*Advances in Reliability, Safety and Security, Part 4 – Kołowrocki, Dąbrowska (eds.)*
*© 2024 Polish Safety and Reliability Association, Gdynia, ISBN 978-83-68136-16-6 (printed), ISBN 978-83-68136-03-6 (electronic)*

**Advances in Reliability, Safety and Security**

ESREL 2024
Monograph Book Series

# Safety Aspects of Introducing Hydrogen For Power Supply Of Electric Construction Machinery

Shenae Lee[a], Marianne Rose Kjendseth Wiik[b] , Kristian Rasmussen[c],
Jens Hjorteset[d], Maria Vatshaug Ottermo[a], Knut Øien[a]

[a]*SINTEF Digital, Strindvegen 4, Trondheim, Norway*
[b]*SINTEF Community, Børrestuveien 3B, 0373 Oslo, Norway*
[c]*Westgass Hydrogen, Kirkegata 13, 4006 Stavanger, Norway*
[d]*PSW Power & Automation, Bleivassvegen 7, 5347 Ågotnes, Norway*

## Abstract

Norway has ambitions to become a low-emission society by 2050, and green hydrogen can be an important contributor towards this goal. Hydrogen has been increasingly adopted as an alternative energy carrier in different application areas like transportation sectors and the chemical industry, to reduce greenhouse gas emissions. In this context, a research project focuses on the feasibility of adopting hydrogen in combination with battery energy storage systems to supply electrical energy to electric construction machinery. Current practice shows that traditional construction machines require large amounts of diesel for operation. For this reason, a pilot renewable energy system is proposed as a solution, where the combination of hydrogen fuel cell system, Lithium-ion battery energy storage system, and photovoltaics are used to supply energy to the site. However, the introduction of hydrogen to the site will introduce new potential accident hazards since hydrogen is extremely flammable. It is therefore of the utmost importance to assess the risk from introducing hydrogen and to suggest measures against these potential risks. The main objectives of this paper are to: 1) Introduce the design concepts of implementing hydrogen in combination with other energy systems on the site, 2) Present preliminary results from the hazard identification for hydrogen systems on the site. The results identify thirteen hazardous events: two events with unacceptable risk, nine with as low as reasonably practicable risk, and two with acceptable risk. The results also give suggestions for risk reduction measures. Further work includes expanding the scope of the assessment to include the fuel cell and PV system. The results are useful as a preliminary assessment of hydrogen on site and can be adapted to other sites. The results are useful for site managers and contractors that are interested in using hydrogen as a renewable energy source.

*Keywords*: hydrogen safety, battery safety, gaseous hydrogen, major accident risk, hazard identification, construction industry

## 1. Introduction

Norway has ambitions on becoming a low emission society by 2050 (Lovdata, 2017), and hydrogen is an alternative energy carrier that can contribute to the reduction of greenhouse gas (GHG) emissions (Pareek et al., 2020). Hydrogen can be used to replace hydrocarbons in different application areas such as in transportation sectors and chemical industry (Pareek et al., 2020). More recently, heavy-duty electric vehicles fuelled by electricity or hydrogen have been deployed in a few countries including Norway (Ihonen et al., 2021; Meng et al., 2021; Nugroho et al., 2021; Teigland, 2020). This article focuses on the feasibility of adopting hydrogen fuel cells to produce electricity for operating electric construction machinery on a stone mass recycling plant in Norway.

The Norwegian building and construction industry is responsible for ca. 15% of national GHG emissions (Larsen et al., 2022). Of these GHG emissions, ca. 22% (2.2 million tons) originate from the direct combustion of diesel in construction machinery (Larsen et al., 2022; SSB, 2023). To combat these GHG emissions, Norway has piloted electric construction machinery and is currently undergoing a transition from traditionally diesel-powered construction sites to emission free construction sites (Wiik et al., 2023b, 2023a, 2023c). Emission free construction sites are defined as construction sites that only use energy sources that do not lead to direct GHG or NOx emissions (e.g., electricity or hydrogen) (SN/TS 3770:2023, 2023). This has proven to work well in cities, where there is easy access to the electricity grid. Here, GHG emissions, local air pollution, and noise pollution are drastically reduced by up to 95%, whilst conditions for construction workers are improved (Wiik et al., 2023b, 2020). However, there have been challenges in spreading the concept of emission free construction sites to areas outside of cities, where the electricity grid infrastructure is not as developed, such as in the North of Norway or in road construction or quarry operations (Høyli et al., 2023; Wiik et al., 2021). There are also challenges relating to the full electrification of construction sites, where energy and power demands are high, especially when multiple large construction machines are in use simultaneously. Efforts are being made to optimize construction operations and logistics to reduce energy and power demands. However, in some cases additional measures are required.

This article documents one of the first examples of hydrogen fuel cells to be used in combination with Lithium-ion battery containers, and photovoltaic systems to cover the energy and power demands of electric construction machinery at a stone mass recycling plant. The focus of the paper is on the design concepts of implementing hydrogen in combination with other energy systems on the site, and preliminary results from the hazard identification process for the systems containing high-pressure gaseous hydrogen on site. The design concepts are described in Section 2, hazard identification and risk assessment are introduced in Section 3, and the preliminary results are presented in Section 4. Discussions follow in Section 5 and conclusions are provided in Section 6.

## 2. System description

### 2.1. Case study

The case study site is located on the West coast of Norway and is a stone mass recycling plant. The site has three main activities: recycling masses, crushing masses, and mass transport. In total, 16 different types of construction machinery and heavy-duty vehicles are used: ranging from excavators, water pumps, washing plants, slurry pumps, wheel loaders, crushers, mass sorters, and dumper trucks. The site currently runs on diesel; however, plans are to convert operations to be emission free. Altogether it is estimated that the site requires ca. 15.8 MWh of energy to maintain daily operations, with peak power demands of ca. 2.5 MW, see Table 1. This gives an estimated annual energy demand of ca. 4.1 GWh (Wiik et al., 2023d). In contrast, the maximum available power on the site from the electricity grid is 230 kW.

Table 1. Estimated power and energy demands for full electric operation on site (Wiik et al., 2023d).

| Activity | Maximum power (*kW*) | Maximum daily energy use (*MWh*) | Annual energy use (*GWh*) |
|---|---|---|---|
| Recycling | 480 | 5 | 1.3 |
| Crushing | 476 | 4.9 | 1.3 |
| Transport | 1 500 | 5.6 | 1.4 |
| Total | 2 456 | 15.8 | 4.1 |

Expanding the electricity grid is not a feasible option as it is too costly and will take too long to upgrade. Therefore, the project manager and partners are investigating alternative renewable energy solutions to electricity from the grid and will pilot a holistic renewable energy system (RES) with hydrogen fuel cell, Lithium-ion batteries, and photovoltaics (PV) to cover the energy and power demands on site.

To be able to use hydrogen-fuelled electrical construction equipment, charging systems should be established on site. In this project, the RES to be installed for charging electric construction machinery consists of four parts: 1) hydrogen storage system, 2) fuel cell system, 3) battery system, and 4) PV system. The hydrogen container will be used for road transportation of hydrogen, and then as a hydrogen storage on the site. Hydrogen storage will be used to supply fuel cell systems that generate electricity. The generated electricity will be stored in the battery system that includes a transformer, inverters, batteries, housing, and auxiliary equipment. Hydrogen will be delivered to the site by road transportation from centralized production sites. Special types of cylinders, categorized as Type IV cylinder (Dragassi et al., 2023) will be used to contain compressed hydrogen at a desired high pressure and the given operating temperatures. These cylinders are mounted in a Multi Element Gas Container (MEGC) that is transported by a truck and will be used as a storage unit on site. In addition to the container, a designated hydrogen dispatching system will be installed for flow control, monitoring, and remote operation of the hydrogen container. Between the hydrogen container and the battery unit, there will be a wall to prevent potential fire from spreading, and for increased protection of workers in case of fire or explosion due to loss of containment events in the hydrogen system. The battery system will most likely consist of 1 MWh containerized battery system, providing around 1MW of energy storage for operation of cable-electric construction machinery, charging of mobile battery units, and charging of battery-electric construction machinery and heavy-duty vehicles (see configuration in Figure 1). The PV system will most likely consist of 168 crystalline silicon modules, with a module performance of 405 Wp, installed on site with a 35º slope angle and 0º azimuth angle. The PV system is estimated to have an energy production of approximately 68 kWp, with an estimated annual energy production of around 68 040 kWh/year. The proposed renewable energy system and its components may be scaled up or down according to changing energy and power needs.

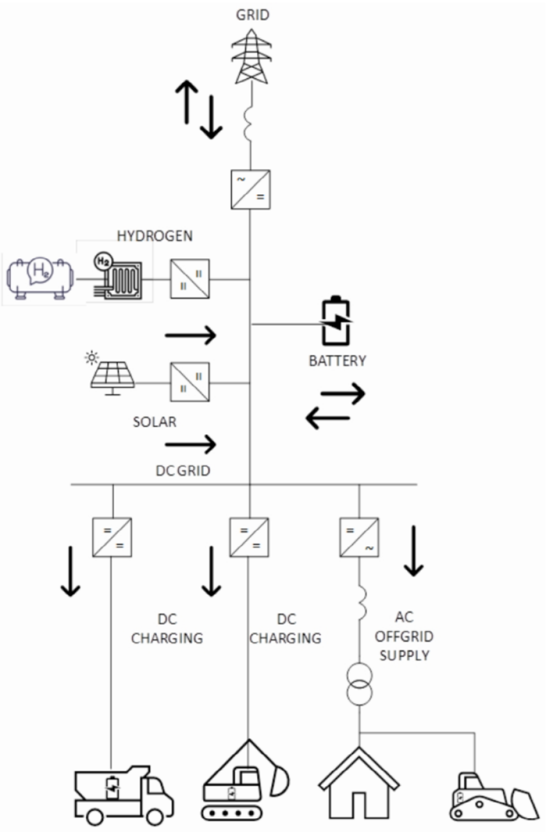


Fig. 1. Technical system configuration of proposed renewable energy system for the site.

### 2.2. Major accident risks related to the RES

The RES has the potential for major accidents. A representative accident in the hydrogen system is a jet fire and/or a hydrogen cloud explosion resulting from unwanted hydrogen leakage from the hydrogen container. For the battery system, a typical incident is the occurrence of a thermal runaway reaction that may lead to accidents like a fire, an explosion, and the release of hazardous vapours. A hazard identification (HAZID) process was performed for the hydrogen system and battery system, to identify and assess potential hazards at the early stages of the project and identify preventive measures to minimize the likelihood and impact of such accidents. This paper focuses on the safety aspects of gaseous hydrogen storage system where the need for safety improvements is identified. The risk associated with batteries are evaluated to be acceptable by the HAZID process. The HAZID for the PV system and fuel cell have not been carried out and are thus excluded from the scope of this paper.

The presence of high-pressure hydrogen on the site represents major accident hazards due to the potential for ignition of a hydrogen leakage (Lee et al., 2022; Sakamoto et al., 2016). The minimum ignition energy of a hydrogen-air mixture is lower than other flammable gases like methane and propane, which means that hydrogen leak can easily ignite. Moreover, hydrogen has a wide flammability range and hydrogen leaks are difficult to detect due to hydrogen's odourless and colourless nature, which makes it more difficult to prevent fires and explosions from hydrogen leakage (Verfondern, 2022). Several hydrogen-related accidents and incidents in the past indicate that even a small leak can result in severe consequences (Hansen, 2019; Hydrogen Safety Panel, 2020). For this reason, this paper reports a preliminary study where the focus is given to the safety aspects of the RES on site, with specific focus on the hydrogen system.

## 3. Method

The methods used were a combination of HAZID, or preliminary hazard analysis (PHA), and a risk matrix, or consequence/probability matrix.

### 3.1. Hazard identification

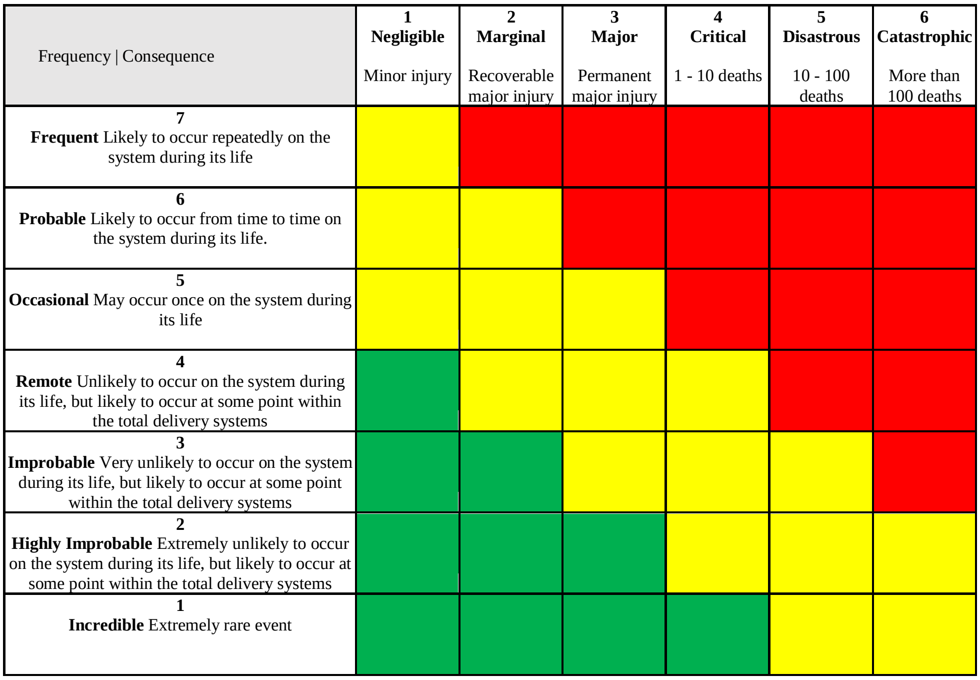
PHA is a simple, inductive method of analysis whose objective is to identify the hazards and hazardous situations and events that can cause harm for a given facility, activity, or system. It is mostly carried out early in the development of a project when there is little information on design details or operating procedures (IEC 31010, 2019). This corresponds to the pilot hydrogen power supply of electric construction machinery on a site and is the reason this method was selected. IEC 31010 (2019) uses the related term risk identification (not hazard identification) as a general part of the risk assessment process where different specific methods such as PHA may be used. Here we use HAZID and PHA interchangeable, although HAZID often is only the first part of a PHA, i.e., the identification of the hazardous events.

A HAZID was applied to the pilot energy system. A designated HAZID session was used for a structured brainstorming by a group of experts. The group consisted of 10 persons representing different partners from the project that includes contractors, RES suppliers, hydrogen supplier, project owner, and safety researchers. An example HAZID worksheet used in the study is shown in Table 2. Since the design of the facility was not completely determined at the time of the HAZID, the HAZID should be updated when more detailed design specifications are available (Rausand, 2011). In addition, the HAZID can be updated when knowledge about hydrogen accident scenarios increases, considering that hydrogen technology is an emerging technology, and that the use of hydrogen on construction sites is a new application area (Paltrinieri et al., 2013).

### 3.2. Risk assessment using risk matrix

The risk matrix (or consequence/probability matrix) is a means of combining qualitative or semi-quantitative ratings of consequence and probability to produce a level of risk or risk rating (IEC 31010, 2019). Often the likelihood scale used is frequency instead of probability, which was the case in the risk assessment of the pilot RES. The risk matrix is a means to communicate the results of the risk assessment in a visual manner; the rating of frequency and consequence can be tabulated or documented in other ways. However, risk matrices are often chosen in qualitative or semi-quantitative risk assessments due to ease of communication and is often used to rank risks.

For each of the hazardous events identified in the HAZID, frequency and consequence ratings were performed using the risk matrix shown in Figure 2 (starting with the consequence, and then assessing the frequency for this specific consequence). Both frequency and consequence rating are expressed by using logarithmic scale, with the increment by one from a frequency rating to the next higher rating. Hence, the frequency scale ranges from 1 to 7, and the consequence rating ranges from 1 to 6. Then the risk rating was achieved by the addition of the frequency rating and consequence rating (Duijm, 2015), meaning the risk rating ranges from 2 to 13. The risk rating is visualized with the colour coding, as shown in Figure 2. The risk rating higher than 8 was indicated by the red colour code, which denotes an unacceptable risk level where additional risk reducing measures must be implemented. The yellow-coloured region indicates the risk rating is between 6 and 8, which implies that the risk should be reduced to as low as reasonably practicable (ALARP) and decision on further risk reduction is made using the ALARP principle (i.e., efforts to reduce risk should be continued until the incremental sacrifice in doing so is grossly disproportionate to the value of the incremental risk). The green-coloured region indicates risk rating lower than 6, which means an acceptable risk and no need for detailed work to demonstrate that the risk is at an ALARP level (HSE, 2001; IEC 61511, 2016). It should be noted that the consequence rating focused has been on the harmful effect to people. The damage to facility and environment has to a lesser degree been considered but have for some cases been used as guidelines for finding the right classification.



| Frequency \| Consequence | 1<br>**Negligible**<br>Minor injury | 2<br>**Marginal**<br>Recoverable major injury | 3<br>**Major**<br>Permanent major injury | 4<br>**Critical**<br>1 - 10 deaths | 5<br>**Disastrous**<br>10 - 100 deaths | 6<br>**Catastrophic**<br>More than 100 deaths |
|---|---|---|---|---|---|---|
| 7<br>**Frequent** Likely to occur repeatedly on the system during its life | 🟨 | 🟥 | 🟥 | 🟥 | 🟥 | 🟥 |
| 6<br>**Probable** Likely to occur from time to time on the system during its life. | 🟨 | 🟨 | 🟥 | 🟥 | 🟥 | 🟥 |
| 5<br>**Occasional** May occur once on the system during its life | 🟨 | 🟨 | 🟨 | 🟥 | 🟥 | 🟥 |
| 4<br>**Remote** Unlikely to occur on the system during its life, but likely to occur at some point within the total delivery systems | 🟩 | 🟨 | 🟨 | 🟨 | 🟥 | 🟥 |
| 3<br>**Improbable** Very unlikely to occur on the system during its life, but likely to occur at some point within the total delivery systems | 🟩 | 🟩 | 🟨 | 🟨 | 🟨 | 🟥 |
| 2<br>**Highly Improbable** Extremely unlikely to occur on the system during its life, but likely to occur at some point within the total delivery systems | 🟩 | 🟩 | 🟩 | 🟨 | 🟨 | 🟨 |
| 1<br>**Incredible** Extremely rare event | 🟩 | 🟩 | 🟩 | 🟩 | 🟨 | 🟨 |

Fig. 2. Example risk matrix.

## 4. Results

This section reports the preliminary results of the HAZID process for the hydrogen system.

### 4.1. HAZID and risk ranking

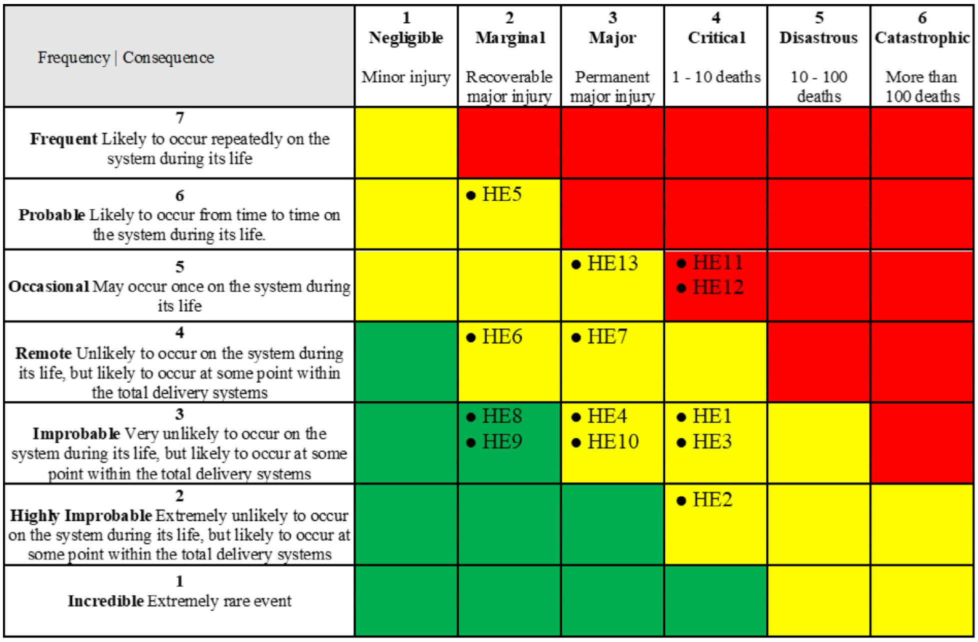
From the HAZID, thirteen hazardous events were identified for the hydrogen container and hydrogen dispatching system. An excerpt of the HAZID worksheet for a generic hazardous event 'Leakage from the tank due to small/medium hole in the tank shell during normal operation or under delivery' is shown in Table 2. Most of the hazardous events identified were similar to the hazardous events that may occur in the hydrogen systems installed in a refuelling site. However, some hazardous events were more specific for the site, such as 'Hydrogen leakage due to the collision with other objects on the site', 'Catastrophic rupture of the hydrogen tank' were associated with flying stones due to the blasting operation taking place in proximity to the hydrogen system. A list of all the hazardous events (HEs) are identified below:

- HE 1: Leakage from the tank due to small/medium hole in the tank shell during normal operation or under delivery;
- HE 2: Rupture of the high-pressure hydrogen tank;
- HE 3: Leakage due to small hole in tank connection valve or tubing at tank side of isolation valves;
- HE 4: Leakage due to small/medium hole in tubing/equipment at manifold side of isolation valves;
- HE 5: Buildup of static electricity in hydrogen container;
- HE 6: Leak due to small/medium hole in system during hydrogen transfer;
- HE 7: Rupture of equipment in the hydrogen dispatching system due to external impact;
- HE 8: Excessive hydrogen vented from the fuel cell system and the hydrogen dispatching system;
- HE 9: Air into hydrogen hose and fuel gas generator set which may damage equipment and cause an explosive atmosphere;
- HE 10: Buildup of static electricity in hydrogen container during transportation;
- HE 11: Small leak from physical impact to the container/hydrogen dispatching system due to the truck backing up too far;
- HE 12: Hydrogen leakage due to the collision with other objects on site;
- HE 13: Hydrogen leakage due to the truck driving off without proper isolation.

Table 2. One example of a HAZID for a specified event (HE1).

| No | System/ Activity | Hazardous event | Cause (non-exhaustive list) | Consequence rating | Likelihood rating | Severity (C+L) | Risk rating (colour code) | Risk reduction measures (non-exhaustive list) |
|---|---|---|---|---|---|---|---|---|
| 1 | Hydrogen container | Leakage from the tank due to small/medium hole in the tank shell during normal operation or under delivery | Fatigue<br>Design error<br>Material failure<br>Human error<br>External impact<br>Malicious act<br>Adverse weather and natural disasters | Jet fire if immediate ignition<br>Explosion if delayed ignition | 3 Improbable | 4 Critical | 7 (Yellow) | Maintenance and inspection<br>Security measures<br>Prevent presence of small particles (e.g. gravel) that could cause mechanical sparks<br>Ventilation openings for all the equipment<br>Fire integrity of system components<br>Marked evacuation routes and zones<br>Explosion and fire walls |

Among the thirteen hazardous events identified, two HEs were evaluated with unacceptable risk, nine HEs were evaluated with ALARP risk, and two HEs were evaluated with acceptable risk. All HEs are plotted in the risk matrix based on the frequency and consequence ratings. The events can then be risk ranked based on the colour coding used as shown in Figure 3.



| Frequency \| Consequence | 1 **Negligible** Minor injury | 2 **Marginal** Recoverable major injury | 3 **Major** Permanent major injury | 4 **Critical** 1 - 10 deaths | 5 **Disastrous** 10 - 100 deaths | 6 **Catastrophic** More than 100 deaths |
|---|---|---|---|---|---|---|
| 7 **Frequent** Likely to occur repeatedly on the system during its life | 🟨 | 🟥 | 🟥 | 🟥 | 🟥 | 🟥 |
| 6 **Probable** Likely to occur from time to time on the system during its life. | 🟨 | 🟨 ● HE5 | 🟥 | 🟥 | 🟥 | 🟥 |
| 5 **Occasional** May occur once on the system during its life | 🟨 | 🟨 | 🟨 ● HE13 | 🟥 ● HE11<br>● HE12 | 🟥 | 🟥 |
| 4 **Remote** Unlikely to occur on the system during its life, but likely to occur at some point within the total delivery systems | 🟩 | 🟨 ● HE6 | 🟨 ● HE7 | 🟨 | 🟥 | 🟥 |
| 3 **Improbable** Very unlikely to occur on the system during its life, but likely to occur at some point within the total delivery systems | 🟩 | 🟨 ● HE8<br>● HE9 | 🟨 ● HE4<br>● HE10 | 🟨 ● HE1<br>● HE3 | 🟨 | 🟥 |
| 2 **Highly Improbable** Extremely unlikely to occur on the system during its life, but likely to occur at some point within the total delivery systems | 🟩 | 🟩 | 🟩 | 🟨 ● HE2 | 🟨 | 🟨 |
| 1 **Incredible** Extremely rare event | 🟩 | 🟩 | 🟩 | 🟩 | 🟨 | 🟨 |

Fig. 3. Risk matrix where the thirteen identified events are plotted.

### 4.2. Risk reduction measures

During the HAZID process, existing risk reduction measures were identified, including both technical and operational measures. Examples of technical measures are safety distances and explosion walls, hydrogen detection, thermal pressure release device (TPRD) and vents directed to safe location, use of explosion protection equipment, pressure monitoring with automatic shut-down, and separate grounding of all equipment. Examples of operational measures include nitrogen purging at start-up, regular maintenance and inspection, personnel training, and response to alarms. In addition to these existing measures, the HAZID study team identified additional measures that should be implemented in the future to reduce the risk to an ALARP level.

Examples of additional risk reducing measures applicable for normal operation were:

- Limitations in operation of the hydrogen dispatching system under extreme cold weather situations, together with the criteria for such limitation. External heating of the hydrogen dispatching system as a mitigating measure is under consideration here.
- The ground should be concrete, as gravel can cause sparks that can ignite a hydrogen leak.
- Lightning rod to protect against lightning strike.

Examples of additional measures related to truck arrival and departure:

- Anti-towing device that prevents the truck from driving away while filling hoses and flexible piping are connected to the hydrogen container.
- Clearing the site of personnel during hydrogen truck arrival and departure and hydrogen delivery.
- Establishment of a safe driving route.

## 5. Discussion

As mentioned in Section 2.1, energy and power demands are based on conservative calculated estimates. There is a large degree of uncertainty when 16 different construction machinery and heavy-duty vehicles will be converted to electric operations, each with varying load profiles. However, reducing energy and power demands will in turn reduce the need for large quantities of hydrogen storage on site, and therefore reduce the risk of large explosions or fires. Next steps involve looking into the operation and charging logistics on site to optimize energy and power efficiency. Another future task is to follow up the HAZID analysis when piloting activities start, as mentioned in Section 3. The HAZID may need adjustments when more detailed design information about the system has been obtained in the later phases of the study. In addition, the risk rating can be reassessed once additional risk reducing measures are implemented. Furthermore, more detailed risk analysis should be performed to build on the present study to ensure a proper basis for decision-making related to additional risk reducing measures. The risk assessment may need to expand by including the fuel cell and PV system, and to perform a more detailed consequence analysis to support decision making related to further risk reduction, for example to assess the need for and dimensioning of a blast wall. Further work also involves developing safety procedures and protocol for the delivery, operation, and maintenance of the hydrogen system on site.

## 6. Concluding remarks

This paper presents preliminary results from risk analysis for a pilot RES to be installed on an existing site. Although the site's layout has not been finalized, a preliminary HAZID is important to identify possible accident scenarios, such that safety concerns can be avoided or handled by design modification or implementing risk reduction measures before operation starts. The results are useful for site managers and contractors that are interested in using hydrogen as a renewable energy source on their sites.

## Acknowledgements

The authors would like to acknowledge RFF Rogaland (grant no. 341293) for funding the 'Nullutslippsanleggsplass' research project, and for insightful contributions from project partners: RISA, Rental.one, Westgass Hydrogen, PSW Power & Automation, Eldrift, Norsolar, Gjesdal kommune and Rogaland Fylkeskommune.

## References

Dragassi, M.-C., Royon, L., Redolfi, M., Ammar, S. 2023. Hydrogen Storage as a Key Energy Vector for Car Transportation: A Tutorial Review. Hydrogen 4, 831–861. https://doi.org/10.3390/hydrogen4040051

Duijm, N.J. 2015. Recommendations on the use and design of risk matrices. Safety Science 76, 21–31. https://doi.org/10.1016/j.ssci.2015.02.014

Hansen, O.R. 2019. Hydrogen Safety: Kjørbo-incident, overview and perspectives 27.

Høyli, R., Kjendseth Wiik, M., Homaei, S., Fufa, S. 2023. Towards emission free construction sites in Northern Norway: Results from a regional survey. In Journal of Physics: Conference Series.

HSE 2001. Reducing risks, protecting people. HSE Books, Sudbury.

Hydrogen Safety Panel 2020. Hydrogen Incident Examples Select Summaries of Hydrogen Incidents from the H2tools.org Lessons Learned Database.

IEC 31010 2019. Risk management - Risk assessment techniques.

IEC 61511 2016. Functional Safety: Safety Instrumented Systems for the Process Industry Sector, Part 1-3. International Electrotechnical Commission, Geneva.

Ihonen, J., Aronsson, B., Skúlason, J.B., Kornelíusdóttir, A.M., Jensen, T.L., Fenne, E., Wilhelmsen, I.T., Gjerløw, J.C., Eriksen, J. 2021. Next Nordic Green Transport Wave – Large Vehicles : Prospectus of using hydrogen in heavy-duty equipment, including non-road mobile machinery.

Larsen, H.N., Sandberg, H.M., Heggelund, E. 2022. Klimabidrag Bygg & Anlegg.

Lee, S., Ottermo, M.V., Vaagsaether, K., Henriksen, H., Lorentsen, O.-A., Håbrekke, S., Johnsen, S., Paltrinieri, N. 2022. Hazard Identification for Gaseous Hydrogen in Storage, Transportation, and Use, in: Book of Extended Abstracts for the 32nd European Safety and Reliability Conference. Presented at the 32nd European Safety and Reliability Conference, Research Publishing Services, 598-605. https://doi.org/10.3850/978-981-18-5183-4_R13-04-240-cd

Lovdata 2017. Lov om klimamål (klimaloven) in LOV-2017-06-16-60. Klima- og miljødepartementet. Lovdata: Norway.

Meng, X., Gu, A., Wu, X., Zhou, L., Zhou, J., Liu, B., Mao, Z. 2021. Status quo of China hydrogen strategy in the field of transportation and international comparisons. International Journal of Hydrogen Energy, HYDROGEN ENERGY SYSTEMS 46, 28887–28899. https://doi.org/10.1016/j.ijhydene.2020.11.049

Nugroho, R., Rose, P.K., Gnann, T., Wei, M. 2021. Cost of a potential hydrogen-refueling network for heavy-duty vehicles with long-haul application in Germany 2050. International Journal of Hydrogen Energy 46, 35459-35478. https://doi.org/10.1016/j.ijhydene.2021.08.088

Paltrinieri, N., Tugnoli, A., Buston, J., Wardman, M., Cozzani, V. 2013. Dynamic Procedure for Atypical Scenarios Identification (DyPASI): A new systematic HAZID tool. Journal of Loss Prevention in the Process Industries 26. https://doi.org/10.1016/j.jlp.2013.01.006

Pareek, A., Dom, R., Gupta, J., Chandran, J., Adepu, V., Borse, P.H. 2020. Insights into renewable hydrogen energy: Recent advances and prospects. Materials Science for Energy Technologies 3, 319–327. https://doi.org/10.1016/j.mset.2019.12.002

Rausand, M. 2011. Risk assessment - theory, methods and applications, Statistics in practice. Wiley, Hoboken,NJ.

Sakamoto, J., Sato, R., Nakayama, J., Kasai, N., Shibutani, T., Miyake, A. 2016. Leakage-type-based analysis of accidents involving hydrogen fueling stations in Japan and USA. International Journal of Hydrogen Energy 41, 21564-21570. https://doi.org/10.1016/j.ijhydene.2016.08.060

SN/TS 3770:2023 2023. Utslippsfrie byggeplasser og anleggsområder (Norsk Standard No. SN/TS 3770:2023). Standard Norge (SN), Lysaker, NO.

SSB 2023. Utslipp av klimagasser. Tabell 5. Utslipp til luft av klimagasser, etter næring. 1 000 tonn CO2-ekvivalenter. [WWW Document]. URL https://www.ssb.no/natur-og-miljo/statistikker/klimagassn/aar-endelige (accessed 9.15.17).

Teigland, K.H. 2020. This hydrogen lorry is powered by sunshine – from the north [WWW Document]. SINTEF. URL https://www.sintef.no/en/latest-news/2020/this-hydrogen-lorry-is-powered-by-sunshine-from-the-north/ (accessed 12.18.23).

Verfondern, K. 2022. Chapter 1 - Hydrogen fundamentals, in: Kotchourko, A., Jordan, T. (Eds.), Hydrogen Safety for Energy Applications. Butterworth-Heinemann, 1-23. https://doi.org/10.1016/B978-0-12-820492-4.00001-4

Wiik, M.K., Fjellheim, K., Azrague, K., Suul, J.A. 2023a. Environmental Assessment, Cost Assessment and User Experience of Electric Excavator Operations on Construction Sites in Norway, in: Littlewood, J., Howlett, R.J., Jain, L.C. (Eds.), Sustainability in Energy and Buildings 2022, Smart Innovation, Systems and Technologies. Springer Nature, Singapore, pp. 97–108. https://doi.org/10.1007/978-981-19-8769-4_10

Wiik, M.K., Fjellheim, K., Gjersvik, R. 2021. Erfaringskartlegging av krav til utslippsfrie bygge- og anleggsplasser (SINTEF Fag No. 86). SINTEF Academic Press, Oslo, Norway.

Wiik, M.K., Fjellheim, K., Suul, J.A., Azrague, K. 2023b. Electrification of Excavators: Electrical configurations, carbon footprint, and cost assessment of retrofit solutions. IEEE Electrification Magazine 11, 24–34. https://doi.org/10.1109/MELE.2023.3264898

Wiik, M.K., Flyen, C., Fufa, S.M., Venås, C. 2020. Lessons learnt from green public procurement in the Norwegian construction sector. IOP Conf. Ser.: Earth Environ. Sci. 588, 022017. https://doi.org/10.1088/1755-1315/588/2/022017

Wiik, M.K., Homaei, S., Høyli, R. 2023c. A mapping of Electric Construction Machinery and Electric Construction Sites in Norway, in: Journal of Physics: Conference Series.

Wiik, M.K., Vandervaeren, C., Homaei, S., Henke, L. 2023d. En utslippsfri anleggsprosess i Rogaland (SINTEF Notat No. 48). SINTEF, Oslo, Norway.