North Sea Energy
HAZID – Offshore Hydrogen Production

As part of Topsector Energy:
TKI Offshore Wind & TKI New Gas

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Document Change Record

This section shows the historical versions, with a short description of the updates.

Version	Short description of change
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1 Introduction

1.1 Objective

The objectives of the HAZID study are to:

- Identify potential hazards and reasonably foreseeable accident events which could lead to escalation, injuries to personnel or fatalities, asset damage and environmental impact; with focus on the differences between a typical gas production platform and the intended change-over to a hydrogen producing platform.
- Identify engineering and / or procedural safeguards already incorporated into the design that will help reduce the likelihood or the severity of consequences related to the identified threat;
- Identify any actions required to help reduce the risk from the threats identified for the future design.

1.2 Scope of the study

The scope of work is to conduct a HAZID study for the proposed "North Sea Energy 3" preliminary design as presented in appendix III. As at the time of the HAZID it was unknown which platform would be used the following assumptions have been made:

- Existing facility will be re-used
- Facility is a manned installation
- Existing facility is a typical gas production platform.
- All equipment and piping used for hydrocarbon production has been removed and wells have been permanently plugged
- PFP (passive fire protection) is provided on Accommodation Building and Main structural steel items – PFP is for hydrocarbon fires (typically H60 or J15)
- F&G system for detection of hydrocarbon releases and fires
- (Dry) Deluge system is available for firefighting / cooling of structural items and equipment during a fire
- Accommodation is classified as Temporary Refuge (TR)
- TR is suitable protected for HC gas releases and fires
- Platform decks are shielded by cladding to ensure good working environment (especially to reduce the wind)

1.3 Background

North Sea Energy is an industry-driven Shared Innovation Program that connects the wind sector and gas industry. North Sea Energy has clear goals focusing on gathering and developing specific knowledge and technology for offshore system integration in the North Sea.

For North Sea Energy project 3 work package 4.3 Yokogawa together with TNO drafted four scenarios relevant to the North Sea Energy consortium. The scenarios are as follows:

1. Offshore hydrogen production on an (un)manned operating platform that produces natural gas.
2. Offshore hydrogen production on an (un)manned stripped electrified platform without natural gas production.
3. Offshore hydrogen production on an (un)manned stripped platform that processes and stores CO_2 but has no natural gas production.
4. Offshore hydrogen production on an energy island.

These scenarios were presented and ranked during the mid-term review on the 9th of July 2019. Scenario 4 topped the vote closely followed by scenario 2. As energy islands are a further into the future solution compared to scenario 2 it was decided to perform a HAZID study for the manned version of scenario 2:

- *Offshore hydrogen production on a manned electrified platform without natural gas production.*

1.4 Abbreviations

In this document, the following acronyms and abbreviations apply:

Abbreviations	Definition
ESD	Emergency Shutdown System
FGS	Fire and Gas System
H2	Hydrogen
HAZID	HAZard IDentification
HVAC	Heating, Ventilation and Air Conditioning
O2	Oxygen
PEM (electrolyser)	Polymer electrolyte membrane (electrolyser)
PFP	Passive Fire Protection
PA	Public Address System

2 HAZID methodology

2.1 Preamble

The HAZID study was conducted using the conventional guideword approach. The principle of HAZID is that accidents occur when operations are conducted under conditions that deviate from the desired intentions. Therefore, HAZID technique starts by understanding the design intentions of a particular process and finds meaningful deviations that can occur in the process. The process then is to understand these deviations and the consequences of these deviations and detect which of these consequences will result in a major hazard. It is used to examine one of the scenarios identified by the NSE3 Project in order to identify and evaluate problems that may represent risks to personnel, equipment or prevent efficient operation.

2.2 HAZID process

The guide words relevant to the NSE3 project are generated using the experience of the facilitator (during the brainstorm no new guide words were identified). The possible causes are listed together with the consequences with respect to hazards, with focus on the differences between a typical gas production platform and the intended change-over to a hydrogen producing installation. The existing protection or safeguard to reduce the possibility of undesirable deviations occurring or to limit the severity of the consequences are considered by the team to determine what actions to recommend, if any, to improve the safety of the process system. All aspects are discussed by the team and recorded in the worksheet.

2.3 Conducting the HAZID sessions

The list of guide words was examined systematically by an expert team, comprising experienced (Process) Engineers and (Energy Transition) Consultants/Advisors, chaired and scribed by Yokogawa. The examination was conducted on the relevant layout and queries raised systematically on every part of it to discover how deviations from the intention of the design can occur and determine whether these deviations can give rise to hazards and whether further protective measures, altered operating procedures or design changes were required.

The questioning was focused around a number of guide words which were derived from method study techniques. The guide words ensure that the questions posed to test the integrity of each part of the design explored every conceivable way in which the operation could deviate from the design intention.

Some of the causes were deemed unlikely and hence the derived consequences could be ignored. Some of the consequences were noted to be trivial and were not considered further. The potential problems were then evaluated for existing safeguards and requirement for remedial action. The HAZID team took note of a fact that immediate solution to a problem was not always obvious and could need further consideration and clarification.

The HAZID studies were conducted under the presence of a Chairman who launched the questions and guided the discussions. All decisions taken were recorded by the secretary in the form of worksheets.

2.4 Guide words considered for the HAZID study

The selection of the guideword was made based on an understanding of the system, on past experience and engineering judgment and the operations to be conducted. The relevant guide words & Hazardous events considered are provided in appendix I. These have been further expanded during the HAZID session.

3 Recommendations

3.1 HAZID study recommendations

During the workshop, 49 recommendations were recorded which require attention for a future design.

Below table presents a summary of the recommendations from the HAZID workshop review.

Action no.	Recommended Actions
[1]	Consider H_2 detection and shutdown and depressurization
[2]	Perform a dispersion study on ventilation for H_2
[3]	Consider minimising the H_2 inventory
[4]	Investigate the blast peak of a explosion in respect to hydrocarbon explosions and impact on blast wall
[5]	Investigate if personal detection of H_2 is required
[6]	Investigate if O_2 measurement can detect O_2 releases
[7]	Investigate the dispersion of O_2
[8]	Consider to install PEM in a controlled environment with forced ventilation
[9]	Reduce O_2 pressure as close to PEM electrolyser as possible
[10]	Investigate the impact on personnel health and safety requirements of high oxygen levels
[11]	Install fire detection suitable for H_2 fires
[12]	Investigate the effect of the temperature of H_2 fire on structural steel and TR and ESD (riser) valves and if the installed PFP is sufficient
[13]	Do not use deluge on H_2 fires because H_2 release will become unignited and form a cloud: possible explosion (see hazard 1a)
[14]	Investigate additional training of personnel for H_2 fire detection and fire fighting
[15]	Investigate the implications of high voltage installation on the platform with respect to interaction on humans, explosions and EM interferences and footprint on the platform
[16]	Consider storage of inventory of any drainage as injecting in the export line is not feasible
[17]	Investigate best location to vent O_2 and keep in mind vessels, helicopter, escape pods, life boats etc.
[18]	Investigate blowdown scenarios
[19]	Investigate best location to vent H_2 and keep in mind vessels, helicopter, escape pods etc.
[20]	Check if CO_2 extinguishing on vent is still feasible
[21]	Check if design of vent piping has sufficient strength to withstand an explosion of H_2
[22]	Check purging of vent to ensure no fire in vent piping
[23]	Perform radiation study on H_2 vent
[24]	Investigate brine sampling. Continuous measurement of O_2 concentration in H_2 recommended. Ensure calibration points are placed such that it will not be a potential ignition source
[25]	Investigate that the start-up and shutdown procedure considers purging of the installation. Further this subject needs to be more specified when design is more mature
[26]	Ensure that gas detectors are modified to detect H_2
[27]	Investigate if there will be a cable to shore, which means auxiliary power is not required
[28]	Investigate if instrument air is required for typical operations
[29]	Investigate if hydraulic stems are required for typical operations
[30]	Investigate if cooling water can be used to reduce typical air cooling hazards
[31]	Ensure PEM is stopped on losing cooling medium

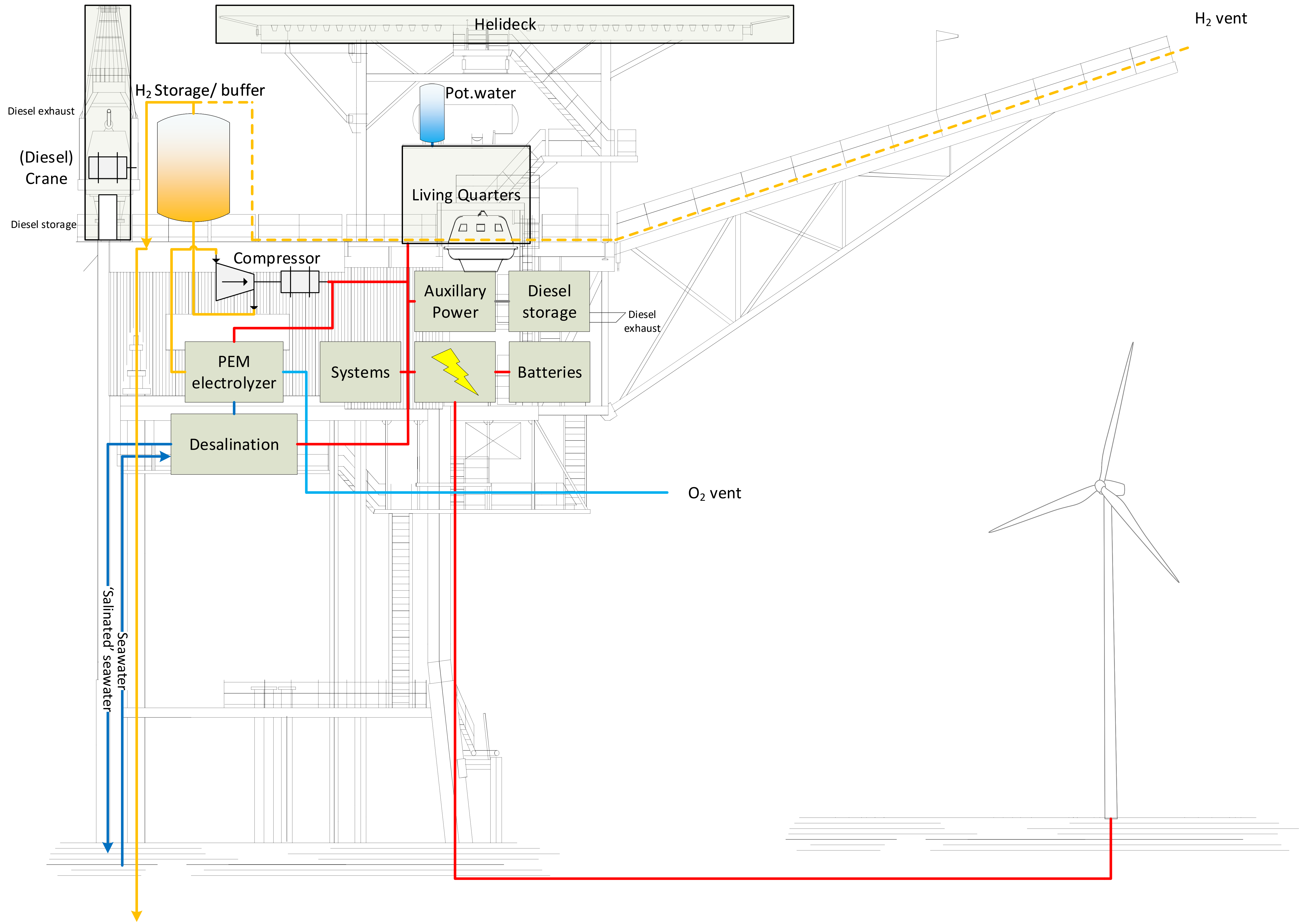
Action no.	Recommended Actions
[32]	Investigate how N2 is provided at the platform and ensure hazards associated with this installation are considered when design is more mature
[33]	No start-up without sufficient purging
[34]	Ensure sufficient buffer of N2 is available for safe shutdown of electrolyser
[35]	Ensure system (piping and equipment) is designed for these products
[36]	Investigate if pipeline is suitable (literature available)
[37]	Investigate the operating philosophy of the biocide/anti-scalant injection to the desalination unit and associated hazards
[38]	Install adequate firefighting equipment on electrical equipment
[39]	Do not use fire extinguishing systems in case of H2 fire (potential of explosions)
[40]	Relocate buffer vessel out of crane reach and/ or install sufficient protection
[41]	Provide sufficient lay-down areas outside any lifting areas from equipment at lower decks
[42]	Ensure PEM is located such that crane can reach the location taking into consideration favourable weather conditions and sea state
[43]	Vent study should also take into account corrosion on the installation
[44]	Ensure structure has sufficient strength for the intended lifetime
[45]	Ensure vessel is selected with sufficient dynamic positioning and minimize weight
[46]	All escape routes shall be reviewed since layout will change and also based on scenarios and radiation
[47]	Review if lifeboat can be lowered to sea, taking into consideration O2 vent
[48]	Ensure equipment can be maintained and reached by crane when required
[49]	Check area classification is suitable for H2

Appendix I – Guide words

Item no.	Guide word	Sub no.	Event
1	**Process Fluid Releases (incl. storage)**	a	Flammable gas release - Unignited (Hydrogen)
		b	Flammable gas release - Unignited (Oxygen)
		c	Flammable gas release - Ignited
		d	Toxic Gas Release
		e	Liquid release
		f	Electrical installation (high voltage from field)
2	**Operations**	a	Draining
		b	Venting
		c	Sampling
		d	Shutdown, Isolation, Start-up
3	**Smoke & Gas ingress (Accommodation)**	a	Smoke Ingress
		b	Gas Ingress
4	**Utility failure**	a	HVAC
		b	Power
		c	Instrument air
		d	Power air
		e	Hydraulic systems on equipment
		f	Cooling medium
		g	Inert gas
5	**Other Hazardous Chemicals**	a	Radioactive
		b	Toxic
		c	Asphyxiant
		d	Corrosive
		e	Explosive
		f	Biocide
6	**Fire protection System failure**	a	Uncontrolled release of fire extinguishing gas (e.g. Inergen)
	Fire water failure	a	Fire extinguishing water /foam system not available or out of service
7	**Dropped objects**	a	Dropped Load
		b	Swinging loads
		c	Unstable lifting of objects
8	**Structural Failure**	a	Collapse (fatigue, design, materials, corrosion)
		b	Abnormal loads (ship collision)
		c	Escalation of a Major Accident
9	**Material corrosion**	a	System leaks, composition change, contamination of product
10	**Accidents caused by external sources**	a	Helicopter crash
11		a	ESD / FGS

Item no.	Guide word	Sub no.	Event
	Miscellaneous: Emergency Systems, Escape, Evacuation	b	PA
		c	Escape routes
		d	Lifeboats / rafts
		e	Communication failure
		f	Control systems failure
12	**Maintenance**	Maintenance accidents	
13	**Hazardous areas**	Non compliances with engineering codes and standards and with safety measures and regulations	

Appendix III – Preliminary design


Helideck
H2 vent
H2 Storage/ buffer
Pot.water
Diesel exhaust
(Diesel) Crane
Diesel storage
Living Quarters
Compressor
Auxillary Power
Diesel storage
Diesel exhaust
PEM electrolyzer
Systems
Batteries
Desalination
O2 vent
'Salinated' seawater
Seawater

Appendix IV – HAZID notes

Item no.	Guide word	Sub no.	Event	Hazard	Worst credible consequence	Safeguards	Recommended Actions	Action no.
1	**Process Fluid Releases (incl. storage)**	a	Flammable gas release - Unignited (Hydrogen)	Rupture or leakage causing a hydrogen cloud	Detonation (explosion), resulting in structural failure and/or fatalities	Unsuitable gas detection	Consider H2 detection and shutdown and depressurization	[1]
						Sheeting around the platform enhances natural ventilation	Perform a dispersion study on ventilation for H2	[2]
							Consider minimising the H2 inventory	[3]
						Blast wall	Investigate the blast peak of a explosion in respect to hydrocarbon explosions and impact on blast wall	[4]
					Suffocation		Investigate if personal detection of H2 is required	[5]
					Helicopter crash, resulting in structural failure and/or fatalities	Vent boom, deck clearance before helicopter approach		
		b	Flammable gas release - Unignited (Oxygen)	Rupture or leakage resulting in an oxygen rich environment	Increase of flammability of all materials resulting in fires (also in normally unexpected locations), resulting in structural failure and/or fatalities	Unsuitable gas detection	Investigate if O2 measurement can detect O2 releases	[6]
							Investigate the dispersion of O2	[7]
							Consider to install PEM in a controlled environment with forced ventilation	[8]
							Reduce O2 pressure as close to PEM electrolyser as possible	[9]
							Investigate the impact on personnel health and safety requirements of high oxygen levels	[10]

Item no.	Guide word	Sub no.	Event	Hazard	Worst credible consequence	Safeguards	Recommended Actions	Action no.
		c	Flammable gas release - Ignited	Fires and jet fires	Structural failure and/or fatalities	Fire and gas system, unsuitable fire detection	Install fire detection suitable for H2 fires	[11]
						Currently H60/J15 PFP is installed	Investigate the effect of the temperature of H2 fire on structural steel and TR and ESD (riser) valves and if the installed PFP is sufficient	[12]
						Deluge system	Do not use deluge on H2 fires because H2 release will become unignited and form a cloud: possible explosion (see hazard 1a)	[13]
							Investigate additional training of personnel for H2 fire detection and fire fighting	[14]
		d	Toxic Gas Release	Team is not aware of toxic gas releases from e.g. batteries				
		e	Liquid release	Leakage	Environmental issues	Open drain system/ bunded area	See 2a, 5f	
		f	Electrical installation (high voltage from field)	High power causing high electrical currents			Investigate the implications of high voltage installation on the platform with respect to interaction on humans, explosions and EM interferences and footprint on the platform	[15]

Item no.	Guide word	Sub no.	Event	Hazard	Worst credible consequence	Safeguards	Recommended Actions	Action no.
2	**Operations**	a	Draining	Expected liquids are water from process parts, brine and diesel	Environmental issues	Open drain system/ bunded area, at a typical HC platform oil is skimmed and injected in the export pipeline	Consider storage of inventory of any drainage as injecting in the export line is not feasible	[16]
		b	Venting	O_2 venting (continuous)			Investigate best location to vent O_2 and keep in mind vessels, helicopter, escape pods, life boats etc.	[17]
				H_2 venting (occasional)	Acoustic fatigue		Investigate blowdown scenarios	[18]
					Hydrogen cloud resulting in an explosion	Vent boom	Investigate best location to vent H_2 and keep in mind vessels, helicopter, escape pods etc.	[19]
					Hydrogen ignited at vent tip	CO_2 extinguishing on vent tip	Check if CO_2 extinguishing on vent is still feasible	[20]
					Hydrogen explosion in vent piping		Check if design of vent piping has sufficient strength to withstand an explosion of H_2	[21]
							Check purging of vent to ensure no fire in vent piping	[22]
							Perform radiation study on H_2 vent	[23]
		c	Sampling	No sampling considered during this HAZID, if continuous H_2 quality analysis is available			Investigate brine sampling. Continuous measurement of O_2 concentration in H_2 recommended. Ensure calibration points are placed such that it will not be a potential ignition source	[24]

Item no.	Guide word	Sub no.	Event	Hazard	Worst credible consequence	Safeguards	Recommended Actions	Action no.
		d	Shutdown, Isolation, Start-up	Insufficient purging with N2			Investigate that the start-up and shutdown procedure considers purging of the installation. Further this subject needs to be more specified when design is more mature	[25]
3	**Smoke & Gas ingress (Accommodation)**	a	Smoke Ingress	No difference with current NG platforms				
		b	Gas Ingress				Ensure that gas detectors are modified to detect H2	[26]
4	**Utility failure**	a	HVAC	No difference with current NG platforms				
		b	Power	Power failure to PEM system	No dangerous consequences			
						Auxiliary power (back-up)	Investigate if there will be a cable to shore, which means auxiliary power is not required	[27]
		c	Instrument air				Investigate if instrument air is required for typical operations	[28]
		d	Power air	No difference with current NG platforms				
		e	Hydraulic systems on equipment				Investigate if hydraulic stems are required for typical operations	[29]
		f	Cooling medium	Air or cooling water failure	Air: rotating equipment failure can be ignition source resulting in an explosion or fire potential structural failure and/or fatalities		Investigate if cooling water can be used to reduce typical air cooling hazards	[30]

Item no.	Guide word	Sub no.	Event	Hazard	Worst credible consequence	Safeguards	Recommended Actions	Action no.
					Overheating of electrizer, which can be ignition source resulting in an explosion or fire potential structural failure and/or fatalities		Ensure PEM is stopped on losing cooling medium	[31]
		g	Inert gas	N2 release			Investigate how N2 is provided at the platform and ensure hazards associated with this installation are considered when design is more mature	[32]
				N2 failure during purging			No startup without sufficient purging	[33]
				N2 failure during shutdown			Ensure sufficient buffer of N2 is available for safe shutdown of electrolyser	[34]
5	**Other Hazardous Chemicals**	a	Radioactive	Not applicable				
		b	Toxic	See biocides, no further toxic hazards are known to the HAZID team				
		c	Asphyxiant	No additional hazards identified				
		d	Corrosive	H2, O2 and Demin water are corrosive resulting in leakages	See hazards listed under item 1.		Ensure system (piping and equipment) is designed for these products	[35]
				H2 is corrosive resulting in leakages			Investigate if pipeline is suitable (literature available)	[36]
		e	Explosive	Not applicable				
		f	Biocide	Selected biocide and anti-scalant expected to be biodegradable and/or allowed by environmental permit			Investigate the operating philosophy of the biocide/anti-scalant injection to the desalination unit and associated hazards	[37]

Item no.	Guide word	Sub no.	Event	Hazard	Worst credible consequence	Safeguards	Recommended Actions	Action no.
6	**Fire protection System failure**	a	Uncontrolled release of fire extinguishing gas (e.g. Inergen)	For existing facilities no differences with				
				Electrical room (new high voltage equipment) fires			Install adequate fire fighting equipment on electrical equipment	[38]
	Fire water failure	a	Fire extinguishing water /foam system not available or out of service	No differences with NG platform identified			Do not use fire extinguishing systems in case of H2 fire (potential of explosions)	[39]
7	**Dropped objects**	a	Dropped Load	Dropped object on buffer vessel from crane	See hazards 1a and 1c		Relocate buffer vessel out of crane reach and/ or install sufficient protection	[40]
				No other differences with NG platform identified				
		b	Swinging loads				Provide sufficient lay-down areas outside any lifting areas from equipment at lower decks	[41]
		c	Unstable lifting of objects	PEM elements are most likely close to the lifting limits of the crane			Ensure PEM is located such that crane can reach the location taking into consideration favourable weather conditions and sea state	[42]

Item no.	Guide word	Sub no.	Event	Hazard	Worst credible consequence	Safeguards	Recommended Actions	Action no.
8	**Structural Failure**	a	Collapse (fatigue, design, materials, corrosion)	H2: No changes in comparison to NG because of ambient temperature and atmospheric pressure				
				O2 release from leakage or rupture is not expected to be very long so no additional corrosion rates				
				Continuous O2 release	Higher corrosion rates, structural failure		Vent study should also take into account corrosion on the installation	[43]
				Additional weight in the topside	Structural failure		Ensure structure has sufficient strength for the intended lifetime	[44]
		b	Abnormal loads (ship collision)	Due to higher lifting weight ships have to be closer to the platform	Collision: structural failure	Current: favourable weather conditions and sea state	Ensure vessel is selected with sufficient dynamic positioning and minimize weight	[45]
		c	Escalation of a Major Accident	No other differences with NG platform identified				
9	**Material corrosion**	a	System leaks, composition change, contamination of product	See before				
10	**Accidents caused by external sources**	a	Helicopter crash	See cooling medium selection (location of fans)				

Item no.	Guide word	Sub no.	Event	Hazard	Worst credible consequence	Safeguards	Recommended Actions	Action no.
11	**Miscellaneous: Emergency Systems, Escape, Evacuation**	a	ESD / FGS	For fire and gas systems see above. No changes to the normal ESD philosophy				
		b	PA	No changes in philosophy				
		c	Escape routes				All escape routes shall be reviewed since layout will change and also based on scenarios and radiation	[46]
		d	Lifeboats / rafts	See O2 venting (item 2b)			Review if lifeboat can be lowered to sea, taking into consideration O2 vent	[47]
		e	Communication failure	No changes in philosophy				
		f	Control systems failure	To be specified in a later stage				
12	**Maintenance**	Maintenance accidents		To be specified in a later stage				
							Ensure equipment can be maintained and reached by crane when required	[48]
13	**Hazardous areas**	Non compliances with engineering codes and standards and with safety measures and regulations					Check area classification is suitable for H2	[49]