Proc. of the European Safety and Reliability Conference (ESREL 2026)
Edited by José C. Matos, Paulo B. Lourenço, Michael Beer, Daniel Oliveira,
Edoardo Patelli, Hélder S. Sousa, Rui A. Silva and Monica Santamaria
Published by Research Publishing, Singapore.
doi: 10.3850/ESREL2026061419_esrel26-p26086-cd

On the use of the ALARP principle for hydrogen systems

Ingrid Glette-Iversen

Department of Safety, Economics and Planning, University of Stavanger, Norway. E-mail: ingrid.glette-iversen@uis.no

Jon Tømmerås Selvik

Department of Safety, Economics and Planning, University of Stavanger, Norway. E-mail: jon.t.selvik@uis.no

Hydrogen systems are increasingly promoted as an important part of the energy transition, yet the development and operation of these systems are associated with significant uncertainties and safety concerns. The ALARP principle, which states that risk should be reduced to a level "as low as reasonably practicable", is commonly referred to in this context. However, there is a lack of clarity and consistency when it comes to how the principle should be operationalized. In the present paper, we present an overview of how ALARP is currently understood and applied in relation to risk assessment and management of hydrogen systems. Drawing on issues previously identified in the broader ALARP literature, we highlight two issues that are of particular relevance for hydrogen systems: (i) assessments are performed at the component rather than system level, risking disproportional outcomes, and (ii) it provides little guidance for evaluating the suitability of risk-reducing measures over time. These issues are discussed in relation to a layered ALARP approach, where the operationalization of ALARP includes judgments on uncertainties, robustness, and broader management concerns. To illustrate the discussion, we use two cases related to the hydrogen context. The paper assesses the extent to which the alternative approach addresses the specified issues. The aim is to provide new insights into the operationalisation of ALARP and its role as risk-informed decision support in hydrogen risk management.

Keywords: ALARP, risk management, hydrogen.

1. Introduction

With the growing implementation and use of hydrogens systems, questions concerning how established risk management principles can be adapted and applied to these contexts have become increasingly important. One such principle is the "as low as reasonably practicable" (ALARP) principle. ALARP is a well-known concept in risk management and safety regulation. Originating from UK safety law, the principle states that risk should be reduced to a level that is "as low as reasonably practicable," balancing the benefits of risk reduction against the costs or burdens of further mitigation (HSE 2001). Over time, ALARP has been adopted and applied in a wide range of industries, including nuclear, oil and gas and the process industry (Baybutt 2014; Hurst et al. 2019). More recently, the principle has also become central in the hydrogen sector, where it is frequently referred to in both scientific literature, regulatory frameworks and guidance documents as a key tool to demonstrate that adequate measures are taken to reduce risk to an acceptable level (Glette-Iversen et al. 2026; Tchouvelev et al. 2019).

A fundamental idea of the ALARP principle, is the so-called 'gross disproportion' criterion, meaning that a risk reducing measure should, as a general rule, be implemented unless it can be proved that the costs are in 'gross disproportion' to the benefits gained. As such, the principle is often seen to represent a so-called "reversed burden of proof", as the default option is to implement the measure. In practice, the gross disproportion criterion is commonly demonstrated using cost-benefit analysis (CBA), in which the expected benefits of the proposed measure are converted into a monetary value and compared to the expected costs. Alternatively, ALARP may be demonstrated by compliance with so-called relevant good practice (RGP), which entails following recognized standards or established industry norms that represent an accepted level of safety (HSE 2001).

Several scholars have questioned the adequacy of traditional operationalizations of ALARP, arguing that the use of CBA to demonstrate the “gross disproportion” criterion represents a narrow focus on expected values, and does not give sufficient weight to uncertainties and other relevant aspects (French et al. 2005; Kletz 2005). In addition to these concerns, several broader issues have been identified in the literature as relevant for the practical implementation of ALARP. While several of these issues and challenges could warrant further investigation, the aim of the present paper is not to provide an exhaustive overview of issues relevant to the operationalization of ALARP, but rather to focus on two selected challenges that allow for a closer examination of the suitability of the layered approach. The first issue considered, is that ALARP assessments are predominantly carried out at component level, with limited consideration of system-wide interactions and cumulative effects (Langdalen et al. 2020). Secondly, although the principle is designed to be applied throughout the lifecycle of a system or facility (Hurst et al. 2019), current approaches and frameworks for operationalizing ALARP contain little guidance on the temporal dimension of the principle, i.e., how the evaluation of risk-reducing measures should be influenced by aspects such as the development of technology, new knowledge or changing regulatory frameworks.

These issues are particularly relevant for hydrogen systems, where the large uncertainties, limited operational experience and rapid technological development challenge the application of established risk management practices and principles (Kashkarov et al. 2022; Mohammadfam and Zarei 2015). Furthermore, hydrogen systems exhibit characteristics that distinguish them from conventional fuel systems, including high flammability, low ignition energy and challenges related to hydrogen embrittlement and leak detection.

To address limitations in existing approaches for demonstrating ALARP, Aven and Vinnem (2007) propose a layered approach that extends the operationalization of the principle beyond traditional CBA. The approach consists of three steps: a crude qualitative assessment, followed by a more detailed analysis, and finally, an assessment of other relevant issues, including uncertainties and broader management concerns.

In this paper, we take a closer look at how the ALARP principle is currently understood and applied in hydrogen-related contexts. Using the layered approach proposed by Aven and Vinnem (2007) as a basis, we aim to explore the extent to which the challenges specified above can be addressed and how the approach might be further adapted to strengthen ALARP as a tool to support risk-informed decision-making for hydrogen systems. To illustrate the discussion, two hydrogen-related cases are used.

2. Current applications and understandings of ALARP in hydrogen contexts

According to current practice, the decision on which risks to reduce ALARP is typically guided by risk tolerability or risk acceptability limits. These limits divide risks into three regions: (1) unacceptable risks, which cannot be justified except under extraordinary circumstances; (2) tolerable risks, which may be accepted if further reduction is impracticable; and (3) broadly acceptable risks, which are so low that no additional measures are deemed necessary (Baybutt, 2014). Risks falling within the middle region (2) are considered relevant for ALARP assessment. In practice, this division is operationalized using risk matrices or F-N curves (representing the cumulative frequency of accidents with N or more fatalities), in which thresholds for each region are defined. For more detailed descriptions on the use of F-N curves, we refer to Aven and Vinnem (2007).

This practice has been widely adopted in the hydrogen industry. However, due to the novelty of hydrogen systems and technology, the thresholds and risk acceptance criteria (RAC) used to support ALARP judgments for these systems are often based on established frameworks and guidelines derived from other, more mature industries, where knowledge and operational data are considerably stronger (Kwak et al. 2024; Glette-Iversen et al. 2026). For example, studies often refer to F-N curves and associated RAC adopted from the Netherlands and UK HSE frameworks when assessing whether risks related to hydrogen facilities fall within the so-called ALARP region (Amer et al. 2024; Kwak et al. 2024; Yu et al. 2023; Mohammadfam and Zarei 2015). In some cases, reference is made to hydrogen-specific RAC proposed by the European Integrated Hydrogen project phase 2 (EIHP2) (Psara et al. 2015; Rosyid 2012; Yuan et al. 2024). However, these criteria build on the same principles and numerical thresholds as those established by UK and Dutch authorities, and thus do not represent a framework specifically tailored to the hydrogen context.

In addition to providing numerical RAC to define tolerable and intolerable regions in an F-N curve, the EIHP2 guidance also outlines how risk matrices can be used as a course assessment in early stages of hydrogen-related projects to identify risks belonging to the ALARP region. By combining judgments on probability and consequence severity, risks are divided into three levels; low, medium and high, where risks belonging to the "medium" category are explicitly categorized as ALARP (EIHP 2003). This approach has been adopted in several hydrogen risk assessment studies (e.g., (Hadef et al. 2020; Xiao et al. 2024).

Once the decision has been made on which risks fall within the ALARP region, the next step in the operationalization of the principle is an assessment of whether these risks are, in fact, reduced to a level "as low as reasonably practicable". In the hydrogen context, there are different perspectives on how this is done. Notably, some authors consider that the placement of risks in the ALARP region per se signifies that the risk is considered reasonable. For example, Gye et al. (2019) state that "After safety barriers are applied to the hydrogen refueling system, the F-N curve moves to ALARP region, meaning the system has reasonable risk (…)" (2019, 1297). In another study related to hydrogen safety, it is stated that existing risks located in the ALARP area can be considered tolerable "if and only if they are consciously under control" (Mohammadfam and Zarei 2015, 13660). This indicates a notion of ALARP as a tool for risk control, not necessarily risk reduction.

As mentioned in the introduction, the most common way of judging whether a risk is ALARP, is using CBA to demonstrate the "gross disproportion". The CBA is also referred to when demonstrating ALARP in relation to hydrogen systems (Hawksworth et al. 2022; Psara et al. 2015; Yuan et al. 2024). However, the literature reveals significant variation in terms of how the approach is interpreted and applied, particularly with respect to the understanding of the 'gross disproportion' criterion. For example, Hawksworth et al. (2022) suggest that risk-reducing measures should be implemented "if the cost is not disproportionate relative to the benefits of risk reduction" (2022, 272). This implies a stricter threshold for implementing measures than the 'gross disproportion' criterion would suggest. Tchouvelev et al. (2019) present an even broader interpretation, stating that the costs of risk reducing measures should not be larger than the benefits. According to this perspective, a measure may be dismissed as soon as it can be demonstrated that costs exceed benefits.

Furthermore, while the ALARP principle generally represents a 'reversed burden of proof', the practical operationalization of the principle in hydrogen contexts indicates that this is not consistently applied. For example, Caliendo and Genovese (2021) suggest that "additional safety measures for the reduction in the risk level would not be necessary in these cases, unless a benefit-cost analysis (…) was able to prove the contrary" (2021, p. 1531). Hence, the burden of proof is essentially inverted; a risk reducing measure requires justification through a CBA rather than being the default option.

Overall, these observations illustrate that there is considerable variation in how ALARP is interpreted and used in hydrogen contexts. Furthermore, current practice indicates that the operationalization of the principle is largely restricted to the use of CBA, with limited consideration of uncertainties, robustness or broader management concerns.

3. The layered approach for ALARP

As an alternative to traditional approaches for demonstrating ALARP that rely mainly on CBA, Aven and Vinnem (2007) propose a layered approach for operationalizing the principle. The approach is motivated by the recognition that decisions about risk reduction cannot be limited to judgments on economic concerns alone; there is a need to take into account a broader range of aspects to fully capture the risks and uncertainties involved (Aven 2009). The layered approach structures the demonstration of ALARP as a three-step process, illustrated in Figure 1.

The first step consists of a crude, qualitative assessment of the benefits and burdens of the risk reducing measure. If the assessment concludes that the costs are not large, gross disproportion has not been demonstrated, and the implementation of the measure can be justified. If the assessment indicates that the costs of implementation are high, a more detailed analysis (typically a CBA or cost effectiveness analysis) is performed (step 2). If the results of these analyses cannot demonstrate gross disproportion, the measure should be implemented.

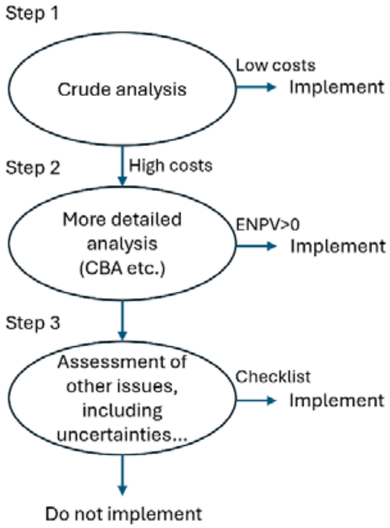

Fig. 1 Layered approach for ALARP (based on Abrahamsen et al. 2017, Aven 2011)

Finally, in cases where the economic analyses do not provide a clear basis for whether or not to implement the measure, the approach calls for explicit considerations of other factors, such as uncertainty, robustness, manageability and broader management concerns (step 3). Aven (2011) suggests that such considerations could be structured using a checklist approach, including questions such as:

- Is there considerable uncertainty related to underlying phenomena, consequences or conditions, and will the measure contribute to reducing these?
- Does the measure significantly increase manageability, for example by improving the ability to control, monitor or respond to unwanted events?
- Does the measure contribute to a more robust solution, capable of coping with unexpected or surprising events?
- Is the measure based on best available technology (BAT)?
- Is there a need for strategic considerations?

If a measure scores positively on a majority of these questions, this provides additional support for concluding that gross disproportion has not been demonstrated, and that the implementation of the measure may be justified. Which aspects to focus on in this stage will depend on the characteristics of the situation at hand.

As noted by Abrahamsen et al. (2017), the practical application of the layered approach relies on how the criteria in the second step are interpreted, and how the checklist-based approach in the third step is formulated. The authors emphasize that the approach allows for a range of interpretations, from contexts where decisions can largely be driven by economic considerations, to contexts where uncertainty-related aspects dominate. Consequently, they argue that the suitability of the layered approach depends on its adoption as a dynamic framework in which the weight given to uncertainties and other concerns is adapted to the specific decision context.

Building on this line of reasoning, the following section uses hydrogen-related case examples to explore a practical application of the layered approach for ALARP. The purpose is not to apply the approach in a prescriptive way, but to use the cases to illustrate how considerations of uncertainty, robustness, system interactions and temporal aspects can be incorporated in ALARP judgments for hydrogen systems. As such, the cases provide a basis for examining to what extent the layered approach can help address the challenges outlined in Section 1, and where further clarification or adjustments could be made to improve its suitability for the hydrogen context.

4. Case examples

This section presents two case examples, reflecting typical decision contexts encountered in the development and operation of hydrogen systems, for which the assessment and management of risk is conducted under conditions of large uncertainties and limited operational experience. The cases are selected to illustrate different trajectories following the implementation of the layered approach. The first case illustrates a situation in which CBA is inconclusive, leading to broader concerns influencing judgments on

ALARP. The second case demonstrates how the approach may lead to decisions at an early stage, given that a measure is justified based on crude analysis or traditional CBA.

4.1. *Case 1: Urban hydrogen refuelling station (HRS) in design phase*

In the initial stages of an HRS project, risk assessments are frequently used to determine whether identified risks fall within acceptable, tolerable (ALARP) or unacceptable regions. The risk assessments could be qualitative, quantitative, or a combination (semi-quantitative). As noted by Xiao et al. (2024), qualitative analyses mostly rely on structured hazard identification methods such as HAZOP or FMEA, while quantitative methods often include the use of failure frequency estimates and consequence modelling. Due to limited hydrogen-specific operational data, failure frequencies are often derived from generic databases or from other industries, such as oil and gas installations. Regardless of assessment methods applied, the analysis is typically structured around individual components or sub-systems, such as storage vessels, compressors and piping. The output of the risk assessment is compared to predefined RAC, either adapted from existing frameworks or hydrogen-specific guidance. In the present case example, the risk assessment reveals a risk of explosion from the storage vessels at the HRS. The risk is placed in the ALARP region, for which the layered approach is applied to judge whether measures to further reduce risk should be implemented. A risk reducing measure considered in the design phase, is relocating the hydrogen storage vessels to a separate area away from the HRS.

The first step includes a crude, qualitative assessment of the benefits and burdens of the identified measure for reducing risk. While the benefits of the measure are high, significantly reducing the exposure to users in the case of explosion, the measure involves relatively high costs related to construction and impacts on the layout of the facility. As the costs cannot be considered negligible, the approach moves on to the next step, in which more detailed analyses (typically CBA) are performed. For the HRS, this step includes using the quantitative risk assessment results and comparing the expected benefits of the measure to the expected economic burden of implementation. The analysis shows that relocating the storage vessels could contribute to reducing the consequences of a potential explosion. However, as the estimated frequency of this type of scenario is relatively low, the monetary value of the benefits (e.g., expected number of lives saved) is significantly smaller than the expected costs of the measure. Thus, the analysis does not provide support for implementing the measure.

In cases where the CBA does not provide a clear basis for decision-making, the layered approach suggests a third step, in which other relevant concerns are evaluated. Among the aspects covered, are uncertainties regarding phenomena, consequences or conditions. In the HRS case, the risk assessment is subject to considerable uncertainties, as the failure frequencies are based on limited hydrogen-related data. The outputs of consequence models are based on a number of assumptions which can be more or less accurate. Relocating the storage vessels would reduce the significance of these uncertainties by physically limiting exposure. Furthermore, introducing a larger distance between users and storage vessels would ensure access control and simplify emergency response in the case of an unwanted event, and thereby improve manageability for the system. The measure could also contribute to increasing robustness; introducing a separation between the storage vessels and users could limit the potential for, and consequences of, unexpected events, cascading effects or human errors.

Thus, while the measure was not justified based on the first two analyses, the considerations from the final step suggest that the measure could contribute to decreased uncertainties and increased robustness. As a result, using the layered approach for ALARP may indicate that the measure should be implemented.

4.2. *Case 2: Hydrogen transport and distribution system*

The second case represents a hydrogen transport and distribution system. The system is currently in operation, supplying industrial facilities and refuelling stations with high-pressure hydrogen. As in the previous case, risk assessments constitute the basis for determining whether the risks associated with the system fall within the ALARP region. The identification of relevant risks follows the same procedure as described in

Section 4.1, including comparisons of risk assessment results with predefined RAC. In the present case, the risk assessment identifies an event in which hydrogen embrittlement causes rupture and leakage in one of the pipeline components. The assessed probability of rupture is relatively low. However, the potential consequences of an undetected leak are significant, and the risk is placed in the ALARP region. A suggested risk-reducing measure is introducing an inspection scheme, including frequent observation, testing and maintenance routines, with the aim of ensuring early detection of potential material embrittlement.

Following the layered approach, a crude assessment (step 1) indicates that the measure introduces costs related to inspection activities, operational downtime and maintenance planning. As these costs cannot be considered negligible, the assessment proceeds to a more detailed CBA, using quantitative data from the risk assessment as a basis. The analysis shows that implementing inspection and maintenance routines could contribute to significantly reducing the potential for an undetected rupture in the pipelines. As the implementation costs are considered moderate, the expected benefits outweigh the expected costs. On this basis, the measure is judged to be justified, and the ALARP demonstration is effectively concluded at this stage.

5. Discussion

The two case examples demonstrate that the suitability of the approach depends on how it is applied, and on which basis. In particular, the degree to which the challenges outlined in Section 1 can be addressed, depends to a large extent on whether these aspects are reflected in the checklist-based evaluation in the third step of the approach. While the concerns presented in the current checklist addresses aspects that are of particular relevance to hydrogen systems, such as uncertainties regarding phenomena and consequences, as well as robustness and the ability to handle unexpected events, there are several important issues that remain uncovered.

5.1.*Component-level perspective*

As emphasized in the case examples, risk assessments are typically structured around individual components or sub-systems, such as storage tanks and pipelines. As the categorization of ALARP risks is determined by the risk assessments, the component-level perspective is inherently adopted in the ALARP evaluations. This is illustrated in the second case, where the proposed inspection and maintenance scheme is assessed primarily in terms of its effect on reducing the probability of pipeline rupture due to material embrittlement. From a system perspective, however, the introduction of frequent inspections and maintenance routines also implies increased human interaction with the system. This could introduce a potential for unwanted events, such as human error during inspection, maintenance-induced failures, or operational disturbances caused by repeated interventions. Such effects are not necessarily captured by the ALARP evaluation, despite their potential relevance for the overall risk of the transport and distribution system. However, the third step of the approach provides an opportunity for addressing this issue; when assessing aspects like uncertainties, robustness and manageability, particular attention could be given to how the considered measure affects the system as a whole, including potential interactions and between sub-systems or components.

5.2.*Addressing changes over time*

In both cases, the ALARP assessment is made with reference to the current status of the system, including existing knowledge base, technological solutions and regulatory requirements. However, changes in knowledge concerning the system, technological solutions and regulatory requirements could significantly influence the judged benefits or burdens of a measure, and lead to different ALARP conclusions. For hydrogen systems, which are characterized by rapid technological developments, knowledge generation and evolving regulatory frameworks, this represents an important limitation. In relation to the first case example, for instance, future developments in knowledge related to hydrogen behaviour, explosion dynamics or human exposure could alter the estimated consequences of a storage vessel failure. Similarly, advances in storage technology, alternative design solutions, or stricter regulatory requirements regarding separation distances could change both the feasibility and perceived necessity of relocating storage vessels. Under such conditions, a measure that is not clearly justified based on current assumptions could become more strongly supported at a later point in time. While such temporal considerations could be incorporated into the third step of the layered approach, for example through reflections on potential changes in knowledge, technological or regulatory developments, they are not explicitly embedded in the current structure of the approach.

Notably, the extent to which either of these issues can be addressed through the layered approach requires that the process reaches the third step. The second case illustrates how ALARP evaluations may be concluded during the first or second step of the procedure, once a measure is justified based on a crude assessment or a traditional CBA. In such situations, no explicit evaluation is made of broader aspects such as system-level effects, robustness over time or the potential implications of future developments. This highlights a fundamental limitation of the approach: even when a third evaluative layer exists, important considerations may remain unaddressed if the process is resolved at an early stage.

6. Conclusions

The present paper takes a closer look at the suitability of the layered approach for operationalizing the ALARP principle in relation to hydrogen systems. Using two case examples, the paper focuses on the extent to which the approach addresses two specified challenges identified in the literature that are particularly relevant for hydrogen contexts, which are characterized by large uncertainties, limited operational experience and rapidly evolving technologies and regulatory frameworks. The challenges relate to the lack of considerations on system-level effects and interactions in ALARP evaluations, as well as limitations in addressing how changes in knowledge, technology or other relevant aspects could influence judgments on ALARP across time.

The case examples illustrate that the layered approach can both enable and limit broader considerations, depending on whether ALARP judgments are resolved early through crude assessments or traditional CBA, or whether the process triggers the final step in which broader concerns are taken into consideration. When ALARP judgments are concluded at an early stage in the process, important aspects such as uncertainties, robustness, manageability and strategic concerns remain unaddressed. On the other hand, when these analyses are inconclusive, the final step of the layered approach opens up for a broader and more comprehensive ALARP evaluation. The degree to which this final step addresses the forementioned challenges, however, depends on how the checklist-based evaluation is structured and formulated. As demonstrated in the case examples, the identification of risks to reduce ALARP is determined by risk assessments that are typically based on a component-level perspective. While the third step of the layered approach provides an opportunity for reflecting system-wide effects and potential interdependencies, the degree to which such considerations are included depends on how the checklist-based evaluation is formulated. Furthermore, the discussion highlights that the layered approach has limitations with respect to capturing how current evaluations on ALARP could change over time, following the development of new knowledge, technology or shifts in regulatory requirements.

While the scope of the present paper focuses on two specific challenges, a number of additional issues related to the operationalization of ALARP have been highlighted in the literature. These issues may also be highly relevant for hydrogen systems, and could warrant further investigation in future research.

Acknowledgement

The authors would like to express their gratitude to the Norwegian Research Council and Consortium Partners in FME HyValue (Norwegian Center for hydrogen value chain research) for financial support and possibility to publish this paper. RCN Project number: 333151.

References

Abrahamsen, Eirik Bjorheim, Jon Tømmerås Selvik, and Håkon Bjorheim Abrahamsen. 2017. ‘A Note on the Layered Approach for Implementing ALARP and the Grossly Disproportionate Criterion’. *International Journal of Business Continuity and Risk Management* 7 (3): 204.

Amer, Mohamed Omar, Seyed Mojtaba Hoseyni, and Joan Cordiner. 2024. ‘Fuelling the Future with Safe Hydrogen Transportation Through Natural Gas Pipelines: A Quantitative Risk Assessment Approach’. *Transactions of the Indian National Academy of Engineering* 9 (4): 763–81.

Aven, Terje. 2009. ‘Perspectives on Risk in a Decision-Making Context – Review and Discussion’. *Safety Science*, Occupational Accidents and Safety: The Challenge of Globalization / Resolving multiple criteria in decision-making involving risk of accidental loss, vol. 47 (6): 798–806.

Aven, Terje. 2011. *Quantitative Risk Assessment: The Scientific Platform*. Cambridge University Press.

Aven, Terje, and Jan Erik Vinnem. 2007. *Risk Management: With Applications from the Offshore Petroleum Industry*. 1. Aufl. Springer Series in Reliability Engineering. London: Springer Verlag London Limited.

Baybutt, Paul. 2014. ‘The ALARP Principle in Process Safety’. *Process Safety Progress* 33 (1): 36–40.

Caliendo, Ciro, and Gianluca Genovese. 2021. ‘Quantitative Risk Assessment on the Transport of Dangerous Goods Vehicles Through Unidirectional Road Tunnels: An Evaluation of the Risk of Transporting Hydrogen’. *Risk Analysis* 41 (9): 1522–39.

EIHP, European Integrated Hydrogen Project [EIHP2]. 2003. *Risk Acceptance Criteria for Hydrogen Refuelling Stations*.

French, Simon, Tim Bedford, and Elizabeth Atherton. 2005. ‘Supporting ALARP Decision Making by Cost Benefit Analysis and Multiattribute Utility Theory’. *Journal of Risk Research* 8 (3): 207–23.

Glette-Iversen, Ingrid, Dikshya Bhandari, and Jon Tømmerås Selvik. 2026. ‘Risk Analysis Frameworks for Hydrogen: A Review and Comparison of Frameworks and Guidelines from Norwegian Regulators’. *Safety Science*.

Gye, Hye-Ri, Seung-Kwon Seo, Quang-Vu Bach, Daeguen Ha, and Chul-Jin Lee. 2019. ‘Quantitative Risk Assessment of an Urban Hydrogen Refueling Station’. *International Journal of Hydrogen Energy* 44 (2): 1288–98.

Hadef, Hefaidh, Belkhir Negrou, Tomás González Ayuso, Mébarek Djebabra, and Mohamad Ramadan. 2020. ‘Preliminary Hazard Identification for Risk Assessment on a Complex System for Hydrogen Production’. *International Journal of Hydrogen Energy* 45 (20): 11855–65.

Hawksworth, Stuart, Thomas Jordan, Kate Jeffrey, and Daniele Melideo. 2022. ‘Risk Assessment’. In *Hydrogen Safety for Energy Applications*. Elsevier.

HSE, Health and Safety Executive. 2001. *Reducing Risks, Protecting People*. HSE Books.

Hurst, John, Jenna McIntyre, Yoshikazu Tamauchi, Hiroshi Kinuhata, and Takashi Kodama. 2019. ‘A Summary of the 'ALARP’ Principle and Associated Thinking’. *Journal of Nuclear Science and Technology* 56 (2): 241–53.

Kashkarov, Sergii, Mohammad Dadashzadeh, Srinivas Sivaraman, and Vladimir Molkov. 2022. ‘Quantitative Risk Assessment Methodology for Hydrogen Tank Rupture in a Tunnel Fire’. *Hydrogen* 3 (4): 512–30.

Kletz, T. A. 2005. ‘Looking Beyond ALARP: Overcoming Its Limitations’. *Process Safety and Environmental Protection*, Hazards XVIII, vol. 83 (2): 81–84.

Kwak, Hyunjun, Minji Kim, Mimi Min, Byoungjik Park, and Seungho Jung. 2024. ‘Assessing the Quantitative Risk of Urban Hydrogen Refueling Station in Seoul, South Korea, Using SAFETI Model’. *Energies* 17 (4): 867.

Langdalen, Henrik, Eirik Bjorheim Abrahamsen, and Håkon Bjorheim Abrahamsen. 2020. ‘A New Framework To Idenitfy And Assess Hidden Assumptions In The Background Knowledge Of A Risk Assessment’. *Reliability Engineering & System Safety* 200 (August): 106909.

Mohammadfam, Iraj, and Esmaeil Zarei. 2015. ‘Safety Risk Modeling and Major Accidents Analysis of Hydrogen and Natural Gas Releases: A Comprehensive Risk Analysis Framework’. *International Journal of Hydrogen Energy* 40 (39): 13653–63.

Psara, N., M. van Sint Annaland, and F. Gallucci. 2015. ‘Hydrogen Safety Risk Assessment Methodology Applied to a Fluidized Bed Membrane Reactor for Autothermal Reforming of Natural Gas’. *International Journal of Hydrogen Energy* 40 (32): 10090–102.

Rosyid, O. A. 2012. ‘Risk Analysis for the Infrastructure of a Hydrogen Economy’. *Jurnal Ilmiah Teknologi Energi*, September 19, 98011.

Tchouvelev, Andrei V., Sergio P. De Oliveira, and Newton P. Neves. 2019. ‘Regulatory Framework, Safety Aspects, and Social Acceptance of Hydrogen Energy Technologies’. In *Science and Engineering of Hydrogen-Based Energy Technologies*. Elsevier.

Xiao, Han, Bei Li, Haoshen Yu, and Chi-Min Shu. 2024. ‘Dynamic Risk Analysis of Hydrogen Refueling Station Gas Cloud Explosions Based upon the Bow-Tie Perspective’. *International Journal of Hydrogen Energy* 82 (September): 89–101.

Yu, Xirui, Depeng Kong, Xu He, and Ping Ping. 2023. ‘Risk Analysis of Fire and Explosion of Hydrogen-Gasoline Hybrid Refueling Station Based on Accident Risk Assessment Method for Industrial System’. *Fire* 6 (5): 181.

Yuan, Wenhao, Jingfeng Li, Rong Yangyiming, Jianbin Peng, Junlong Xie, and Jianye Chen. 2024. ‘Quantitative Risk Assessment of China’s First Liquid Hydrogen Refueling Station’. *Risk Analysis* 44 (4): 907–17.