements for pipeline systems - Part 2: Additional specifications for steel pipelines'*. Of importance is that several outstanding issues require additional research before it can be implemented in the future revision of NEN 3650-2 and NEN 3656.

Electrification

Under the heading of electrification both electricity grids between platforms, substations and wind turbines and electrification of the platforms are considered
For both topics relevant standards and standardization bodies have been addressed in RA1 (4.1.4). In RA2 (4.2.4) it appears that standards already seem to be applicable for the NSE4 activities. Main issue is when scaling up to the scale of 500MW additional standardization needs might become applicable as described in RA3 (4.3.4).

1 Introduction

Background of this Work Package

National, European and international standards are pivotal for the offshore energy system. Standardization is a tool to cover aspects on safety, reliability, interoperability and life-cycle analysis. From a standardization perspective, several aspects governing the offshore energy system require further analysis. Although several national, EU (CEN/CENELEC) and international (ISO/IEC) standards are already available, it can be difficult to understand simply which standard applies to what application/process, and what are the gaps.

This Work Package on standards will identify relevant standards for the activities in the North Sea Energy project. Secondly, the offshore system integration of the North Sea energy system raises questions on the interaction between legislation and standardization, for example cross-border supply chains of hydrogen production, transportation, storage and utilization. It is important to identify non-state-of-the-art or missing standards based on an impact assessment, and to formulate recommendations related to the identified barriers including those from the interaction between legislation and standards to be addressed at the relevant standardization committees and/or governmental bodies. Finally, to ensure that the value of standards also contribute to innovation in the offshore energy system, lacking standards will be brought to the attention of the relevant standardization committees in parallel with market developments.

In general, standardization can:

- enhance the public's perception on issues related to safety, reliability and efficiency in the off-shore energy system
- help to increase productivity, reduce costs and gain access to new markets
- demonstrate conformity to (statutory) regulations, at lower costs
- give access to markets around the world

The inclusion of the topic of standardization was addressed in NSE3 for the following four topics:

1. Carbon capture, utilization and storage
2. Technology, structural integrity and safety of hydrogen transport, compression, processing offshore
3. Pipeline systems
4. Offshore power grids – joint development of offshore platform electrification of multiple platforms

NEN participated in the NSE3 and provided as a first step on the four topics a user-friendly mapping of the existing standards and the standards in preparation. Steps have been taken on conducting a gap analysis to identify which standards form a barrier to the deployment of an offshore system integration of the North Sea energy system (standards that lack specific requirements, contain conflicting requirements or standards that are missing). The work have been continued as an integrated activity in NSE4 and is based on technical assumptions, as best foreseen by interviews which have been performed with relevant stakeholders.

Research questions

The main research question to be answered is: What is still needed to govern multi-use energy structures in the offshore?

Sub-questions are:

- How can standards support the deployment of an offshore energy system?
- Which relevant national, European and international standards are available, which standards are missing, and which standards form a barrier to the deployment of such an energy system?
- How do (international) standards interact with (international) legislation?

Project objectives and scope

The objective of this WP is to address and include the standardization aspects and needs. The study includes national, European and international standards as well as the interaction of these standards with legislation. This WP is divided in four research activities (RA):

1. Identifying standards and their interaction with legislation;
2. assessing the impact of (missing) standards – and their interaction with legislation;
3. formulating recommendations for relevant standardization or governmental bodies to remove barriers or revise/improve (the use of) standards;
4. dissemination of findings and results.

Included in activity 1 and 2 is the identification which relevant national, European and international standards are available, and which standards form a barrier to the deployment of such an energy system (standards that lack specific requirements or contain conflicting requirements or standards that are missing)?

The scope of these activities have been fed by the specific challenges that will be established for the selected energy hubs in WP 1.

Since the NSE project involves several innovative activities, the existing standards must be analysed for the extent to which they facilitate and support this future project development.

Scope NSE4

1. NSE 4 will continue with the last 3 research activities (RAs) of NSE3. This is in alignment with WP1 activities "North Sea Energy Hubs & Transport Infrastructure" – including large scale production, WP2 legal (standards and their interaction with legislation) and WP3 "Safety, Integrity & Reliability of system aspects integration options". For the topic of hydrogen transportation more research has been performed and therefore also the pipelines have been actively looked into instead of only monitoring which was the recommendation from NSE3. The NSE3 activities have been integrated in the NSE4 project.

2. Activities that are newly being looked into in NSE4 are:
   - Platform activities - the different types of platforms e.g platforms for PtoH2, Platform with CCS activities, platforms making use of electrification.
   - Structure (new or re-use)
   - Admixture process
   - Mode of transport
   - Electrification on the platforms where applicable

The sand island with the purpose of Power to Gas will be a second priority if it fits within the current budget and planning.

Moreover – third priority - a long list has been drafted with additional topics that could be looked into if it fits within the current budget and planning.

2 Standardization scoping

The following events gave input for the scoping of NSE4:

- The meeting of 21/22 September 2020 gave a first indication on the feedback of stakeholders.
- In the workshop of 11 November 2020, with NSE stakeholders and in conjunction with WP1, several standardization activities were identified and prioritized and the continuation of NSE3 mapping activities and next steps were elaborated.
- Verification and alignment with WP1 was carried early February 2021 resulting in the scope as described.

Besides WP1, the main work packages for interaction are:

- WP2 (legal) because of the interaction with standardization.
- WP3 (safety), because safety is a very important topic within standardization.

In NSE4 the NSE3 standardization work has been continued.

The topics have been dealt with in NSE3 on the following topics:

1. Carbon capture, utilization and storage
2. Technology, structural integrity and safety of hydrogen transport, compression, processing offshore
3. Pipeline systems
4. Offshore power grids – joint development of offshore platform electrification of multiple platforms

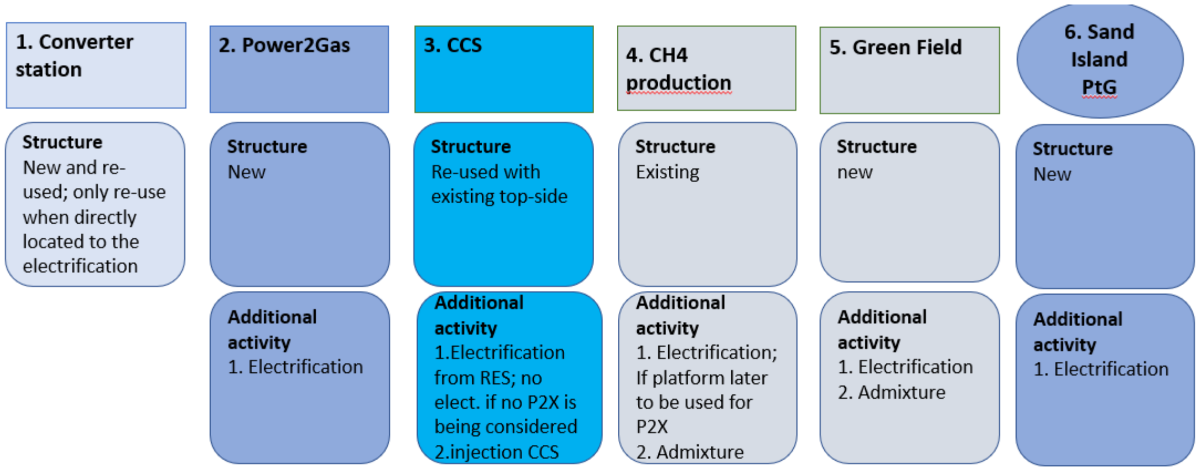
From the four research activities the first research activity (RA1) has been performed and RA2 “assessing the impact of missing standards” had started. RA activity 3 “Formulating recommendations for relevant standardization or governmental bodies to remove barriers or revise/improve (the use of) standards” (RA3) and disseminating the findings and results (RA4) are carried out under the scope of NSE4.

The additional topics for NSE4 are:

- Platform activities - the different types of platforms
- Structure (new or re-use)
- Mode of transport
- Additional activities on the platform:
- Admixture
- Electrification

Platforms

The platforms that have been looked into are types of platforms with distinguishment in activities/functions.



Mode of transport

1. Electric cable
2. Pipelines
   a. CO_2 from shore
      – New or re-use
   b. Hydrogen to shore
      – New or re-use
   c. Admixture H_2 with NG to shore pipeline
      – New or re-use
      Note: only new pipelines when green field development is combined with P2G otherwise always the existing pipeline.

Additional activities on the platform

- Admixture
- Electrification

For interaction other workpackages and critical input and exchange needed with other WPs see Annex 1.

3 Methodology for standardization

This section describes the methodology which has been applied for this WP on standardization. For each topic the research activities (RA) have been performed:

3.1 Methodology steps

3.1.1 Platform activities

For the platforms the topics that have been looked into are the following (see also WP3):

Platform aspects:

- Platform aspects
- Functional safety perspective
- Asset integrity
- Reliability/efficiency engineering
- Structural integrity
- Safety of machinery
- Fire prevention and fire control
- Inspection and maintenance
- …

Operational aspects:

- Personnel competence
- Education and training
- Safety
- Gas detection
- How to deal with hydrogen
- What to do in case of fire / emergency
- Occupational health and safety management
- Emergency procedures
- Risk management
- …

3.1.1.1 Converter station

- Design structure, reliability, integrity, safety standards
- Equipment standards
- Maintenance and operation standards

3.1.1.2 Power to Gas

- Continuation NSE3 topic “Technology, structural integrity and safety of hydrogen transport, compression, processing offshore” , In NSE3 inclusion of integrated activities; focus NSE4 have been the new dedicated Power to Gas structure
- Design structure, reliability, integrity, safety standards

  Focus on: Hydrogen production facility components:

  a) Electrolyser (PEM)
  b) High-voltage transformers (incl. rectifiers)
  c) Desalination

d) Deoxidizers & dryers
e) Storage hydrogen > line packing
f) Storage oxygen to be defined

- Processing/storage/pipelines on the platform
  a) Compressors
  b) Hazardous areas
  c) Explosion prevention
  d) Safety distances
  e) Safety of personnel
  f) Leak detection
  g) Handling of Oxygen – depending on waste product or air release
  h) Safety shut down procedures

- Cross cutting
  - H2, H2NG and O2 quality
    - H2 entry and exit; pure and H2NG admixtures
    - O2 exit (NEW)
    - Metrology; Challenges and solutions regarding metering technologies for hydrogen (NEW)
  - Guarantee of Origin
  - Inspection and Maintenance

3.1.1.3 CCS

- Continuation NSE3 "CCS"
- Re-used platform with existing top-side > check on design structure, reliability, integrity, safety standards
- Injection process
  - Hazardous areas
  - Explosion prevention
  - Safety distances
  - Leak detection
- Cross cutting CO2
  - Quality/conditions of the CO2 to be compressed and injected
  - Metrology; challenges and solutions regarding metering technologies for CO2

3.1.1.4 CH4 production

No standardization gap analyses > standards are there

3.1.1.5 Green Field

No standardization gap analyses > standards are there

3.1.1.6 Sand Island PtG

This is the priority 2 in the scoping depending on time and money
Hydrogen production on an Island (power to gas) (> 4 GW)
Unfortunately due to time the topic has not been looked into.

3.1.2 Mode of transport

CCS pipelines

Re-use of existing pipelines and new pipelines

Pipeline standards

- Qualification re-use current pipelines
- The dimensions of the offshore pipeline
- Sensors in the pipelines
- Safety monitoring
- Leak detection

H2 and H2NG pipelines

Continuation of NS3 work

- Re-use of existing pipelines
- Integrity
- Inspection if they can be re-used
- Possible occurrence of pit corrosion
- Multitude of internal diameters
- Hydrogen embrittlement
- New pipelines
- Dimensions of the offshore pipeline
- Sensors in the pipelines
- Safety monitoring
- Leak detection
- Transport:
- Material properties, fittings, valves etc.
- Inventory of inspection
- Maintenance requirements

3.1.3 Additional activities

Admixture

- Admixture equipment
  - Compressor
  - Flow assurance
  - Gas turbine
  - injection facility
- Cross cutting aspects
  - Leak detection
  - Safety aspects
  - Metrology
  - ..

Electrification

- Continuation NSE3
  - Connection platform to the grid
- Electrification on the platform

- (Re)placement of the current installed gas turbines used in mechanical trains such as compressor trains
- Integration of auxiliary power requirements in power distribution – connection to a new platform nearby the existing platform that hosts the electric equipment to provide a 66 kV supply to the H2 production platform.

3.1.4 Long list

In the process of the scoping together with WP1 also topics have been identified – long list - that might be of interest if it fits within planning and budget.

- Ecological aspects
- Environmental impact assessment
- Community engagement
- Power quality
- Intermittency in output
- Off time
- Power stability
- Electric system stability
- Load factor and peak
- Cable connecting the gas platform with the substation
- Offshore RES
- Storage of hydrogen and oxygen incl the safety aspects. Platforms have little space and pipeline to be considered as storage medium
- Hydrogen storage in empty gas fields
- Logistics for O&M of offshore gas and wind (WP5)
- Floating structures
- Ship-based transport of CO2

4 Research activities

An objective is to provide an overview of the relevant standards with the main focus on Dutch continental shelf in the southern North Sea and which standards are missing.

First steps have been taken in performing interviews with TotalEnergies, Neptune Energy and Bureau Veritas, this together with WP3. Discussed were questions on which standards are being used on topics related on the platform on safety, reliability, and integrity and also on H2/H2NG pipelines.
The exchange with partners is pivotal in relation to these activities.

For each standardization scoping topic, the four research activities (RA) have been performed.
NSE4 research activities have been performed with integration of the NSE3 topics for continuation.

In this report we refer to national, European and International standards. National standards are standards starting with NEN or PGS, European with CEN or CENELEC (CLC) and International with ISO or IEC. The NEN, CEN, CENELEC, ISO and IEC standards are the developed through the (international) standard development organization composed of representatives from the national standards organizations of member countries. Also for example there is reference to ASME or DNV standards. These are standards developed by a specific company and can be used also for the relevant activity. Also there are references to European guidances e.g. ATEX or Directives e.g. Pressure Equipment Directive (PED).

The activities have been carried out in co-operation/alignment with WP1, WP2 legal aspects and WP3 on safety related aspects.

For each item several interviews have been performed and a workshop has been held.

Project team
The project team consists of the following NEN persons including their responsibility:

NEN responsible	
Françoise van den Brink	Overall coordination
Jarno Dakhorst	CCUS
Lennart de Waart	Platform activities
Sui Wan	Pipelines
Peter Welleman	Electrification
Remco Perotti	Electrification

4.1 Research activity identification of standards and their interaction with legislation

4.1.1 Platform activities

The objective was to continue the work which was started under NSE3 and expand the mapping of relevant standard and assess possible gaps & barriers and formulate recommendations considering the aforementioned.

General

For the platform activities specifically was looked into the Platform and operational aspects and the power to Gas aspects. The main information was gathered through interviews and workshop with the partners:

- Neptune Energy
- Bureau Veritas
- TotalEnergies
- Gasunie
- Onedyas

In general, the mentioned topics from 3.1.1 have been looked into.

Regarding platform aspects, ISO/TC 67/ SC 7 Offshore structures has an extensive portfolio on offshore platforms on the abovementioned topics (see Annex 1).

4.1.1.1 Converter station

The converter station will be situated on a new or re-used platform. Either way it is assumed the conversion will feed the electrolyser system, which consists of the electrolyser stacks, the demin water supply loop, transformers and the rectifiers. For the electrolyser stacks there is a lot of improvement expected of the various technologies in the next couple of years. This might impact the standards required to (re-)build a platform for this purpose.

The topics that have been looked into

- Design structure, reliability, integrity, safety standards
- Equipment standards

For the design structure the ISO/TC 67 standards are applicable. Also, reliability, integrity, lifesaving equipment and safety for offshore structures including the topside structure is included in these standards.

Design structure, reliability, integrity, safety standards: ISO/TC 67 standards ISO 19900 - 19905 from ISO/TC 67/SC 7 (see list above) should be used. The standards also include requirements for re-use and even for transfer of the offshore structure. The re-use of the topside structure is described in ISO 19901-3 "*Petroleum and natural gas industries — Specific requirements for offshore structures — Part 3: Topsides structure*"

4.1.1.2 Power to Gas

Beside the specific aspects for power to gas also the platform and operational specifics have been looked into. The focus of NSE4 is the new dedicated P2G structure, based on the concept design of the 500 MW hydrogen platform.

Design structure, reliability, integrity, safety standards
See converter station

Hydrogen production facility components/electrolyser

1. **Hydrogen production**

   a) **Electrolysers**

Safety requirements for hydrogen systems are outlined in ISO/TR 15916:2015 *Basic considerations for the safety of hydrogen systems*. It identifies the basic safety concerns, hazards and risks, and describes the properties of hydrogen that are relevant to safety.

Water electrolysis is described in ISO 22734 *Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications*

Steam methane reforming is outlined in ISO 16110 *hydrogen generators using fuel processing technologies*

Offshore environment: When placing and choosing the materials for the equipment on the platform, the offshore environment and salty air must be taken into account. It is assumed the electrolyser is situated in a conditioned area. The transformers are assumed to be constructed to the outside of the platform, for cooling purposes. When installing, care must be taken not to put materials/corrosive metals against each to avoid corrosion. If this is not possible, the material must be sufficiently shielded. Interviewees indicated that regarding materials in some cases aluminum is applied. See also WP3.

Action 1: The application of the abovementioned standards for offshore hydrogen production, rectifiers and transformers e.g., regarding offshore maritime environment, should further be investigated while they are not developed specifically for offshore conditions. If these standards are fully applicable to offshore hydrogen production, or offshore power conversion, could be mentioned in the scope of the relevant standards.

Ventilation zoning is sufficiently described in ATEX 114 *Equipment for potentially explosive atmospheres* and ATEX 153 on worker protection, and the IEC 60079-10-1 *Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres* on the application of forced air.

   b) **High-voltage transformers (incl. rectifiers)**

The rectifiers are always supplied with charging voltage. High voltage should take into account the safety distances and preferably in a Faraday cage.

Action 2: A recommendation for further research is to further explore if relevant guidelines or standards addressing EMC for offshore hydrogen production exist.

Gap: static electricity: hydrogen is susceptible to static electricity of electromagnetic fields. If the feed to the electrolyser will get bigger – 500 MW configuration and 66 KV for the electrolyser - this will have impact. As a consequence, large transformers will be needed. To meet normative specifications, to avoid ignition and electrostatic shock hazards arising from static electricity, these big installations shall be verified with IEC 60079-32 or other ATEX related standards.

The standards developed under the Electric magnetic compatibility Directive (EMC) are applicable. This relates to the transformers and rectifiers for the electrolyser. This impact can be calculated. One should go back to the basic design of the electrical installation. It is assumed Faraday cages can mitigate EMC problems. The IEC 61000-series for EMC immunity requirements are relevant. More in general: work procedures for electric installations are described in the NEN 3840 *Operation of electrical installations – High voltage* and e.g. IEC 62305 *Protection against lightning*, IEC 60255 *Measuring relays and protection equipment*. Also of relevance are API 520 *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries –Sizing and Selection* and 521*Pressure-relieving and Depressuring Systems.*

Action 3: It is recommended to look in more detail how the electromagnetic fields might impact the electrolyser or its control electronics. Also the EMC impact of the electrolyser itself on other electric equipment might be subject of further research.

c) Desalination

The quality of the water is of importance for the electrolyser. The desalination should be fit for purpose for this quality. A relevant standard is the ISO 22519:2019 *Purified water and water for injection pretreatment and production systems*.

Action 4: It should be assessed if the ISO 22519: 2019 is applicable to electrolysers and if there is need to add desalination to the electrolyser standard ISO 22734 *Hydrogen generators using water electrolysis — Industrial, commercial, and residential application.*

d) Deoxidizers & dryers

Deoxidizers & dryers are described in the ISO 22734 *Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications*

e) Storage hydrogen > line packing

This has not been taken into account separately from transportation H2 and H2NG.

f) Storage oxygen to be defined

This has not been taken into account

2. Processing/storage/pipelines on the platform

The American Society of Mechanical Engineers (ASME) B31.12 "*Hydrogen Piping and Pipelines standard*", can also be used for top-side piping, describes the choice for materials exposed to hydrogen and is used to determine if the materials in a standard application are suitable for hydrogen usage. The ASME B31.12 is also applied when converting existing installations that are not (fully) adapted to hydrogen.
Storage battery energy; PGS 37 (Energy storage systems) and NEN 4288 (Working procedures for battery storage systems) are relevant.

a) Compressors & pumps

The American Society for Testing and Materials (ASTM) PTC 10 *Performance Test Code on Compressors and Exhausters* standard is applicable for compressors for hydrogen and H2NG. The variation in flow is technically an interesting issue but has most probably no impact on standardization.

Action 5: Regarding choice of materials, the material scientific phenomenon of hydrogen indulged cracking for rotating equipment should be addressed can possibly be amended in the standard.

The ASTM PTC 10 addresses onshore pumps for compressors.
Action 6: Offshore application of this standard should be investigated.

b) Hazardous areas

More details needed to be looked into in relation to design.

c) Explosion and -prevention

Hydrogen extinguishing systems are outlined in the US National Fire Protection Association (NFPA) hydrogen technologies code NFPA 2 – Fire Safety Standards.

An Explosion safety document (ESD) is drawn up per location conform ATEX 114, hydrogen specific risks can also be considered with this method. This needs to be included in the ATEX Risk Inventory and evaluation (RI&E).

d) Safety distances/ Safety distances: buffer storage & electrolyser

Safety distances dependent on the size of the buffer storage, which is part of the installation design and possibilities regarding onshore buffering. A smaller buffer storage (e.g., 130 liter) can be part of the design as part of pressure control of the piping system. The following is of relevance:

- The buffer storage / electrolyser is captured in the risk assessment when it meets the Pressure Equipment Directive (PED).
- Regarding safety distances, ISO 19901 Petroleum and natural gas industries — Specific requirements for offshore structures and ISO 19902 Petroleum and natural gas industries — Fixed steel offshore structures and its API equivalent RP2a is of relevance regarding platform design. This standard still applies e.g., when a change is made to the process installation (e.g., adding an electrolyser). Hydrogen specific risks do not require a change to the approach as outlined in these standards.
- The EU Safety of Offshore Oil and Gas Operations Directive requires that a standardized HSE safety case is drawn up for offshore platforms. When making a change in the process installation (e.g., adding an electrolyser), the HSE safety case should be revised reflecting this change. This is a legal requirement and is used in accordance with the Dutch Mining Act (Mijnbouwwet). Applicable paragraphs/articles are:

  Note 1 Article 6 paragraph 1 of the Mining Act sets out the licensing obligation.

  Note 2 Article 18 paragraph 1 under b Mining Act indicate the change of the permit.

  Note 3 Section 4.1a.1.1 of the Mining Act concerns the report on major hazards for a production installation. In the event of a general change to a production installation, the operator must submit an amended report to the Inspector of Mines (Article 45e paragraph 1 Mining Act). If it concerns a non-production installation, Article 45i paragraph 1 of the Mining Act is important.

  Note: Article 43 paragraph 1 Mining Act indicates that a safety zone of 500 m applies around a mining installation.

Buffer storage and safety distances are also addressed in the mandatory explosion safety document (ESD), ATEX and risk assessment.

e) Safety of personnel

Education / training personnel

NOGEPA offers training courses for offshore personnel. Additionally, the interviewees indicated that operators provide their own personnel with instructions and training regarding hydrogen.

<u>Action 7</u>: It is recommended to test whether hydrogen is addressed sufficiently in NOGEPA standard training courses and whether an addition to the curriculum is desirable. It is also recommended that this curriculum is aligned with NL safety regions (Veiligheidsregio's – NIPV) where a lot of work is done on hydrogen and standard training material has already been developed.

f) Leak detection

Leak detection requirements are outlined in the API RP 14 G *Recommended Practice for Fire Prevention and Control on Fixed Open-type Offshore Production Platforms*. This document defines an upper limit of acceptable (hydrogen) concentration in the atmosphere.

Interviewees stated that companies may apply stricter concentration limits, e.g., 10% of the defined upper limit. More stringent upper limits may be defined based on the on-site conducted risk assessment and ATEX also considering location specific aspects (e.g., presence of other explosive atmospheres (fuels) or high-impact locations).

Portable gas detectors:

Gas detectors are available that can detect hydrogen molecules as well as C and H atoms. Committee NEC 216 follows European standard development for industrial gas detection.

g) Handling of oxygen – depending on waste product or air release - oxygen exit

Whether, how and where oxygen should be ventilated is part of the discussion in the NSE 4 program and should be further investigated (see NSE WP 3).

The standard AIGA 067/17 *Safe location of oxygen and inert gas vents* also applies to oxygen. For venting, a standard plume study is performed to map where the oxygen ends up. A plume study on this matter will also be carried out within the NSE 4 project by NSE WP 3.

In WP3 more information is available on the oxygen venting and distances that should be taken into account.
When venting upwards, helicopter flights and evacuation must be taken into account. When venting downwards (sub-sea release), ships and bunkering must be taken into account. A possible recommendation for standardization will be based on the developments in NSE 3 WP 3.

h) Safety shut down procedures

Emergency shut-down devices are covered by the API Standard 521 *Pressure-relieving and Depressuring Systems*. The standard covers risk assessment, pressure safety valves, implementation methods and detection.

Risk assessment

Interviewees pointed out that the platform design is not generic but geared towards a specific application. A Qualitative Risk Assessment (QRA) is performed on every aspect / application on the platform and revised when a platform is reused and/or a modification to the platform is made.

The following is of relevance:

- ISO 19901 Petroleum and natural gas industries — Specific requirements for offshore structures and ISO 19902 Petroleum and natural gas industries — Fixed steel offshore structures and its API equivalent RP2a is of relevance regarding platform design. This standard still applies e.g., when a change is made to the process installation (e.g. adding an electrolyser). Hydrogen specific risks do not require a change in the approach as outlined in this standard
- The EU Safety of Offshore Oil and Gas Operations Directive requires that a standardized HSE safety case is drawn up for offshore platforms. When making a change in the process installation

(e.g., adding an electrolyser), the HSE safety case should be revised reflecting this change. This is a legal requirement and is used in accordance with the Dutch Mining Act (Mijnbouwwet).

- **An explosion** safety document, ATEX and performing a QRA.

It is important to include the correct parameters in the QRA to prevent incorrect assumptions. These parameters also affect what standards to apply. With regard to risk assessment for a hydrogen installation located offshore on a platform, controlled burning can be considered due to the lack of damage to the environment / buildings and population in the vicinity and the risks associated with firefighting. For this reason, controlled burning preferred by platform administrators under certain circumstances.

3. Cross cutting

H2, H2NG and O2 quality, H2 entry and exit, pure and H2NG admixtures.

Metrology; Challenges and solutions regarding metering technologies for hydrogen

Metrology is important to accurately measure (and bill) the purity and quantity (flow) of gases and to detect leaks in all phases of the production, distribution and (industrial) application process. The fiscal aspect of metering is important for the billing and the ultimate profitability and confidence in new gases.

When mixing hydrogen with natural gas, it is important to know how much gas flows through the pipeline in order to meet the integrity thresholds set for existing pipelines. Policymakers in many EU countries are currently considering an expansion towards 10% hydrogen for existing natural gas pipelines. When using pure hydrogen, it is important to be able to measure the purity of hydrogen, (e.g., 99%) but above all what impurities remain (e.g., the 1%).

The International OIML R137 Part 1: *Gas meters - Metrological and technical requirements* and Part 2: *Metrological controls and performance* may be applied however measurement accuracy regarding hydrogen and hydrogen-enriched natural gas (H2NG) remains a challenge. A gap is accurate flow and quality measurement of pure hydrogen and hydrogen-enriched natural gas in existing and hydrogen dedicated infrastructure.

Action 8: Further research in flow metering and gas analysis impurity measurement is needed, which is a prerequisite for upscaling hydrogen and H2NG. [1]
Currently a study performed by Gasunie and Emerson is looking into this subject and awaiting results.

Guarantee of Origin
The guarantee of origin standard EN 16325 is being revised[2] and expanded at European level (CEN/CLC) in addition to electricity, with hydrocarbons (incl. biomethane), hydrogen and heat & cooling. The EN 16325 also covers energy conversion (e.g., electricity → hydrogen). This standard can in the future be

[1] A research project that started in July 2021 that focuses on measurement challenges regarding flow metering and quality measurement of hydrogen and H2NG is the EMPIR Metrology for decarbonising the gas grid. NEN is leading the work package dedicated to standardization and uptake.

[2] NEN functions as the secretariat of the working group responsible for the revision

applied to offshore hydrogen installations for issuing of certificates of origin for the produced energy. These certificates can be freely traded within the EU+EEA.

The standard is referred to in European legislation (RED II, future RED III) as the standard that will set up and shape the guarantee of origin system in the EU.

Inspection and Maintenance

Action 9: It was concluded from the interaction with partners that it needs to be looked into what the need for maintenance and inspection is for electrolysers and specifically the PEM stacks. It could be a decision to replace the stack with a certain frequency instead of flying in maintenance and inspection personnel. This decision depends on the frequency and impact of the maintenance and inspection and on the CAPEX and OPEX. Also, the risks of the maintenance and inspection need to be taken into account.

4.1.2 CCS

The objective was to continue the work which was started under NSE3 and expand the mapping of relevant standard and assess possible gaps & barriers and formulate recommendations considering the aforementioned. For CCS the standardization development is still mainly done on an ISO level. No activities yet on a national or European level.

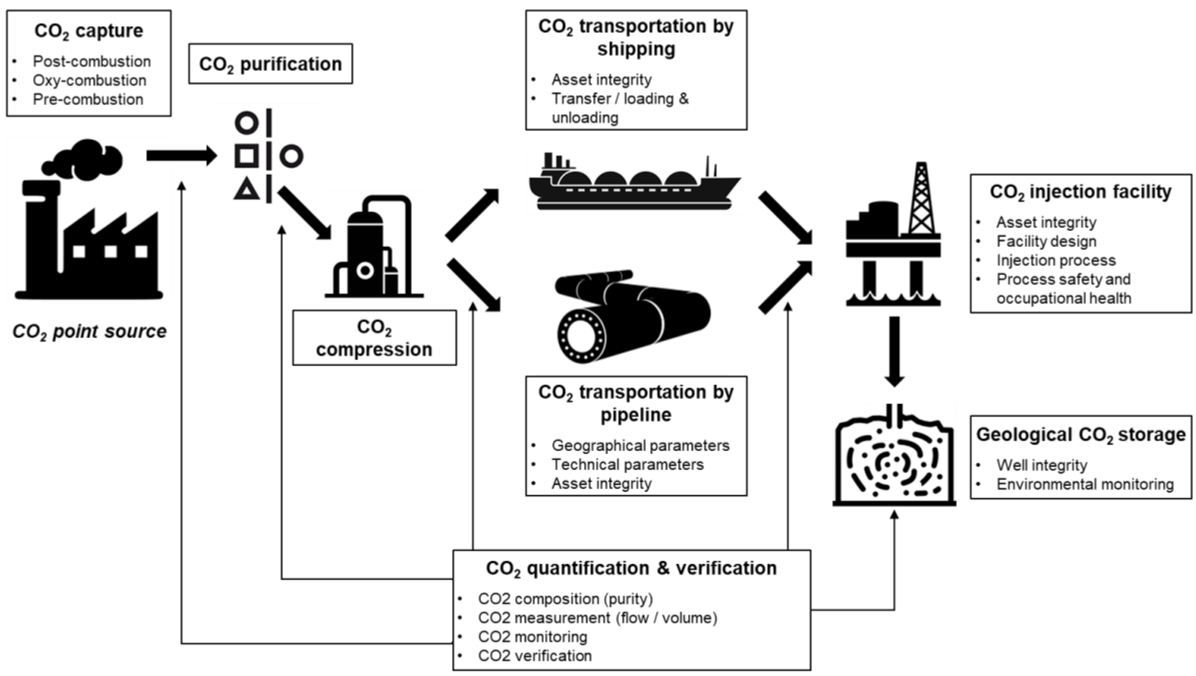


Figure 1 – Simplified CCS value chain
(Note: See Figure 1 in NSE 3 WP 4.2 deliverable for a more detailed flowchart about technology, structural integrity and safety standardization mapping)

Requirements for offshore structures are described in the ISO 19900 series of standards developed and maintained by ISO/TC 67/SC 7 'Offshore structures' (see also mapping spreadsheet). Existing offshore structures can be re-used to facilitate the injection of CO2 in depleted gas fields either at their current location or by removal to another location. While standards address aspects related to life-time extension, structural integrity management, re-use and removal as well as marine operations, the standards are not designed for CCS related activities. The applicability of these standards will be discussed with other experts to identify possible standardisation needs.

Operational aspects of offshore production installations are addressed in several standards developed and maintained by ISO/TC 67/SC 6 'Processing equipment and systems' (see also mapping spreadsheet). While standards are designed for hydrocarbons operation, the principles are considered applicable to CO_2 operations as well. Personnel involved in the offshore CO_2 storage activities should be aware of the particularities of working with CO_2 to ensure safe operations. The applicability of these standards will be discussed with other experts to identify possible standardisation needs.

Concerning CO2 storage, ISO/TC 265 'Carbon dioxide capture, transportation, and geological storage' has developed standards for both (onshore and offshore) geological storage and enhanced oil recovery (EOR) by CO2 injection in which CO2 will be stored underground (see also mapping spreadsheet). As these standards are designed for global application, it should be assessed if specific requirements are needed for offshore CO2 storage in the North Sea area, using existing platforms or using new facilities. This also to be discussed with other experts.

CCS – CO2 Injection and storage

Relevant standards
ISO 1990X series on offshore structures for petroleum and natural gas industries:
ISO 19900, General requirements for offshore structures
ISO 19901 series, Specific requirements for offshore structures [10 parts]
ISO 19902, Fixed steel offshore structures
ISO 19903, Concrete offshore structures
ISO 19904, Floating offshore structures
ISO 19905 series, Site-specific assessment of mobile offshore units [4 parts]
ISO 279XX series for carbon dioxide capture, transportation and geological storage
ISO 27914 *Geological storage*
ISO 27916 *Carbon dioxide storage using enhanced oil recovery (CO2-EOR)*
ISO/TR[3] 27923 *Geologic storage of carbon dioxide injection operations and infrastructure*
ISO/TR 27926 *Carbon dioxide enhanced oil recovery (CO2-EOR) — Transitioning from EOR to storage*
ISO 16530 *Petroleum and natural gas industries — Well integrity —Life cycle governance*

Questions to identify possible needs for standardisation
- Which types of offshore structures are considered for re-use / removal to other location to support CO2 storage?
- Which types of offshore structures are considered for new-build facilities for CO2 storage?
- Which standards or similar documents are used for design, construct and operate offshore structures to inject CO2 in geological storage facilities (e.g. depleted gas fields)?
- Are there ‘gaps’ (technically, legally, otherwise) that need to be bridged through standardisation to enhance safety, improve cost-effectiveness, support interoperability and system integration?
- Are the ISO/TC 265 standard on geological storage of CO2 (including CO2-EOR) considered? And if so, are they suitable for North Sea area or do they need to be supplemented with region specific requirements?
- What are the key challenges that still need to be resolved to start injecting CO2 in geological storage facilities and to monitor these facilities to prevent leakage?

[3] TR: Technical Report

- Any other issues?

CCS – CO2 quantification and verification

Relevant standards
ISO 279XX series for carbon dioxide capture, transportation and geological storage
ISO/TR 27915 Quantification and verification
ISO 27920 Quantification and verification => project cancelled after "DIS stage", quantification and verification related to geological storage to be considered in revision of ISO 27914
ISO/TR 27921 CO2 stream composition
ISO/TR 27925 Flow assurance
ISO 14064 series, Specification with guidance for quantification and reporting of greenhouse gas emissions and removals [3 parts]
ISO 19694 series, Stationary source emissions — Determination of greenhouse gas (GHG) emissions in energy-intensive industries [7 parts (under development)]

Questions to identify possible needs for standardisation

- What minimum CO2 purity / composition is required (e.g. in view of asset integrity across CCS value chain during entire lifecycle), and can this quality easily be achieved?
- Which standards or similar documents are used to determine CO2 composition?
- Which legal requirements apply for monitoring, measurement and verification of CO2 streams also in view of financial incentives like EU-ETS, SDE++? And is reference made to standards to demonstrate compliance?
- Which metrology challenges need to be resolved to ensure consistent and adequate CO2 measurements?
- Any other issues?

4.1.3 Mode of transport

In respect to new pipelines or re-use of existing natural gas pipelines standards are an important tool for the deployment of CO_2 and H_2 in the North Sea (and beyond). The overview has been established with subject-matter experts from Neptune Energy, TAQA and Bureau Veritas and is discussed and 'validated' with other experts in a workshop organised on 14 July 2021.

The strategy for re-use of existing hydrocarbon pipelines for H_2 or CO_2 transportation is in principle to perform a risk assessment covering the entire life cycle. When another medium is used then the pipeline originally was designed for, at least temperature and pressure shall be taken into account in this risk assessment. Using historic information, such as information embedded in the Pipeline Inspection Management System (PIMS) of an operator, will support the risk assessment.

The current edition of NEN 3656, '*Requirements for submarine steel pipeline systems*' is already in force and is referenced in the Mining Act as part of the Dutch legal framework. This standard is based on international recognised standards, supplemented with requirements addressing specific needs. NEN 3656 can also be applied for CO2 and H2 pipelines concerning design, operation, inspection and maintenance in the Dutch continental shelf of the North Sea. NEN 3656 is risk-based standard for group 1 pipelines with the medium and their damage mechanism as the starting point. The revised NEN 3656 is published in March 2022.

The sub-sea steel pipeline sub-group as part of the standardisation group NC 310004 has worked on the review of the current available standards and possible gaps in the available standards.

While the current focus is on CO2 transportation by pipeline, there is increased interest in CO2 transportation by shipping, especially if the CO2 point sources are not closely located near the shore or if no existing pipeline infrastructure is available. To date, no standards exist for the transfer and transportation of liquefied CO2; the industry can learn from the experiences gained with LNG as cargo. For this report it has not been taken into account.

4.1.3.1 CCS pipelines

For the transportation of CO_2 through sub-sea steel pipeline needs to have a certain purity. The composition of CO_2 needs to be measured, monitored and verified. To date, ISO/TC 265 has only developed technical reports (informative deliverables); an important standard on quantification and verification throughout the CCS value chain has been cancelled due to process and content issue (see also mapping spreadsheet).

For new pipelines, existing international and national (Dutch) standards can be used that are either designed for CO_2 transportation specifically or for various mediums including CO_2 (see also mapping spreadsheet). The content of these standards however might need updating in view of developments and new insights. For the re-use of existing pipelines for CO_2 transportation, the risk assessment as described in DNVGL-RP-F104 *Design and operation of carbon dioxide pipelines* is considered too conservative. The most critical elements of existing pipelines seem to be the appendages and safeties like valves. There are several aging mechanisms that differ from natural gas, such as pipeline length, erosion due to impurities (particularly for supercritical CO_2), that need to be considered. For new pipelines this should not be an issue as extra fail mechanism(s) can be integrated in design and construct. The rupture criteria of a CO_2 pipeline are based on new concepts and test methods of running ductile, in which the rupture characteristics can be followed. Wintershall and Neptune Energy currently investigate the rupture characteristics for CCS projects. Determining rupture characteristics is complex. Together with experts, it needs to be determined which risks are acceptable when taking dispersion models into account and a possibility is to take this up in a standard.

Main standards used in the Netherlands / Dutch continental shelf of North Sea:

NEN 3656, Requirements for submarine pipeline systems in steel
- Annex F (normative) containing materials specifications [oil and gas classes]
- Annex Q (informative) providing guidance for submarine CO2 pipelines
- **Draft revised** edition mid 2021 under public consultation and new edition published 2022.

NEN 3650-2, Requirements for pipeline systems — Part 2: Additional specifications for steel pipelines
- Annex G (normative) providing specific requirements and guidance for CO2 pipelines

Other standards

- DNVGL-RP-F104 Design and operation of carbon dioxide pipelines
  - New edition published in February 2021
  - Can be combined with DNVGL-RP-F101, Corroded pipelines
- ISO 27913 Carbon dioxide capture, transportation and geological storage — Pipeline transportation systems
  - High level document to be globally applicable

  - Proposed for revision to incorporate development and experience of past 5 years and to consider new edition of DNVGL-RP-F104
- ISO 13623 Petroleum and natural gas industries — Pipeline transportation systems
  Standard used for developing ISO 27913

Proposed for revision to cover CO2 (and hydrogen) transportation as well

The revised draft NEN 3656 contains normative addressing the material specifications in which the classes are for oil and gas (Annex F) and an informative annex Q with specific guidance for submarine CO2 pipelines. Besides the design criteria for rupture, the integrity monitoring of the technical condition of the pipeline will have a significant role in the safety to environment and operations. The physical properties of CO2 behaviour requires understanding by the operator to avoid unsafe operations. The public consultation can be used to propose changes in NEN 3656 to improve applicability of this standard for CO2 transportation by pipeline, also by considering transforming guidance into requirements.

In addition, NEN 3650-2, additional specifications for steel pipelines, can be used. This standard describes the process and the aspects to be taken into account, and contains a normative annex G with specific requirements and guidance for CO2 pipelines including materials, crack propagation. This annex provides good provisions for making the design more specific for CO2. Ideally, these provisions should be included in a standard. It should be assessed whether the current provisions are fit for purpose or need to amended and supplemented.

The mining application for Porthos CO2 transport and storage (June 2020) refers to the NEN 3650 series of standards with respect to pipeline aspects (see application).

Key findings / intermediate results:

- Current standards in principal suitable
- Risk assessment per DNVGL-RP-F104 considered too conservative for re-use existing pipelines
- Appendages and valves safety-critical elements in re-use considering different ageing mechanisms
- Rupture characteristics need more investigation to determine rupture criteria
- NEN 3650 series could be better structured and reformulated to address CO2 pipelines
- Physical properties of CO2 need to be well understood

Possible actions:

- Review draft NEN 3656, especially Annex Q, to provide comments during public consultation => Should annex be normative?
- Review NEN 3650-2, especially Annex G, to provide suggestions for next edition
- Translate research results about rupture characteristics into standards requirements
- Consider participation in revision of ISO 27913 and ISO 13623 to ensure alignment and to facilitate cross-border transportation
- Do we need a specific document for CO2 pipeline transportation in North Sea area building on existing standards on (CO2) pipeline transportation systems?

4.1.3.2 H2 and H2NG pipelines

For the transportation of H_2 and H_2NG through sub-sea steel pipeline the relevant standards are:
NEN 3656, “Requirements for submarine pipeline systems in steel”. Draft revised edition mid 2021 under public consultation and new edition published 2022.
NEN 3650-2, “*Requirements for pipeline systems — Part 2: Additional specifications for steel pipelines*”
Actions to be taken are described in paragraphs 4.2.3 and 4.3.3.
The following principles are used:

- In respect to new pipelines or re-use of existing natural gas pipelines, it may be expected that after approx. 2040 the mining of natural gas will economical not be feasible anymore. However, import from other regions (e.g., Norway, Russia, Denmark) may still continue after approx. 2040. The transition to hydrogen will strongly depend on the development of windparks/solarparks.

- H_2 in the mixture with NG pipelines to shore (NGT, NOGAT and WGT are mentioned as pipelines for hubs for hydrogen transport (NSE WP1). The mixture of Natural Gas with H_2 to be transported to shore will strongly depend on the development of wind/solar parks which will be used for the production of green hydrogen. Regarding the development of wind parks offshore it is expected that there has to be considered three H_2 mixtures during the energy transition: approximately (0 – 20) %, (20 – 70) % and (70 to 100) %. In this stage it is not yet clear if 100 % pure hydrogen can be transported in existing pipeline systems without avoiding contamination of the purity. For onshore there is, on a European level, a Standardization New Work Item Proposal taking into account a minimum of 98% purity when making use of the existing infrastructure.

The two main challenges are permeability problems, mainly related to plastic seals of appendages and valves in existing pipelines. For new pipelines suitable material for hydrogen purposes can be selected. Permeability considerations should also be considered in case of plastic pipelines / flexibles. The other critical damage mechanism is Hydrogen Induced Stress Cracking (HISC). This should be further investigated in combination with fatigue.

4.1.4 Additional activities

4.1.4.1 Admixture

Mixing hydrogen and natural gas needs close attention. This is especially true when applying varying amounts of hydrogen. This topic is for the admixture in pipelines is addressed in 4.1.3.2.

It needs to be further looked into with regard to admixing (blending the Natural gas with hydrogen) activities at the platform.

4.1.4.2 Electrification

Electricity grids between platforms, substations and wind turbines

During NSE3 one identified issue stemmed from the (current) absence of agreements between suppliers and buyers of electrical energy in the North Sea. This also refers to operational aspects of the electrical power system – specifically for the fixed frequency Alternating Current (AC) generated by wind turbines. The intermittent nature of electricity generation by wind turbines may cause a drop in AC frequency, voltage or current. The unanswered question from NSE3 is whether this issue can be addressed by standards. There are no standards or a “North Sea grid code” that enforce and guarantees stability and delivery. Because the operator of the grid in the Dutch part of the North Sea, TenneT, has had no customers at sea so far. The networks aim at collecting electrical energy for delivery to a station on land. This station ensures that delivery to the country grid complies with the grid code. PosHYdon is temporarily (but perhaps permanently) connected to a landline: this is a stable and reliable source of electricity.

Also, one stakeholder (Boskalis) pointed out various, technical and testing-related, issues with the existing corpus of standards for electrical cables. Mainly, the current standards are written for onshore conditions and can be further be developed as the medium and high-voltage inter-array cables used between the platforms, substations and the wind-turbines are subsea. Specific standardization needs are to be addressed at IEC TC 20 (Electric Cables). The NEN technical committee NEC 20 (Draad en kabel voor elektrische sterkstroominstallaties) is the Dutch mirror committee of IEC TC 20, and provides access to and influence on the working program of this IEC TC.

During the workshop July 2021 feedback was provided with the engineering experts on disturbances from electromagnetic fields, vibrations, the risk of electrocution or degradation by the elements are – from a standardization perspective – nothing new. Some relevant standards discussed:

- NEN-EN 55011 Limits and methods of measurement of radio interference characteristics of industrial equipment
- NEN-EN 55014 Limits and methods of measurement of radio disturbance characteristics of electrical motor-operated and thermal appliances for household and similar purpose, electric tools and similar electric apparatus
- NEN-EN 55022 Limits and methods of measurement of radio disturbance characteristics of information technology equipment
- NEN-IEC 60533 Electrical and electronic installations in ships -Electromagnetic compatibility
- NEN-EN-IEC 61000 Electromagnetic compatibility
- NEN-EN-IEC 61800 (all parts) EMC requirements for power drive systems

Electrification of platforms

To identify and map existing and missing series of standards for electrical installations on fixed platforms interviews with offshore experts (Neptune Energy, New Energy Coaliton and OneDyas) and a brief literature study have been conducted, including a rudimentary concept design, based on many assumptions. Additional interviews were conducted with experts in the Dutch Technical Committees NEC 64-9, “low voltage installations, interpretation NEN 1010” (In Dutch: laag spanningsinstallaties, interpretatie NEN 1010) and Technical Committee NEC 18 “Electrical installations on ships and on movable and fixed units in water” (in Dutch: Elektrische installaties op schepen en op verplaatsbare en vaste eenheden te water). None of the interviews with experts, nor the literature study, point to a gap in the existing corpus of standards. The addition of new elements in the electrification of fixed offshore platforms did not appear to require development of new standards, apart from the usual revision of standards for electrical installations. This might though be applicable in relation to electromagnetic fields and needs to be looked into further – see also 4.1.1.2.

In recent decades, a great deal of experience has been built up in the design, construction and maintenance of electrical installations such as generators, transformers, switchgear, batteries, electric motors for pumps or winches on offshore platforms. Also, chemical-electrical processes, such as in desalination plants, have been used in practice for many years. Dutch companies have experience even with the demolition and disposal of these installations at the end of their lifespan. There is no reason to assume that the already existing and applied standards would not cover the standardization needs. Because the offshore industry is internationally oriented, international standards are used, maintained by international committees, such as IEC TC 18 (Electrical installations of ships and of mobile and fixed offshore units), responsible for instance for IEC 61892 “Mobile and fixed offshore units - Electrical installations“. IEC TC 18 is mirrored by the Dutch standards committee NEC 18 (In Dutch: “Elektrische installaties op schepen en op verplaatsbare en vaste eenheden te water”). Other relevant committees are: IEC TC 99 “Insulation co-ordination and system engineering of high voltage electrical power installations above 1,0 kV AC and 1,5 kV DC”, IEC TC 64 “Electrical installations and protection against electric shock” and IEC TC 88 “Wind energy generation systems”.

Another reason is that the designs for electrical installations in corrosive environments such as the North Sea are not substantially different from those on the mainland; they just need to be more resistant and protected against these elements. Installations are often shielded from the environment as much as possible, for example by placing them in a steel container or closed space. In the design, direct contact with the saline environment is avoided including cooling by seawater. Where possible, electrical installations are already built in a container on land and then hoisted and connected to the platform. This requires compact, modulated designs. This is common practice in the offshore industry. To make this possible, the product and system specifications are based on existing standards. These design requirements are familiar in the industry, and so are the standards that can be used. Where shielding is not (completely) possible, e.g. due to air cooling, high product specifications (corrosion resistance) and careful management, such as strict inspection and replacement, will be required. There are no indications that existing product and business standards are inadequate for this.

For the production of hydrogen on a North Sea platform, an electrolyser or electrolyser stacks will be added as the only new element in the design of the electrical installation. It seems electrolysers at sea do not require different standards than on land with regard to electrification. The design will have to provide a controlled space with a constant temperature, with low humidity and low saltiness of the air. The conditioned environment must meet the operational specifications of the electrolyser. In addition, the reactor and the power electronics are housed in a gas-tight steel cabinet. The same applies for other parts of the installation, such as pumps and filters, these can also be accommodated in steel containers. An example of such a modular system is the PosHYdon. Since the conditions on land and sea for the electrolyser under these conditions do not differ, it is unlikely that electrification will require any other than existing standards. The improved performance of the electrolyser outweighs the cost of the conditioned environment. It is therefore unlikely that the electrical installation in the electrolyser module must meet exceptional environmental requirements that require different standards development.

Conclusion: from a technical point of view and based on many design assumptions, it does not appear that the current corpus of standards is inadequate with regard to electrification of platforms, even when including stacks of electrolysers. From an economic point of view, standards development of electrolyser module design could be interesting, if a market were created for several of these modules and the configuration of existing North Sea platforms allow this.

Even though at present electrification of H_2 production platform does not seem to require new series of standards, more detailed concepts detail research might indicate a need to review of adjust existing standards. As these concepts will be developed, further operational and system analyses are to be conducted, for instances in cascade approach, starting with review the operations, followed by the system design:

Operations

- Operational aspects
- Operational modes
- Technical availability
  - **Systems design**
    - Electrical system
    - Seawater supply system
    - Electrolysis system
    - Post processing system
    - Cooling system

Structural system

It might be worthwhile to verify the scopes of present standards for the maximum capacity of the systems since 500 MW is exceptional for any offshore design: so far only transformer station Borssele Alpha (700 MW) tops this. Preliminary study however shows many high voltage standards, e.g. NEN 3840 'Bedrijfsvoering van elektrische installaties - Hoogspanning", have a minimum limit, not a maximum.

4.2 Research activity assessment of the impact of (missing) standards and their interaction with legislation

Research activity identification of standards and their interaction with legislation was the basis to come to the Research activity assessment of the impact of (missing) standards and their interaction with legislation.

A workshop was held in July 2021 to assess the identification for a possible need of standards or revise standards. Key take-aways of the North Sea Energy Standardization workshop July 2021 with the follow up of actions including the activity assessment of the impact of (missing) standards.
Also actions were formulated from the research activity identification based amongst others on interviews with NSE4 partners Bureau Veritas and Neptune Energy. The actions have been validated with a wider group of experts during the July workshop, supplemented with input of the participants, and subsequently endorsed by the participants of the workshop. Actions are drafted in this paragraph.

The topics that were discussed during the workshop:
1. Platform and power to gas aspects
2. CCS and CO2 transportation
3. Transportation H2 and H2NG
4. Electrification – incl transport of electricity from windenergy > platform

4.2.1 Platform and power to gas aspects.

Table 2 Summary of actions Platform and power to gas aspects

N°	Description	Action owner	With expertise input from	Results
P-1	Review applicability of ISO/TR 15916 and ISO 22734 on hydrogen production in an offshore environment (exposure to salty water or wind, corrosion, choice and placement of materials).	NEN	NSE 4 partners	The standards ISO/TR 15961 and ISO 22734 have been reviewed by NEN. In both documents, offshore circumstances are not explicitly mentioned, although it is mentioned that environmental circumstances should be taken into account for material selection. Both standards originate from ISO/TC 197. NEN will reach out to the parent committee ISO/TC 197 about either a) to test the need for extension of the standard to cover offshore conditions or initiate a NWIP on offshore electrolysis, b) to suggest to explicitly mention offshore in the scope of both standards provided that these already apply to offshore hydrogen production. During the standardization workshop of 24 January 2022 a link with essential safety requirements from the pressure equipment directive and offshore environment was suggested.
P-2	Review if relevant EMC guidelines addressing offshore hydrogen exist.	NEN	NSE 4 partners /	Electric installations for hydrogen generators, including electrolysers, are not exempt from the EMC Directive (2014/30/EU). This Directive is applicable for the European economic area, which includes the North Sea continental shelf of EU members. The Directive is therefore relevant.
P-3	Explore how the electromagnetic fields might impact the equipment on the platform, especially the electrolyser, radio, safety of air traffic and its effect on human beings.	NEN	NSE 4 partners /	The design of the electric installation determines the magnitude of the electric magnetic field and its possible interference with other systems. However in general it's assumed that: • Installations are built with commercially off-the-self electric equipment that has to comply with the EMC Directive. As a result the integration of this equipment in an electric installation of any kind, is not deemed to cause any relevant magnetic disturbance. • The main component that is different from a typical electric installation is the electrolyser. Normally an electrolyser runs on direct current, which doesn't cause any frequency disturbance, even if it is of considerable size. The overall design of the electric installation, including the electrolyser should comply with the EMC directive, but given the above, no major technical obstacles are to be expected. EMC analysis should be conducted on

				the basic design as part of the standard engineering process.
P-3.1	Review IEC 61892 series Mobile and fixed offshore units – Electrical installations		NSE 4 partners	IEC 61892 series specify requirements related to environmental conditions for electric installations, including transformers. It is assumed in the basic design transformers are situated on the outside of the platform due to air cooling. This might implicate contact with sea breeze as covered by these series. It needs to be checked if this if action on standards are needed.
P-4.1	Review whether standards apply or are needed for the use of sea water as process water per electrolysis technology type and if additional guidance is needed for the use of sea water for offshore H2 production.	NEN	NSE 4 partners /	NEN has conducted a mapping of relevant standards on desalination and input process water for electrolysis. The two standards below have been identified as most relevant and have been reviewed. The ISO 22519: 2019 *Purified water and water for injection pre-treatment and production systems* specifies design, materials selection, construction and operation of Purified Water and Water for Injection pre-treatment and membrane-based production systems. In this standard, no mention is made of desalination. ISO 23044 *Guidelines for softening and desalination of industrial wastewater for reuse* considers industrial wastewater. Desalination of seawater as input process water is not explicitly mentioned. As offshore electrolysis is a relatively new development it is possible that at this stage no standard is covering the topic. However, due to offshore hydrogen productions potential to rapidly increase in importance and occurrences, a standard on this topic may be needed in the short / medium term. During the standardization workshop of 24 January 2022, the responsibility of the Original Equipment Manufacturer (OEM) was highlighted. Quality of the input process water can be captured in OEM specifications. It was suggested to look into the ASME paper on: Development and Verification of an "Integrated Seawater Desalination and Renewable Energy System Model" VVS2021-65284. Further, onshore/offshore OPEX costs (manning costs) are a point of attention. As a next step, NEN will liaise with 1) Neptune Energy due to its experience with offshore hydrogen production and 2) the international hydrogen community on needs for standards on desalination and input process water for offshore electrolysis.
P-4.2	Assess if ISO 22519: 2019 on desalination is applicable to offshore electrolysis per technology type.	NEN	NSE 4 partners	
P-5	Check company internal discussion on hydrogen indulged cracking on rotating equipment and provide feedback.	GasUnie		This remains an open action

P-6.1	Review applicability of ASME PTC 10 on offshore pumps and compressors for hydrogen.	NEN	NSE 4 partners	This remains an open action
P-6.2	Review applicability of standards of ISO/TC 118 Compressors and pneumatic tools, machines and equipment.	NEN		Most common compressors for offshore hydrogen production are centrifugal compressors. Due to the high throughput and average compression ratio, centrifugal compressors are suitable for use in pipelines. NEN-EN-ISO 10439-1 *Petroleum, petrochemical and natural gas industries — Axial and centrifugal compressors and expander-compressors — Part 1: General requirement*s may be applicable to offshore hydrogen production. Section 4.5 of the standard clearly states that the choice of material must take into account the (possibly corrosive) conditions. In addition, section 7.3.5.3 states that a manual must be prepared for the use of the compressors in extreme conditions. Integral compressors are best suited for hydrogen compression.[4] NEN-EN-ISO 10439-3 ISO 10439-3:2015 *Petroleum, petrochemical and natural gas industries — Axial and centrifugal compressors and expander-compressors — Part 3: Integrally geared centrifugal compressor* mainly refers to NEN-EN-ISO 10439- 1 and is therefore also applicable for offshore hydrogen production. Considering that the standard focuses solely on compressors and that the standard deals with (corrosive) conditions appears to be sufficient to its application to offshore hydrogen production. However, it should be looked into if other aspects deriving from a platform and offshore environment can impact compressors how this consequently affects the applicability of abovementioned standards. During the standardization workshop of 24 January 2022, it was recommended to look into the applicability of these standards to hydrogen. An important aspect to take into account are differing compression ratios. NEN should contact ISO/TC 118 Compressors and pneumatic tools, machines and equipment to verify the applicability of these standards to (offshore) hydrogen and H2NG.
P-7	Assess whether hydrogen is addressed sufficiently in NOGEPA standard training courses and whether an addition to the curriculum is desirable. alignment with	NEN	NSE 4 partners	This remains an open action

[4] https://www.turbomachinerymag.com/view/integrally-geared-barrel-compressors-address-the-challenges-of-hydrogen-compression

	Safety regions training material is recommended.			
P-8	Concretize metrology needs for hydrogen and H2NG.	NEN		Several metrology needs have been identified: It is currently not possible to calculate flow of alternative energy gases in the gas grid such as hydrogen and hydrogen-enriched natural gas for determining costs when charging customers with required accuracies. A major issue is billing related to flow and methods for compensating price for (a possibly varying) energy content. Other metrology needs are: Gas composition measurements are required in the gas grid to determine energy content (for costing)and quality purposes to avoid, for example, degradation of appliances. Currently there is a lack of traceable gas analysis methods 100 % hydrogen, and also no validated method for rapid measurement of hydrogen in natural gas to ensure blending is within tolerance limits Leak detection: Decarbonising the gas grid requires some modification of safety measures such as leak detection (where portable monitors should be able to distinguish between a hydrogen and natural gas leak). There are several EU projects on metering via the European Metrology Program Euramet. These are: https://newgasmet.eu/deliverables https://www.decarbgrid.eu/ https://www.ready4h2.com NEN will continue to monitor these projects for relevant NSE standardization needs.
P-9	Review maintenance and inspection needs for PEM stacks.	NEN	NSE partners	Liaise with ITM Power.

Oxygen

Another topic raised during the 24 January meeting was oxygen handling and contact of oxygen with surroundings and in particular the electrolyser stacks. NEN will have a follow up with TNO and Bureau Veritas with the recommendation to have a guideline for venting of oxygen.

4.2.2 CCS and CO2 transportation

Concerning the CCS value chain, the standardization activities within framework of NSE 4 are distinguished in three main categories:

1. CO_2 transportation by pipeline
2. CO_2 injection and storage
3. CO_2 quantification & verification

Actions (C-x) are summarized in table 3.

4.2.2.1 CO_2 transportation by pipeline

It was confirmed the ongoing public consultation of the revised draft NEN 3656 offers opportunities to address the needs for CO_2 transportation by pipeline (as well as hydrogen transportation. *[*action NSE partners: review draft NEN 3656 and provide comments (**action C-01**) | action NEN: collate comments related to CO_2 transportation (**action C-02**)]
With respect to the question whether a specific document for CO_2 pipeline transportation in North Sea area would be needed, which build on existing standards on (CO_2) pipeline transportation systems, it was commented that existing standards are suitable for use by economic operators. The question raised was whether the regulator would have particular needs that would require such a specific document. [action NEN: check with SodM about use of standards in permitting / surveillance (**action C-03**)]

4.2.2.2 CO_2 injection and storage

It was clarified that in the current CCS projects only consider reuse of existing infrastructure with respect to both CO_2 injection facilities and geological storage in depleted reservoirs, in order to present a healthy business case. In the short term, reuse of existing infrastructure will offer sufficient opportunities to deploy the CCS sector. Within NSE, an inventory has been carried out to possible fields that will qualify for CO_2 storage, in which the operators NAM, Neptune Energy and TotalEnergies are involved. Reference was made to an explanatory study Transport and storage of CO_2 in the Netherlands by EBN and Gasunie that also looked into the reuse of existing infrastructure.
Concerning injection facilities, it was clarified that mainly fixed steel offshore structures will be (re)used for CO2 injection. [action NEN: check whether IOGP JIP 35 'Standardisation of Offshore Structures Specifications' offers possibilities to address CO2 aspects (**action C-04**)]. In addition, subsea facilities will be considered. [action NEN: complete mapping spreadsheet with relevant subsea standards (e.g. ISO 13628 series / API 17 series) (**action C-05**)]

4.2.2.3 CO_2 quantification & verification

Concerning CO_2 composition, it was commented that central CO_2 purification would be more efficient than decentral (i.e. at CO2 capture location), acknowledging that CO_2 should conform to a minimum quality specification to maintain asset integrity. The purity level and location of purification within the CCS value chain should be a good balance between CAPEX and OPEX. Specifying CO_2 purity levels will be more important when using the CO_2 (i.e. CCU). Nevertheless, it was confirmed that harmonised CO_2 composition that also addresses maximum levels of impurities would be helpful from an asset integrity point of view.
Concerning metrology, reference was made to the Dutch Metrology Act, the EU-ETS legislation and OIML publications like R 137 'Gas meters' and R 140 'Measuring systems for gaseous fuel' as well as activities by CEN/TC 237 "Gas meters" and metrology projects by EURAMET, the European Association of National Metrology Institutes. [action NEN: check aforementioned sources with respect to CO2 (and hydrogen) measurement, monitoring and verification aspects and possible references to standards (**action C-06**)]
Concerning CO2 monitoring during geological storage, it was brought forward that different monitoring techniques are available and applied. It might be helpful to list monitoring techniques including their characteristics to enable comparison and identify possibilities for harmonisation and alignment [action NSE partners: provide information about available CO2 monitoring techniques (applied in other CCS projects) (**action C-07**)]

4.2.2.4 General

Reference was made to the Northern Lights FEED report, which could provide information about the standards they have identified in this large-scale CCS project. *[action NEN: screen FEED report on references to standards (**action C-08**)]*

Although it was observed that the existing standards are suitable for CCS projects, it was acknowledged that not all these standards were designed for CO_2 transportation and storage. It might be beneficial that future editions of these standards explicitly specify this applicability to CO_2 in their scope and confirm that requirements are also applicable to CO_2. This would also help seeking recognition of these standard by the regulator. *[action NSE partners: provide list of referenced standards in their CCS projects (**action C-09**) | action NEN: identify standards for scope expansion (possibly combined with hydrogen) (**action C-10**)]*

It was acknowledged that the CCS sector is still at an early stage of development with several challenges that first need more investigation to identify possible gaps that could be bridged with standards.

Pipeline integrity management systems (PIMS) is an important topic in CO_2 asset integrity (as well as hydrogen asset integrity), which is also reflected int the NEN 3650 series. In European and international standardisation, PIMS is mainly a topic for oil and gas assets. Input from NSE could be disseminated to European and international standards addressing the integrity of CO_2 (and hydrogen) assets.

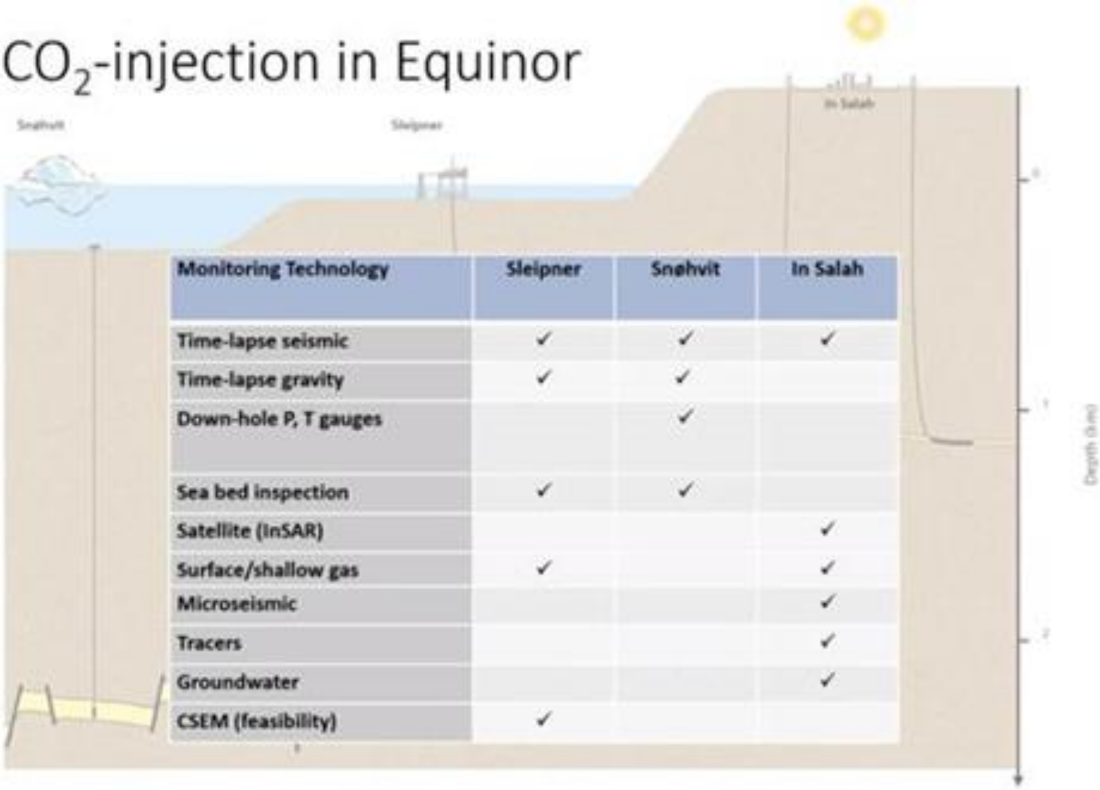
Table 3 Summary of actions CCS and CO2 transportation

N°	Description	Action owner	Results
C-01	Review draft NEN 3656 and provide comments related to CO_2 transportation aspects to NEN	NSE partners	No comments have been received directly. However, several comments were submitted during public consultation via normontwerpen.nen.nl (see C-02)
C-02	Collate comments on draft NEN 3656 per action C-01 and present them to NSE partners before submittal to NEN 3656 working group	NEN	Comments – not NSE partners specific – related to CO_2 transportation (i.e. NEN 3656, Annex Q) have been collated under the revision of NEN 3656 activity. The working group secretary advised that the experts intend to resolve all comments, but that due to time constraints caused by urgent need for English translation, some comments might be parked for the next edition. Key issues include but are not limited to: • more attention to risk assessment of (reuse of) existing pipelines; • addressing operational aspects including integrity management; • link and alignment with onshore CO_2 transportation; • specification of CO_2 properties and behaviour in different phases; • addressing protective measures; • clarification about crack propagation; • addressing offshore platform risers.
C-03	Check with SodM about use of standards in permitting / surveillance on CO_2 transportation	NEN	Hans Weenink (observer in the NEN standards committee on oil and gas exploration and production (NC 310 008) has been contacted to provide information on this matter. He has forwarded this request to several of his colleagues,

			but despite reminder no input has been received to date.
C-04	Check whether IOGP JIP 35 offers possibilities to address CO_2 aspects	NEN	JIP35 team has been contacted, from which it became clear that CCS is on their agenda for future activities related to offshore structures. André van der Stap (Shell) is the Dutch representative in JIP35, who could support in reaching out to relevant Dutch parties (e.g. NSE partners) to develop standards that are fit for the future, also considering that CCS is gaining more and more attention in the Netherlands and the upper limit for CO2 storage has recently been increased by the Dutch government to meet their 2030 climate targets.
C-05	Complete mapping spreadsheet with relevant subsea standards	NEN	The 'mapping spreadsheet' has been completed with subsea standards (API, ISO en NORSOK); the database with CCUS related standards is included in ANNEX 3
C-06	Check gas metrology sources with respect to CO_2 (and hydrogen) MMV aspects and possible references to standards	NEN	• OIML R137: No specific aspects have been found concerning CO_2. In addition, it is questionable whether CO_2 is within the scope of this document, which will depend on the phase of appearance of CO_2. • OIML R140: No specific aspects have been found concerning CO_2. [NB: document was published in 2007] • CEN/TC 237 'Gas meters': Standards are applicable to first and second family gasses (i.e. town gas/syngas and natural gas), so not to CO_2 (or hydrogen). • EURAMET: One of the nine EURAMET's European Metrology Networks (EMNs) focusses on 'energy gases' in which CO_2 is one of the six topics. No results have been published in the public domain to date; also an overview of projects is not yet available. When searching for relevant projects within the energy and industry domain, one hit was found: Metrology for decarbonising the gas grid (in which NEN is project partner) that recently had its kick-off meeting.
C-07	Provide information about available CO_2 monitoring techniques	NSE partners	Only TotalEnergies has provided information on this matter referring to the CO_2 injection monitoring technologies applied by Equinor (see picture below this table).
C-08	Screen Northern Lights FEED report on references to standards	NEN	• [Safety strategy onshore facilities] Design of equipment to safety process and CO_2 storage based on recognised standards

	NOTE We [Northern Lights] are developing an open and flexible infrastructure to transport CO_2 from capture sites by ship to a terminal in western Norway for intermediate storage, before being transported by pipeline for permanent storage in a reservoir 2.600 metres under the seabed. Our transport and storage facilities will offer safe and permanent underground storage to industries from across Europe. The project is the transport and storage component of Longship, the Norwegian Government's full-scale carbon capture and storage project Northern Lights will be the first ever cross-border, open-source CO2 transport and storage infrastructure network. Phase one of the project will be completed mid-2024 with a capacity of up to 1,5 million tonnes of CO2 per year.		• [Health and working environment] Reference to ISO 11064 series, *Ergonomic design of control centres* as requirement • [Environmental budget] Total greenhouse gas (GHG) budget calculated based on ISO 14040, Environmental management — Life cycle assessment — Principles and framework and EN 3720, Method for greenhouse gas calculations for buildings [note; wrong reference] • [CO_2 pipelines] Critical wall thickness calculated based on methods described in ISO 27913, Carbon dioxide capture, transportation and geological storage — Pipeline transportation systems or DNVGL-RP-F104, Design and operation of carbon dioxide pipelines | Qualification of non-metallic materials in accordance with NORSOK M-710, Qualification of non-metallic sealing materials and manufactures or NACE TM0297, Effects of high temperature, high-pressure carbon dioxide decompression on elastomeric materials | System pressure test in accordance with DNVGL-ST-F101, Submarine pipeline systems | Integrity management system also based on DNVGL-RP-F104 and DNVGL-RP-F116, Integrity management of submarine pipeline systems • [CO_2 tanks on ships] Materials for ship tanks in accordance with EN 10028-6, *Flat products made of steels for pressure purposes - Part 6: Weldable fine grain steels, quenched and tempered* or equivalent as long as recognised by IGC Code • [Ship-shore interface] Reference to SIGTTO and OCIMF documents as well as EN 1474-2, Installation and equipment for liquefied natural gas - Design and testing of marine transfer systems - Part 2: Design and testing of transfer hoses and IEC/PAS 80005-3, Utility connections in port – Part 3: Low Voltage Shore Connection (LVSC) Systems – General requirements • [Wells] Decommissioning of wells in accordance with NORSOK D-010, *Well integrity in drilling and well operations*

			• In addition, references are made to use standardised equipment without specifying based on which standards as well as company (Equinor) standards / requirements
C-09	Provide list of referenced standards in own CCS projects	NSE partners	No input has been received to date.
C-10	Identify standards for scope expansion based on input per action C-09	NEN	See C-09



Monitoring Technology	Sleipner	Snøhvit	In Salah
Time-lapse seismic	✓	✓	✓
Time-lapse gravity	✓	✓	
Down-hole P, T gauges		✓	
Sea bed inspection	✓	✓	
Satellite (InSAR)			✓
Surface/shallow gas	✓		✓
Microseismic			✓
Tracers			✓
Groundwater			✓
CSEM (feasibility)	✓		

Figure 2: CO2 injection in Equinor

In addition to the actions in Table 3, Porthos has presented the following slide at the online meeting on European agreements in the field of CCUS & carbon accounting on 24 September (see full report at NEN website):

Figure 3: Porthos CCUS presentation

4.2.3 Transportation H2 and H2NG

Strategy for re-use of existing pipeline for H2 and H2NG

In principle, a risk assessment, when making use of NEN 3656 and 3650-2, should be performed for the entire life cycle. When another medium is used, temperature / pressure must be taken into account. By using historic information like PIMS the future and past of the pipeline is taken into account. For hydrogen, the Hydrogen Induced Stress Cracking (HISC) is a critical damage mechanism, this should further investigated in combination with fatigue.

Conclusion and recommendations

The current standard NEN 3656 already in force and appointed in the mining act legal Dutch framework can be applied for hydrogen pipelines for design, operation, inspection and maintenance in the Netherlands. The standard is risk based with the medium and their damage mechanism, as the starting point.

At this moment experience of in-service subsea pipelines for hydrogen transport are gathered. Therefore, the damage mechanisms need to be further developed as a part of subsea pipeline system standards.

Critical damage mechanism and deterioration mechanism are not sufficient highlighted the in the current set of standards such as NEN 3656 and AMSE B31.12. This requires more specifications to avoid unsafety designs.

Permeability problems are mainly related to plastic seals of appendages and valves in existing pipelines. For new pipelines resistant material can be selected. Permeability considerations should also be considered in case of plastic pipelines / flexibles.

Regarding the development of wind parks offshore is expected that there have to be considered the three H_2 mixtures during the energy transition. The concentrations H2 are approximately(0 – 20) %, (20 – 70) % and (70 to 100) %. In this stage it is not yet clear if 100 % pure Hydrogen can be transported in existing pipeline systems without avoiding contamination of the purity. For onshore there is, on a

European level, a Standardization New Work Item Proposal taking into account a minimum of 98% purity when making use of the existing infrastructure.
It is recommended if this could also be applicable for offshore pipelines, this should be investigated.

Actions (T-x) based on the recommendations are summarized in table 4.

Table 4 Summary of actions H2 and H2NG

N°	Description	Action owner	Deadline
T-01	Hydrogen Induced Stress Cracking (HISC) should be further investigated in combination with fatigue.	NEN with experts	This could not be done before publication revised NEN 3656 therefore new deadline to be defined based on revision date NEN 3656.
T-02	Highlight critical damage mechanism and deterioration mechanism in the current set of standards such as NEN 3656 and AMSE B31.12.	NEN for NEN 3656 and contact AMSE B31.12.	This could not be done before publication revised NEN 3656 therefore new deadline to be defined based on revision date NEN 3656.
T-03	Initiate discussion what quality might transported in existing pipeline systems	NEN	This could not be done before publication revised NEN 3656 therefore new deadline to be defined

The recommendations should be taken into account in the next revision of NEN 3650 and NEN 3656. The stakeholders in the NEN committees have expressed the importance to follow up the CO_2 and H_2 comments in NEN 3650 and NEN 3656 such as the damage and deterioration mechanism. The findings from pilot studies and experiences needs to be further elaborate. This takes time and the pace of the revisions is dependent on availability of the experts. A collaboration with the NSE partners can speed up the process.

4.2.4 Electrification – including transport of electricity from wind park to platform

An unaddressed electrification-issue from NSE3 (electrification between platforms) regarded transport aspects of the sub-sea array cables. Electricity supply on the cable could be a problem when there are no delivery agreements for the electrical energy. Electricity from wind turbines involves issues related to the intermittent nature of this source: fluctuating wind. This can result in a drop in alternating voltage frequency and voltage of current. The installation on the platform must be designed accordingly. However, this seems to be an issue addressable with current technology – where no new standards need to be developed. Battery storage standards, supporting interoperability, are covered in PGS 37, NEN 4288 and battery product norms as drafted by IEC TC 120. If batteries are capable of absorbing and delivering all surplus energy is a matter of design, not of standards. Technical standards for sub-sea cables have recently been developed by IEC TC 20 *Electric cables*. New standards address more specific amendments to the off-shore conditions – related to for example vibrations, temperature and humidity.

Exploitation of the electrical grid is a matter of negations between producers and operators of electrical energy in the North Sea – specifically for the fixed frequency Alternating Current (AC) generated by wind turbines. The intermittent nature of electricity generation by wind turbines hinders constant energy supply to the electrolyser installation. However electric energy buffering, flexible H2 production, auxiliary land supply, or a combination of these all, are feasible with existing standards.

Electrification on platforms

Regarding the electrification on platforms, it seems new standards specifically for electrical installations on sea-platforms do not need to be developed. Instead of a gas turbine that supplies power to the platform via a generator, the platforms receive power directly via a cable from the wind farm hub. The electrical installation on the platform, from a standardization point of view, does not need much altering when compared to onshore equivalents. Assuming the installations are shielded and placed in conditioned spaces.

Findings for specific offshore conditions

- Are there any available platform designs - specifically for the electrical installation?
  A basic design for a 500 MW P2G platform came available and is recently reviewed: it is mainly an exploration of possible layouts of the electrolyser stacks on a not specified platform. However in this design it is assumed no onshore power connection is possible. So for standby mode either batteries or fuel cells are suggested, over a gas generator, avoiding CO_2 emissions (and another type of gas on the platform). These findings indicate the use of existing standards for those particular technologies, as previously discussed.
- Are operators/engineering designers actively using/referring to standards?
  Neither hydrogen production nor fuel cells are common practice on the North Sea nowadays, there are no specific standards for those technologies in those particular geographical circumstances. However it is assumed both hydrogen production, as well the vice versa process of a fuel cell, will happen in a controlled area, comparable with the land situation. Therefor it is assumed the existing volume of standards for these technologies will suffice.
- Which unique offshore aspects influence electrical installations on (sea) platforms versus comparable installations on land?
  In the basic design it is assumed no electric installations are subject to harsh North Sea conditions, except transformers on outside parameters of the platform, due to air cooling. Requirements for this are covered in IEC 61892. The rest of the components should be housed in a steel container / cabinet: (electrolyser, power electronics, pumps, batteries.)

4.3 Formulation of recommendations for relevant standardization or governmental bodies to remove barriers or revise/improve (the use of) standards

Based on the research activity assessment of the impact of (missing) standards and their interaction with legislation recommendations for relevant standardization or governmental bodies to remove barriers or revise/improve (the use of) standards can be drawn up. If no recommendations could be drawn up yet, the actions to come to the recommendations are described and have to be taken further.

The recommendations have been assessed with stakeholders during a workshop in January 2022 and presented at the NSE4 80% meeting in April 2022.

As a step to define the priorities for standardization – impact of missing standards - NSE 4 partners have been asked for their priorities on standardization activities for **platform and power to gas** aspects and **CCS**. This is given through a Mentimeter survey (see figure 4 and 5).

4.3.1 Platform and power to gas aspects

Priorities as expressed by NSE 4 partners after 80% reporting meeting April 2022. Because the number of responses was not very high and only from NSE partners these priorities have to be seen in that respect.

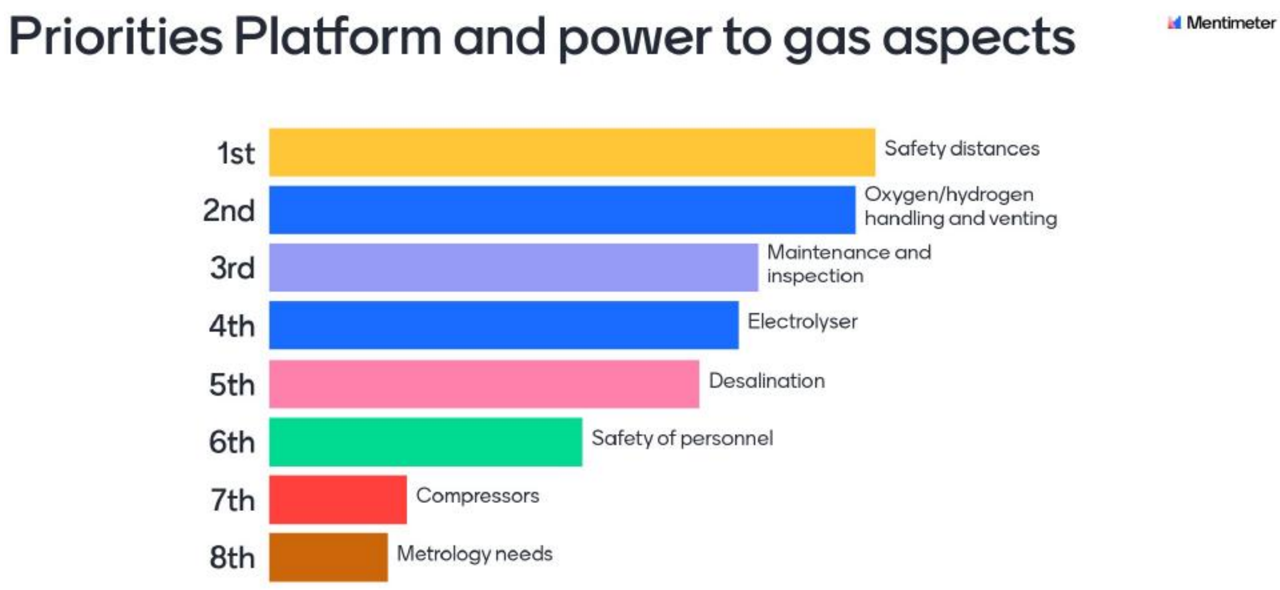


Figure 4: priorities platform and power to gas aspects from NSE4 after 80% meeting

Recommendations for prioritized topics are described in the following paragraphs.

The topics are being dealt in the order as done in this report.

4.3.1.1 Electrolysers (priority 4)

NEN to reach out to ISO/TC 197 Hydrogen technologies about:

- to test the need for extension of the standards ISO/TR 15916:2015 and ISO 22734:2019 to cover offshore conditions or initiate a review or New Work Item Proposal on offshore electrolysis
- to suggest to explicitly mention offshore in the scope of both standards provided that these already apply to offshore hydrogen production
- a link with essential safety requirements from the pressure equipment directive and offshore environment was suggested.

4.3.1.2 Desalination (priority 5)

Considering that offshore electrolysis is a relatively new development, it is possible that at this stage no standard on the use of sea water as process water for electrolysis technology is available. A standard on this topic may be needed in the short / medium term. Quality of the input process water might be captured in OEM specifications. Recommended is:

1. to assess the ASME paper on: Development and Verification of an "Integrated Seawater Desalination and Renewable Energy System Model" VVS2021-65284. Onshore/offshore OPEX costs (incl. manning costs) are a point of attention.
2. NEN to liaise with Neptune Energy due to its experience with offshore hydrogen production and the international hydrogen community on desalination and input process water for electrolysis.
3. Exchange with the international hydrogen community on desalination and input process water for electrolysis.

4.3.1.3 Processing on the platform (priority 7)

1. to verify needs regarding hydrogen indulged cracking on rotating equipment by Gasunie
2. to review the applicability of ASME PTC 10 on offshore compressors and exhausters for hydrogen byNEN.
3. Liaise with ISO/TC 118 Compressors and pneumatic tools, machines and equipment about the
4. applicability of its standards to (offshore) hydrogen and H2NG.

4.3.1.4 Safety distances (priority 1)

Considering the design of large scale electrolysis, standardization for internal safety distances (for offshore) the safety distances is thé priority to be looked into.

4.3.1.5 Safety of personnel (priority 6)

1. assess whether hydrogen is addressed sufficiently in Element NL (previously NOGEPA) standard training courses and whether an addition to the curriculum is desirable.
2. alignment with NL Safety regions (Veiligheidsregio's) training material should be ensured.

4.3.1.6 Maintenance and inspection (priority 3)

to review maintenance and inspection needs for PEM (other?) stacks and related standardization needs. NEN to reach out to OEMs

4.3.1.7 Metrology needs for hydrogen and H2NG (priority 8)

A gap is accurate flow and quality measurement of pure hydrogen and hydrogen-enriched natural gas in existing and hydrogen dedicated infrastructure.

- currently it is not possible to calculate flow of alternative energy gases in the gas grid such as hydrogen and hydrogen-enriched natural gas for determining energy content related to billing when charging customers with required accuracies.
- accurate gas composition measurements are required for measurement of composition but also quality and safety purposes to avoid, for example, degradation of appliances. Currently there is a lack of traceable gas analysis methods of pure hydrogen and H2NG. Also no validated method for rapid measurement of hydrogen in natural gas to ensure blending is within tolerance limits.

In the view of the above,

1. NEN will continue to monitor the various European metrology project on hydrogen infrastructure / decarbonization of the gas grid such as NewGasMet, decarbgrid and Ready4H2.
2. Decarbonising the gas grid requires some modification of safety measures such as leak detection. Check where this is covered in standards or if there is an additional need (where portable monitors should be able to distinguish between a hydrogen and natural gas leak).

4.3.1.8 Oxygen and hydrogen (priority 2)

Recommendation:

NEN to align with TNO on:

a) Oxygen and hydrogen handling and contact of oxygen and hydrogen with surroundings and in particular the electrolyser stacks.
b) oxygen and hydrogen venting

To look into current standards/guidelines for onshore applications of hydrogen or oxygen or for other gasses as a learning for offshore. This might lead to an offshore guideline need.

4.3.2 CCS

Priorities as expressed by NSE 4 partners after 80% reporting.

Because the number of responses was not very high and only from NSE partners these priorities have to be seen in that respect.

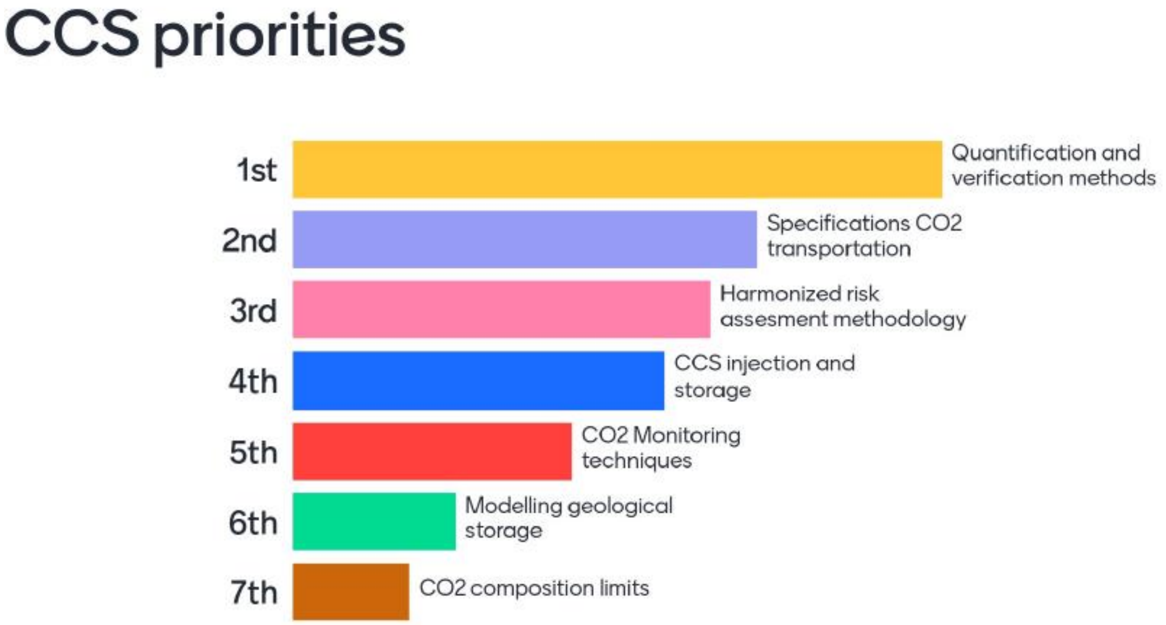


Figure 5: priorities CCS from NSE4 after 80% meeting

Recommendations for prioritized topics are described in the following paragraphs.
The topics are being dealt in the order as done in this report.

4.3.2.1 CO2 Injection and storage (priority 4)

Clarified that mainly fixed steel offshore structures will be (re)used for CO_2 injection.

- Participate in the recently initiated revision of ISO 16530 on well integrity in view of possible applicability or CO_2 storage wells. (standardization activity priority 4)
- Proactively liaise with IOGP JIP35 team / ISO/TC 67/SC 7 to address CO_2 injection facilities on offshore platforms including mooring and CO_2 transfer in the offshore structure's standards portfolio (lifetime extension and reuse / refurbishment of existing structures as well as design and construction new structures). (standardization activity priority 4)
- Agree on a harmonised risk assessment methodology to be applied for CCS projects in (Dutch shelf of) North Sea and onshore, inspired by ISO/TS 27924 *Risk management for integrated CCS projects* and recognised by the (Dutch) regulators. (standardization activity related to priority 3)
  This methodology can also serve as input for next edition of ISO/TS 27924 (or ISO 27924). This also to be discussed with NSE4 WP2 legal.

4.3.2.2 CO2 quantification and verification (priority 1)

General on CO2 composition.

- Need for CO2 monitoring during geological storage
- Central CO2 purification would be more efficient than decentral (i.e. at CO2 capture location)
- Acknowledging that CO2 should conform to a minimum quality specification to maintain asset integrity
- Purity level and location of purification within the CCS value chain should be a good balance between CAPEX and OPEX
- Specifying CO2 purity levels will be more important when using the CO2 (i.e. CCU). Nevertheless, it was confirmed that harmonised CO2 composition that also addresses maximum levels of impurities would be helpful from an asset integrity point of view.

Recommendations:

1. List CO2 monitoring techniques including their characteristics to enable comparison and identify possibilities for harmonisation and alignment. (priority 5)
2. Define standardization needs for CO2 monitoring techniques including leak rate monitoring during geological storage. (priority 5)
3. Identify needs on modelling on geological storage. (priority 6)
4. Participate in the revision of ISO 27914 on geological storage [once initiated] as it is proposed to address quantification and verification aspects as well. Agree first on national level about quantification and verification aspects and feed this input in the work of ISO 27914. Input to be discussed with NAM and Neptune.(standardization related to priority 6)
5. Participate in the revision of ISO/TR 27915 on quantifying and verifying GHG emissions and reductions at the project level [once initiated]. It covers all components of the CCS chain (e.g. capture, transport, storage) and includes a lifecycle assessment approach to estimating project level emissions and emission reductions from project assessment, construction and operations, through to completion and post-closure activities. Input to be discussed with NAM and Neptune.(standardization related to priority 1)
6. Define with partners what the specifications should/could be for CO2 transportation and what limits for CO2 composition should be. (priority 2 and 7)
7. Second step, agree on and standardize the CO2 composition for pipeline transportation (and possibly shipping) to be met by suppliers of (captured) CO2, including the minimum specifications and associated determination methods as well as (flow) measurements, and taking into account developments related to smart CO2 hubs that also covers CO2 utilisation with different suppliers and buyers of CO2.

4.3.2.3 Transportation CO2 by pipeline

Question

Is there a need for a specific document for CO2 pipeline transportation in the North Sea area, which build on existing standards on (CO2) pipeline transportation systems. Main standard for the NS area is NEN 3656 “Requirements for submarine pipeline systems in steel” - Annex Q.

Answer
Existing standards are suitable for CCS projects, it was however acknowledged that not all these standards were designed for CO2 transportation and storage. It might be beneficial that future editions of these standards explicitly specify this applicability to CO2 in their scope and confirm that requirements are also applicable to CO2. Confirmed through public consultation 2021 that NEN 3656 offers opportunities to address the needs for CO2 transportation by pipeline.

Key issues – but not limited to:
- more attention to risk assessment of (reuse of) existing pipelines
- addressing operational aspects including integrity management
- link and alignment with onshore CO2 transportation
- specification of CO2 properties and behaviour in different phases
- addressing protective measures
- clarification about crack propagation
- addressing offshore platform risers

Recommendations:
1. Prepare amendment to the new edition of NEN 3656, especially Annex Q, that address the comments not covered in NEN 3656:2022.
2. Participate in review NEN 3650-2, especially Annex G, to provide suggestions for next edition.
3. Check with SodM about use of standards in permitting / surveillance on CO2 transportation.
4. Participate in the revision of ISO 27913 (ISO/TC 265) on pipeline transportation [once initiated] and share best practices of the NEN 3650 series with the global CCS community for alignment (and setting the standard).
5. Participate in the newly proposed ISO document on shipping of liquefied CO2 in view of future projects in North Sea Area not connected with pipeline transportation infrastructure and cross-border trading of CO2 [when legally possible]. This also to be discussed with NSE4 WP2 legal.

Ensure that research results on materials properties and behaviour and the associated risk and integrity management aspects are disseminated to the relevant standards to improve these standards, while not jeopardising innovation (i.e. performance-based / functional standards); likewise, define research questions that emerge during the standards development process.
See for further recommendations 4.3.3.

4.3.3 Transportation H2, H2NG and CO2

For both CO_2 and H_2 critical damage mechanism and deterioration mechanism are not sufficiently addressed in the current set of standards. This requires more detailed specifications to avoid unsafe designs (and constructions). At this moment, experience of in-service subsea pipelines for hydrogen and CO_2 transport are gathered. Therefore, the damage mechanisms need to be further developed as a part of subsea pipeline system standards.

Other standards, in addition to NEN 3656 and NEN 3650-2 can be used as a guideline, such as:
H2
- AMSE B31.12, suitable for H_2 onshore pipeline;

CO2

- DNVGL-RP-F104 in combination DNVGL-RP-F101, FFP but conservative;
- ISO 27913, a high level standard and proposed for revision;
- ISO 13623, for oil and gas, proposed for revision to possibly cover hydrogen and CO_2 as well.

The conclusion is that the content of the listed standards are useful for all life cycle phases of H_2 and CO_2 pipelines (design, installation and maintenance). Future learnings from the damage mechanisms should be incorporated in the next revision of NEN 3650/NEN 3656.

It has been concluded that there is a need to extend the H2, H2NG and CO2 transportation activities to an International level.

Aspect that have been identified for inclusion of NEN 3656, based on the comments received on the revision of NEN 3656:2015 and not yet included in revised version NEN 3656:2022.
Key issues – but not limited to:

1. Pressure load considering pressure fluctuations due to fatigue - CO2/H2
2. Reuse of pipelines assessment for - H2 /CO2
3. Minimum inspection requirement for reuse - H2 /CO2
4. Material constrains - H2 /CO2
5. Lifetime evaluation
6. Corrosion inhibitor - H2 /CO2
7. Sealing materials valves - H2/CO2 media
8. Run ductile fracture behaviour (RDF)
9. Exposure H2 /CO2 leakage (LOC)
10. Risk assessment for H2/CO2 pipelines
11. Atex classification for H2/CO2/O2

4.3.4 Electrification including transport of electricity from wind parks to platform

In NSE3 various, technical and testing-related, issues with the existing corpus of standards for electrical cables were mentioned mainly because the current standards are written for onshore conditions and might need adaptation as the medium and high-voltage inter-array cables used between the platforms, substations and the wind-turbines are submarine.
Recommendation: It is logical that sub-sea cables are derivatives of land cables although the volume of land cables is many times greater. These specific standardization needs can be addressed at IEC TC 20 (Electric Cables) through the NEN technical committee NEC 20 (Draad en kabel voor elektrische sterkstroominstallaties), Dutch mirror committee of IEC TC 20 “Electric cables”.

The basic NSE4 design suggests constant delivering electric power to the H_2 production platform, provided by a 66 kV line. In practice however, as previously mentioned, this constant power supply might be difficult to guarantee, because wind is hardly constant, even over a wider stretch of sea. Since there is no land line to supplement wind power and battery buffering is deemed to be insufficient, electrolyser stacks are a good option, of course taking into account that they sometimes will operate at sub-optimal level in less windy conditions. Or some of the stacks might even be switched to standby mode when there is no or very light wind. Standardisation of electrolyser stack management might be useful for trade negotiations among producers and network operators of both H_2 and electric power. Technically, switching frequently to operation or standby mode of electrolyser stacks is not expected to be uncharted territory and existing design and operation standards are equally expected to suffice.

Recommendation: No specific standards for electrolyser stack management for optimized operation exits nowadays. Due to the different characteristics of various designs and electrolyser types, overall system management standards have not emerged. The main technologies are based on alkaline electrolysis, PEM electrolysis (Proton Exchange Membrane) or Solid Oxide Electrolysis (SOE). When one of the types becomes dominant throughout the industry or chosen for NSE4 activities, standardisation for this particular type could be considered, including its management systems.

More in general, management systems are not only designed for optimal production, but also for safety and operability. Universal standards that could by applied, e.g:
IEC 61508 “Functional safety of electrical/electronic/programmable electronic safety-related systems”: This standard defines the design and safety requirements that must be considered while
designing a programmable electric and electronic system for safe operation.
IEC 60068-2-series “Environmental testing”: This series define a set of functional and safety tests to study the influence of operating environmental conditions like humidity, temperature, vibration, shock etc., on the behaviour of electronic equipment.
It can be looked into whether they might be applicable for electrolyser stack management.

In summary, standards for offshore electrical systems, on national, European and international level, are available. These are sufficient for the safe design of offshore electrical installations, including electrolysers. Also on a national level there are no special requirements for electrical installations for electrolysers in NEN 1010:2020: - Dutch implementation of the HD-IEC 60364 series. The national committee has concluded there is no need for special specifications for electric installations that feed electrolysers.
Operation of electrical systems for networks, to transport energy obtained from harnessing the wind with windmills or wind turbines, is sufficiently defined in standards for offshore electric installations, based on industry interfaces, to work with a variety of products or systems, at present or in the future. However, beside the subsea cables and electrolyser stack management standard there is an additional recommendation for possible future standardization.

Recommendation: on a practical level, there are electrical design considerations for offshore installations that might lead to new standards:

1. Standardisation of design of containerised electrolysers for production in series
2. The absence of requirement to comply to the Netcode if the local offshore network is stand-alone: not connected to the onshore grid
3. The abundance of cooling sea water in case of thermal runaway of Li-Ion batteries: standardization of calamity abating electrical installations based on sea water cooling.

4.4 Dissemination of findings and results

In this paragraph only the recommendations to specific standardization Technical Committees have been included for action to approach. Other recommendations/actions from Paragraph 4.3 also need to be followed up.

NSE4 partners have been asked for their priorities on standardization activities, see recommendations. This has been taken into account for the disseminations activities. Follow up of the dissemination recommendations needs to be further discussed.

Platform and power to gas aspects

Priorities as expressed by NSE 4 partners

1. Safety distances
   Not ready for standardization dissemination action yet, see recommendations to be followed up.
2. Oxygen/hydrogen handling and venting
   Not ready for standardization dissemination action yet, see recommendations to be followed up.
3. Maintenance and inspection
   Not ready for standardization dissemination action yet, see recommendations to be followed up.
4. Electrolyser
   Standardization action formulated, additional recommendations to be followed up
5. Desalination
   Standardization action formulated, additional recommendations to be followed up
6. Safety of personnel
   Not ready for standardization dissemination action yet, see recommendations to be followed up
7. Compressors
   Standardization action formulated
8. Metrology needs
   Not ready for standardization dissemination action yet, see recommendations to be followed up

Technical Committees to be approached:

1. Electrolysis/hydrogen production; ISO/TC 197 "Hydrogen Technologies" aspects related to ISO 22734 *Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications* (priority 4)
2. Desalination; ASME paper on: Development and Verification of an "Integrated Seawater Desalination and Renewable Energy System Model" VVS2021-65284. (priority 5)
3. Offshore pumps and compressors (priority 7), applicability of:
   - ASME PTC 10 on offshore pumps and compressors for hydrogen.
   - ISO/TC 118 ISO/TC 118 Compressors and pneumatic tools, machines and equipment standards to hydrogen

4.4.1 CCS

Priorities as expressed by NSE 4 partners:

1. Quantification and verification methods
2. Priority 2, 5, 6 and 7 are also related to the quantification and verification. Standardization activities set for 1 and 6 and additional recommendations for action at 1, 5 and 7.
3. Specifications CO2 transportation
4. Not ready for standardization dissemination action yet, see recommendations to be followed up.
5. Harmonized risk assessment methodology
6. Standardization action formulated, additional recommendations to be followed up.
7. CCS injection and storage
8. Standardization action formulated, additional recommendations to be followed up
9. CO2 monitoring techniques
10. Not ready for standardization dissemination action yet, see recommendations to be followed up.
11. Modeling geological storage
12. Standardization action formulated, additional recommendations to be followed up.
13. CO2 composition limits
14. Not ready for standardization yet, see recommendations to be followed up.

Transportation of CO2; Standardization on the transportation of CO2 had already been considered as a priority. Standardization action formulated, additional recommendations to be followed up.

Technical committees to be approached:

1. Well integrity; ISO/TC 67 ISO 16530 on well integrity in view of possible applicability for CO2 storage wells (priority 4)
2. CO2 injection facilities on offshore platforms including mooring and CO2 transfer in the offshore structure's standards portfolio (lifetime extension and reuse / refurbishment of existing structures as well as design and construction new structures): liaise with IOGP JIP35 team / ISO/TC 67/SC 7 (priority 4)
3. Harmonised risk assessment methodology to be applied for CCS projects in (Dutch shelf of) North Sea and onshore; ISO/TC 265, ISO/TS 27924 *Risk management for integrated CCS projects* (priority 3)
4. Geological storage; Participate in revision of ISO/TC 265, ISO 27914 on geological storage [once initiated] as it is proposed to address quantification and verification aspects as well. Agree first on national level about quantification and verification aspects and feed this input in the work of ISO 27914. Input to be discussed with NAM and Neptune.(priority 6)
5. Quantifying and verifying GHG emissions and reductions at the project level [once initiated]; Participate in the revision of ISO/TC 265 ISO/TR 27915. Input to be discussed with NAM and Neptune.(priority 1)
6. CCS transportation by pipeline (priority was already identified):
   a) Participate in preparation amendment to the new edition of NEN 3656 that addresses the comments not covered in NEN 3656:2022 (NEN NC 310004)
   b) Participate in Review NEN 3650-2, especially Annex G, to provide suggestions for next edition (NEN NC 310004)
7. Pipeline transportation [once initiated] ISO/TC 265, participate in the revision of ISO 27913 on and share best practices of the NEN 3650 series with the global CCS community for alignment (and setting the standard). (priority was already identified):
8. Shipping of liquefied CO2 ISO/TC 265, participate in the newly proposed ISO document in view of future projects in North Sea Area not connected with pipeline transportation infrastructure and cross-border trading of CO2 [when legally possible].

4.4.2 Transportation H2 and H2NG

Main activities:

- Give input to / involvement in NEN 3656 though participation in NC 310004.
- Explore what could be done with regard to research actions needed for revision NEN 3656 and 3650-2 (see 4.3.2.3 and 4.3.3).
- Extend the H2, H2NG and CO2 transportation activities to an International level, ISO/TC 67 SC2 and ISO/TC 265 and other relevant standardization bodies..

4.4.3 Electrification including transport of electricity from wind parks to platform

Specific standardization needs on subsea cables can be addressed at IEC TC 20 (Electric Cables) through the NEN technical committee NEC 20 (Draad en kabel voor elektrische sterkstroominstallaties), Dutch mirror committee of IEC TC 20.

Offshore electric power production to feed electrolysers, wind driven or otherwise, is not different than electric power production for electric pumps, -winches or any other offshore electric equipment. Therefore it is safe to assume that technology for offshore power production and distribution, including generators, subsea cables and transformers can be applied to power electrolysers. For that reason demand for additional standard development for offshore power supply and distribution, to power electrolysers, is unlikely.

In one aspect electrolyser can be different from usual electric offshore equipment: in case AC is fed they need rectifiers, of considerable size, to transform AC to DC. But also this technology is well developed so designs can incorporate existing industry standards.

5 References

General

- Working paper on Standardization mapping and gap analysis for offshore system integration Document D.2.4

Pipelines

- API Recommended Practice 571, Damage Mechanisms Affecting Fixed Equipment in the Refining Industry,
- https://www.deltalinqs.nl/stream/h-vision-annexes-to-the-main-report/20190702124825, (for general information on CO2 risks p.7 en p.65.)
- https://www.ifv.nl/kennisplein/Documents/20201201-BIOR-maatregelen.pdf
- Waterstofleiding Gasunie van Dow naar Yara in gebruik genomen › Gasunie
- https://www.dewereldvanwaterstof.nl/gasunie/infrastructuur/
- https://www.vshanab.nl/nl/projecten/detail/eerste-h2-transport-via-bestaande-gasleiding

Electrification

- Tennet Kwaliteits- en Capaciteitsdocument “Net op zee 2016”
- Ontwikkelkader windenergie op zee, vastgesteld in de Ministerraad van 20 mei 2020
- VERORDENING (EU) 2016/631 VAN DE COMMISSIE tot vaststelling van een netcode betreffende eisen voor de aansluiting van elektriciteitsproducenten op het net
- Germanischer Lloyd Rules for electrical and electronic equipment on fixed offshore installations and mobile offshore units, part 6
- IEC 60092:2021 Series Electrical installations in ships
- NEN 3140+A3:2018 Bedrijfsvoering van elektrische installaties – Laagspanning
- NEN 3840+A3:2018 Bedrijfsvoering van elektrische installaties – Hoogspanning
- NEN 1010:2020 Elektrische installaties voor laagspanning
- IEC 61892 series Mobile and fixed offshore units - Electrical installations
- IEC 60079 series Explosive atmospheres
- PosHYdon Pilot Offshore green hydrogen, presentation FACTS & FIGURES – JULY 2019
- ISO 22734:2019 Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications
- TNO: OPTIMISING PRODUCTION OF SUSTAINABLE HYDROGEN WITH ELECTROLYSIS

ANNEX 1 Interactions other workpackages and planning

Interactions other workpackages

Table 1 Overview interaction other WPs

WP	Information needed	Information contribution
WP1 Hubs	• Define In close cooperation with WP 1 the generic and specific topics – could be economic, technical, environmental, social and regulatory challenges – where from a standardization perspective needs to looked into.	• Scoping and follow up activities
WP2 Legal WP2 Standards WP2 Stakeholder Management WP2 Communication	• Create good interface with WP2 activities • Align Legal with Standards – impact legal/standards related to LCE technologies	• Interaction with legislation
WP3 Safety	• Safety, Integrity & Reliability of system integration options are topics where standards can have a big benefit. Define with WP3 the items to look into	• Common interest safety, integrity and reliability – exchange stakeholders
WP4 Ecology WP4 Environment	• Identify with WP4 whether there is an interest in mapping relevant standards	• Depending on answer column2, mapping standards on carbon footprint has been identified.
WP5 Logistics	• From logistics - M&O - it is of importance to look into what is standardized and what is needed. Standards can benefit the logistics	• No priority
WP6 Energy atlas-mapping WP6 System modelling	• Define topics that need to be further looked into from a standardization point of view e.g.: This includes perspectives on the system integration technologies, including CCS, hydrogen developments, energy storage, platform electrification and power to x.	
WP7 Roadmap	•	• To be defined

Critical input - exchange needed with other WPs

	2021											2022										
Actions	jan	feb	mrt	apr	jun	jul	aug	sep	okt	nov	dec	jan	feb	mrt	apr	jun	jul	aug	sep	okt	nov	dec
WP1: Exchange WP1 storylines > Standardization needs and priorities		■				■			■		■	■	■	■	■							
WP2-legal: alignment standardization - interaction with legislation		■	■	■	■			■			■	■	■	■	■							
WP3: aligment data gathering on platform and pipeline safety, integrity and reliability	■	■	■				■	■	■		■	■	■	■	■							
WP4: standards overview carbon footprint					■																	
WP7: Technology briefs for fact based potentials, targets and innovation needs - to be defined																						

Planning and timeline

Actions	2021											2022										
	jan	feb	mrt	apr	jun	jul	aug	sep	okt	nov	dec	jan	feb	mrt	apr	jun	jul	aug	sep	okt	nov	dec
Data gathering - RA1																						
Review data gathering NSE3 irt NSE4		■	■	■																		
data gathering New topics			■	■	■																	
interviews stakeholders (with WP3)	■	■		■	■																	
workshop						■																
Impact assessment - RA2																						
assesment approach defined						■																
assesment interviews						■	■	■														
assesment results								■	■													
workshop									■													
Recommendations -RA3																						
analysis assesment									■	■												
defining recommendations workshop											■											
reporting recommendations												■										
Dissemination - RA4																						
define dissemination activities											■	■										
dissemination												■	■	■	■							
Final reporting																						
Final results/reporting															■	■	■					
internal review																	■	■				
external review																			■			

ANNEX 2 Standards for platform aspects

Regarding platform aspects, ISO/TC 67/ SC 7 Offshore structures has an extensive portfolio on offshore platforms.

- ISO 10855-1:2018 Offshore containers and associated lifting sets — Part 1: Design, manufacture and marking of offshore containers
- ISO 10855-2:2018 Offshore containers and associated lifting sets — Part 2: Design, manufacture and marking of lifting sets
- ISO 10855-3:2018 Offshore containers and associated lifting sets — Part 3: Periodic inspection, examination and testing
- ISO 19900:2019 Petroleum and natural gas industries — General requirements for offshore structures
- ISO 19901-1:2015 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Metocean design and operating considerations
- ISO 19901-2:2017 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 2: Seismic design procedures and criteria
- ISO 19901-3:2014 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 3: Topsides structure
- ISO 19901-4:2016 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 4: Geotechnical and foundation design considerations
- ISO 19901-5:2016 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 5: Weight control during engineering and construction
- ISO 19901-6:2009 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 6: Marine operations
- ISO 19901-6:2009/COR 1:2011 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 6: Marine operations — Technical Corrigendum 1
- ISO 19901-7:2013 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units
- ISO 19901-8:2014 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 8: Marine soil investigations
- ISO 19901-9:2019 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 9: Structural integrity management
- ISO 19901-10:2021 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 10: Marine geophysical investigations
- ISO 19902:2020 Petroleum and natural gas industries — Fixed steel offshore structures
- ISO 19903:2019 Petroleum and natural gas industries — Concrete offshore structures
- ISO 19904-1:2019 Petroleum and natural gas industries — Floating offshore structures — Part 1: Ship-shaped, semi-submersible, spar and shallow-draught cylindrical structures
- ISO 19905-1:2016 Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 1: Jack-ups
- ISO/TR 19905-2:2012 Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 2: Jack-ups commentary and detailed sample calculation
- ISO 19905-3:2021 Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 3: Floating units
- ISO 19906:2019 Petroleum and natural gas industries — Arctic offshore structures

ANNEX 3 CCUS Database CCUS related standards

For CCUS an upgrade of the database as being developed under NSE 3 has been developed.

In collaboration and appreciation to

TNO
New Energy Coalition
Rijksuniversiteit Groningen
Royal HaskoningDHV
NEN
Energieke Communicatie
MSG
TKI Nieuw Gas
Total Energies
Shell
NAM
EBN
Gasterra
Gasunie
ONE-Dyas
Bilfinger Tebodin
DEME Offshore NL
Boskalis
Neptune Energy
IV Offshore & Energy
Bureau Veritas
HINT Europe
NGT
NOGAT
Peterson Energy
Port of Den Helder
Port of Amsterdam
Port of Rotterdam
SmartPort
Element NL
Equinor Energy
Net Zero Technology Centre

Sounding board

Dutch Marine Energy Centre
Ministerie Economische Zaken & Klimaat
IRO
Stichting Natuur & Milieu
Nexstep
Stichting Noordzee
NWEA
Tennet
TKI Wind op Zee
Visned
Rijkswaterstaat
Topsector Energie
BOZ

North Sea Energy

offshore system integration