PUBLIC SUMMARY

In April and May, 2021, HYEX Safety organised a risk design screening workshop documented with a preliminary risk assessment report, and an early phase HAZID workshop for the planned Green Ammonia Berlevåg (GAB) site developed by Aker Clean Hydrogen (ACH). Ammonia system provider, Haldor Topsøe, participated together with representatives from ACH, Aker Solutions and HYEX Safety. The main ambition with these workshops and reporting were to identify and try quantifying the main contributions to major accident risk. With the insight from these workshops and reports ACH has further developed and matured the facility design with a focus to prevent or mitigate potential major accidents. Due to an ongoing revision process of area zones in Berlevåg municipality related to the development of Berlevåg Industrial Park, HYEX Safety was asked to issue an updated version of the early risk assessment. For GAB it is important that the new area zones will be consistent with expected future risk contours around the facility.

In this report the various parts of the facility and operations have been assessed with the following conclusions:

Hydrogen production

No supplier has yet been selected for the hydrogen production systems. The systems are still described with a good level of detail. Based on a described system design, with pipe diameters, flow rates, pressures, temperatures, and assumed hydrogen inventories in the different systems, leak frequencies and rates, as well as possible consequences, have been estimated. In the assessment it was concluded that the fatality risk from the hydrogen clusters from jet-fires, flashfires and explosions can be kept within the property of GAB. If non-return valves and/or flow restriction orifices are included in addition to isolation valves and installed from the clusters into the hydrogen header the risk contours may be further reduced. While such measures should not have any implications for the permitting process, they are expected to reduce the risk exposure for the workers on the site, as well as potential minor explosion damage to buildings nearby.

Currently the hydrogen production units are planned placed outdoor. There may however be a need for winterisation of the units. If the clusters are placed indoor, a new risk assessment is required.

Ammonia production loop

The ammonia production loop consists of feed syngas compressor (3:1 hydrogen and nitrogen), the ammonia loop at high pressure and temperature, and vessels with pressurised ammonia to be flashed and transferred to the storage tank. Both in the feed syngas compressor and the ammonia loop the gases are at high pressure, contain significant fraction hydrogen, and are highly buoyant relative to ambient air. A release would therefore likely flow upwards once the leak has lost momentum, so that risks related to ammonia dispersion is mostly limited. The significant hydrogen fractions will also make ignition and explosion very likely if there should be a major leak.

In the ammonia loop there are vessels in which liquid ammonia at pressure is collected, most prominently the let-down vessel. If there is a significant release from this vessel a major dense ammonia fog cloud could be generated and disperse far away along the ground in the direction of the wind. This is one of the scenarios evaluated representing the highest risk. The frequency for this scenario is too low for an inner zone to be defined, but because of large dispersion distances significant middle and outer consideration zones are predicted. If the vessel is isolated and blowdown of vapour space to vent mast is initiated at major leak detection the risk from releases from the let-down vessel can be strongly reduced.

Ammonia storage

The ammonia storage tank is single walled, thus there is a certain frequency of major leaks into the bund. From an assessment of these scenarios quite significant consideration zones resulted. As tank leak scenarios cannot be stopped alternative mitigation strategies should be applied. For this assessment it was assumed that the consequences of a release can be strongly reduced within 30 min either by mitigation measures or by evacuation of people within the hazard zone. Proper ways to limit the severity of major spills should be aimed for.

Ammonia loading

The ammonia loading process will take place approximately every 14 days. The operation is expected to take 8 h. While modern loading arms with various safety features implemented are aimed to be used, the risk related to the loading process is still significant. In the assessment conservative assumptions were made. It was assumed to take 5 min to detect and stop a severe leak it was also assumed that all spilled ammonia would fall into the sea with 30% evaporation rate. A strategy to collect spilled ammonia in bunds on the vessel or onshore is assumed to reduce the estimated risk. To prevent possible incidents with major ammonia releases exposing passengers at Hurtigruten during stopover in Berlevåg, it has been concluded that loading operations shall be carried out outside the times where Hurtigruten is at quay.

Vent/flare stack

The vent/flare stack will primarily be used for emergency blowdown of the high-pressure ammonia loop and for low-pressure venting of ammonia vapours from the ammonia storage tank. For the rare situation with emergency blow-down of the ammonia loop, and venting of highly flammable hydrogen rich gas it may be considered to ignite the vented gas. For pure ammonia flows cold venting is assumed due to challenges burning ammonia. The vent stacks should be designed for safe venting and no consideration zones should be required related to the vent stack.

Escalation risk to or from other activities

No significant escalation risk is identified towards or from nearby activities. A hydrogen storage from Varanger Kraft, with future expansion plans has been assessed, potential consequences to GAB are not considered to be of significant concern.

Estimated risk consideration zones from GAB

Based on the assessment risk contours have been developed for GAB, including inner, middle, and outer consideration zones for land use planning. The main risk contributions outside the facility comes from pressurised ammonia releases from the let-down vessel, from ruptures and major leaks from the refrigerated ammonia storage tank, and from the ship loading operation. The estimated zones are shown in Figure A.1. The risk contours around the jetty are related to the ammonia ship loading process and will only represent a risk during the actual loading operations. It has been stated by GAB that they as a preventive measure will avoid ship loading operations during the time Hurtigruten makes stopovers in Berlevåg.

Due to the concept phase of the assessment, there may be risk-contributing systems that are overseen or not properly quantified, on the other hand conservative assumptions are made regarding risk reduction, in practise it can be expected that risk reduction measures can be implemented which will reduce the risk significantly, see examples below:

- Let-down vessel => isolation and blowdown of vapour space at gas detection.
- Storage tank => fast detection and proper mitigation actions are needed.

- Ship loading => surveillance or detection to stop ammonia supply in case of leak, prevent ammonia from falling into water.

It can also be mentioned that the wind data used for the assessment has not been very detailed, and it is believed that some assumptions based on the wind rose have led to a slight overestimation of hazard distances in directions with low wind. It is therefore assumed that the proposed zones will be sufficient.

The hazard distances may be slightly increased when production at GAB may be increased in phase 2 of the development. If the risk reduction measures mentioned above are implemented this is believed to reduce risk more than the expected increase from a phase 2 development, thus the proposed zones would be expected sufficient.

Finally, it should be mentioned that this is a concept risk assessment in which precision level and depth of the analysis can be improved. For many of the consequence assessment computational fluid dynamics (CFD) could be used for better precision of dispersion and explosion processes.

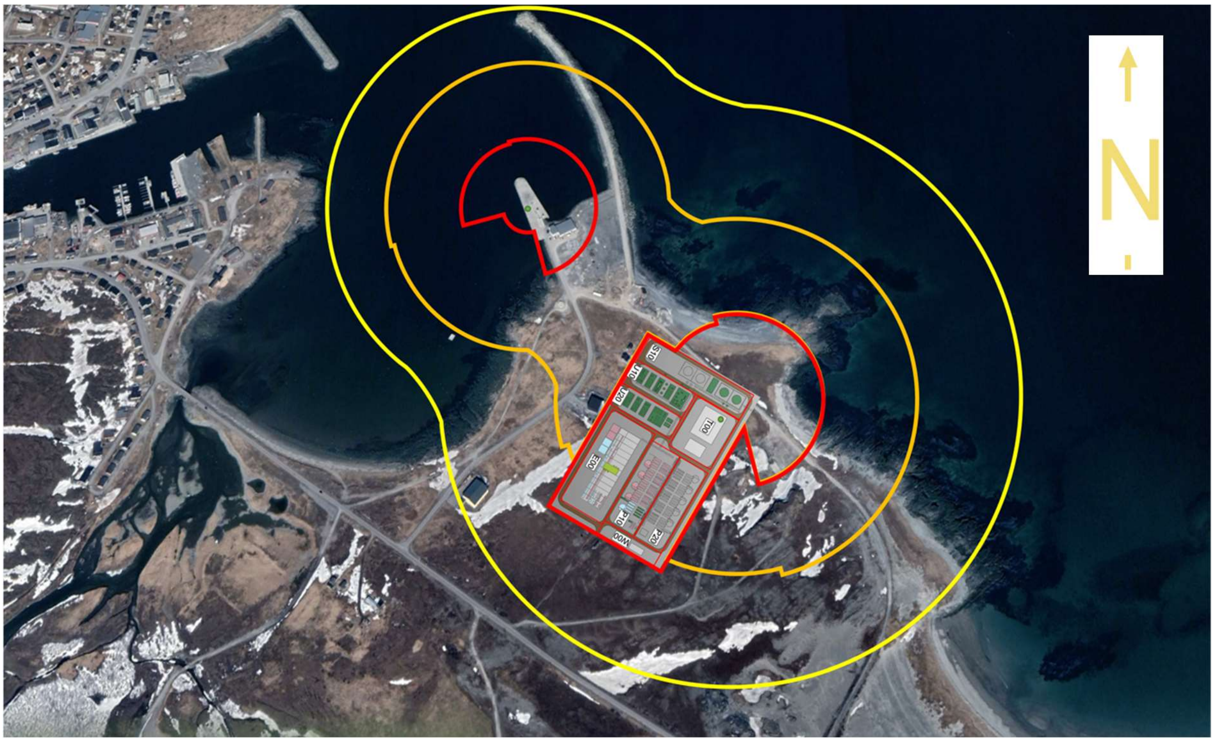

Figure A.1: Estimated inner (red), middle (orange), and outer (yellow) consideration zones for the Green Ammonia Berlevåg plant and loading quay. Map: Google Earth.

