Proceedings of the 35th European Safety and Reliability & the 33rd Society for Risk Analysis Europe Conference
Edited by Eirik Bjorheim Abrahamsen, Terje Aven, Frederic Bouder, Roger Flage, Marja Ylönen

doi: 10.3850/978-981-94-3281-3_ESREL-SRA-E2025-P8190-cd

On the use of the precautionary principle in the context of the hydrogen systems

Dikshya Bhandari

Faculty of Science and Technology, University of Stavanger, Norway, Dikshya.bhandari@uis.no

Jon Tømmerås Selvik

Faculty of Science and Technology, University of Stavanger, Norway, jon.t.selvik@uis.no

Ingrid Glette-Iversen

Faculty of Science and Technology, University of Stavanger, Norway, ingrid.glette-iversen@uis.no

Eirik Bjorheim Abrahamsen

Faculty of Science and Technology, University of Stavanger, Norway, eirik.b.abrahamsen@uis.no

The precautionary principle is a decision-making tool commonly applied in the EU to manage high-risk systems. It’s also relevant outside the EU, for example related to hydrogen developments in Norway. When it comes to its use and understanding, there exist different definitions and interpretations of the principle. These definitions and interpretations represent significant variations with respect to the extent to which they incorporate specific approaches and prescriptions for how the principle should be operationalized. This paper reviews and compares the EU’s definition and interpretation of the precautionary principle with an alternative definition proposed in the Society for Risk Analysis (SRA) glossary and applies them to the case of hydrogen systems. The EU has established detailed guidelines on how to apply the precautionary principle. Some of the specific recommendations in these guidelines are challenging to implement in the current hydrogen context due to insufficient information about hydrogen scaling and associated risks. Especially, the EU’s definition is vague on how to handle scientific uncertainty. SRA’s definition focuses on understanding scientific uncertainties and emphasize the need for action but do not specify the extent of such action. The paper suggests that combining both interpretations of the precautionary principle can better address the risks associated with hydrogen projects in Norway.

Keywords: Energy transition, Hydrogen, Hydrogen scaling, Human error, Precautionary principle, Risk management

1. Introduction

Hydrogen energy has become central to the transition to sustainable energy systems in Europe. The goals set by the European Union (EU) for reducing emissions by 2030 and 2050 rely heavily on the use of hydrogen (EU, 2021). In Norway, industries are adopting hydrogen and ammonia as key solutions to meet emission reduction targets. Norway considers hydrogen energy to be a critical part of its plan for a more sustainable future (Cheng et al., 2024).

Achieving Norway's ambitious energy goals and aligning with the EU’s broader clean energy transition requires the rapid scaling of green hydrogen infrastructure. However, this scaling comes with significant risks and uncertainties related to safety, infrastructure, and technological feasibility (Razmjoo et al., 2021). Managing the complexities of this evolving technology requires robust principles to handle the inherent risks and uncertainties and make informed decisions.

One such principle for making risk-informed decisions under uncertainty is the precautionary principle (PP), which has been widely applied in the EU to manage high-risk systems. See e.g. discussion in Goldner Lang (2021) on the application of the precautionary principle related to the COVID-19 and free movement of persons.

The EU (n.d.) describes this principle as follows: *"The precautionary principle is an approach to risk management, where, if it is possible that a given policy or action might cause harm to the public or the environment and if there is still no scientific agreement on the issue, the policy or action in question should not be carried out. However, the policy or action may be reviewed when more scientific information becomes* available".

This definition is standardized through EU law. However, the interpretation is debated, partly due to the flexible and complex character, allowing for an inconsistent application by policy makers (Donati, 2021; De Smedt & Vos).

An authoritative source providing an alternative definition and interpretation of the PP is the glossary from the Society for Risk Analysis (SRA). The glossary has been developed by a group of senior risk scientists with support from members of the society, and covers key terms, concepts and principles within the field of risk analysis. SRA's glossary allow for multiple definitions to be provided for the entries to encompass a broader spectrum of interpretations; allowing for a representation of different perspectives and aims. Considering the diverse nature of some entries, it might be inappropriate to converge upon a singular unified definition. For the PP, there are two definitions listed (SRA, 2018):

a) "e*thical principle that if the consequences of an activity could be serious and subject to scientific uncertainties, then precautionary measures should be taken or the activity should not be carried out at all"*;

b) "a principle expressing that regularity actions may be taken in situations where potentially hazardous agents might induce harm to humans or the environment, even if conclusive evidence about the potential harmful effects is not (yet) available."

Each represent a distinct interpretation of the PP. Definition a), also proposed in Aven (2011), is the most proactive of the two, focusing on the need for risk reduction, and deemed as most appropriate for the discussion presented in this paper (referred to in this paper as 'SRA's interpretation'). Definition b) represents a more passive mindset; focusing on permitting regularity actions in situations where there is a human or environmental threat regardless of evidence. It opens for a consideration of precautionary actions but does not require any action.

The EU's definition and SRA's definition present similar perspectives on the conditions under which the PP should be invoked: the lack of scientific information on the potential consequences of an activity. However, while SRA's perspective holds the principle to be a fundamental, normative principle to guide decision-making, the EU's interpretation is followed by detailed prescriptions for how the principle should be operationalized as outlined in communications from the EU Commission (EC, 2000). These differences could lead to conflicting regulatory approaches, creating uncertainty for industries, investors, and policymakers. Consequently, progress toward sustainable hydrogen solutions might slow, hindering innovation and regulatory alignment.

Despite extensive research on the PP, limited applied research has been conducted on its use in hydrogen systems. A search in the Web of Science database using the keywords '*hydrogen*' and '*precautionary principle*' returned no relevant results, which shows the gap in research on the application of the PP for hydrogen energy systems. By using two case studies of hydrogen energy systems, this paper explores the practical implications of the EU's and SRA's definition and interpretation of the PP for decision-making under uncertainty in the context of hydrogen infrastructure development in Norway.

2. Interpretations of the precautionary principle

The PP originated in the early 1970s as the German Vorsorgeprinzip (foresight principle) and entered international law after the 1987 North Sea Conference. It was formalized in the 1992 Rio Declaration and has since been invoked in numerous international declarations, treaties, and conventions, as well as incorporated into the environmental policies of several countries. The principle has been applied across various domains (Schettler et al., 2013). Following the Rio Declaration, the EU made the PP an official rule by including it in Article 191 of the Treaty on the Functioning of the European Union (TFEU). Since then, the principle has become a key decision-making tool in the EU for managing high-risk systems (EU, n.d.).

While the PP is frequently referred to in both scientific and non-scientific contexts, there have been substantial debate concerning its rationale, effectiveness and practical application (see e.g., Rechnitzer, 2022; Sandin, 1999). Among the key issues discussed, is the extent to which interpretations of the PP should be inherently linked to decision rules and prescriptions for its operationalization. According to some scholars, a set of criteria to guide its application could help decision-makers structure their thinking in a way that fosters debate and agreement (Aldred, 2013; Gardiner, 2006). However, the decision-rule interpretation of the PP has been questioned by several authors (Aven, 2023; Rechnitzer, 2022), the central argument being that as the PP is intended for situations characterized by scientific uncertainties, frameworks for prescriptive decision-making cannot be justified.

In addition to providing a general definition of the PP, as referenced in the previous section, the guidance document, prepared by the European Commission, outlines the conditions under which the PP should be applied (EC, 2000). In the guidance document, it is stated that the principle should be seen as a tool for managing risks and can only be applied after conducting a scientific evaluation of the available data about the risk (known as a risk assessment). For the PP to be triggered, the risk assessment must identify potential harmful effects from a product or activity and demonstrate that the scientific data is insufficient to determine the level of risk. Once these conditions are met, a political decision is required to determine if precautionary measures should be taken (Mossman & Marchant, 2002). The scientific evaluation should also "where possible, identify the degree of scientific uncertainty" (EC, 2000). While the guidance document specifies during which stages of the scientific method 'scientific uncertainties' could arise, no clear interpretation of the concept is provided.

According to the EC (2000), if the PP applies, its application must follow five key principles.

- Measures should be proportional to the risk and include less restrictive alternatives.
- They must be non-discriminatory, meaning comparable situations should not be treated differently.
- Measures should be consistent with those already adopted in similar circumstances.
- The costs and benefits of action and inaction should be assessed.
- Precautionary measures should be reviewed and adjusted as new scientific data becomes available.

The principles are intended to serve as authoritative guidance on how to operationalize the PP. In the interpretation represented by the definition in SRA's glossary (SRA, 2018) as referred to in Section 1, the PP is defined with respect to two main aspects; the potential for severe consequences, and the existence of scientific uncertainties in relation to what these consequences could be. If both conditions apply, the PP can be justified, leading to the implementation of precautionary measures or the decision to refrain from conducting the activity. While the concept of 'scientific uncertainties' is not provided an explicit definition in SRA's glossary, Aven (2011) presents a thorough discussion of the concept, relating it to the difficulty of establishing accurate prediction models for the consequences considered. According to this line of interpretation, the principle should be seen as "expressing a normative obligation, position, or perspective" (Aven, 2023). Following this reasoning, the main motivation for applying the PP should not be to adhere to specific approaches for its operationalization, but rather "to introduce measures to avoid extreme outcomes and at the same time allow more knowledge to be gained and the uncertainties being reduced" (ibid.).

3. Comparison of the interpretations using two hydrogen cases

Using two cases to illustrate the discussion, the present section compares the EU's and SRA's interpretation of the PP in relation to their practical application for hydrogen infrastructure development. For each case, the paper identifies the actions, the actors, and the quantum of action following the EU's interpretation of the PP, as well as SRA's interpretation.

3.1. *Case 1: Safety and environmental concerns in hydrogen scaling*

Hydrogen has been used as an energy carrier since the late 19th and early 20th centuries (Zuttel et al., 2008). Today, most hydrogen is currently produced through steam methane reforming, a method that is not environmentally friendly unless coupled with carbon capture and storage (Domingues et al., 2013). The production of hydrogen using renewable energy sources is still relatively new, and there are ongoing debates about whether these sources can supply sufficient hydrogen to meet growing demands in industrial and domestic sectors (Flynn et al., 2012). Economic and technical feasibility remain key reasons why hydrogen is not widely adopted, and significant risk concerns are associated with green hydrogen production through water electrolysis (Guo et al. 2024). Technical safety concerns, such as the possibility of hydrogen leakage, pipeline failure, fire hazards, and land and water use, are valid concerns in the context of hydrogen infrastructure.

The expected large-scale growth in hydrogen use will lead to new hydrogen production, storage, and distribution facilities that are different from the industrial facilities used in the past. Razmjoo et al. (2021) have noted that the complexities of scaling hydrogen infrastructure mean that even well-understood risks could behave differently in real-world, large-scale deployments. A significant issue related to scaling hydrogen from lab-scale testing to wider system adoption quickly. Humans already maintain much more risky systems with a good level of safety (e.g., mass aviation), but these systems did not transition from lab to wide-scale adoption within a short timeframe. In the case of hydrogen, the plan for rapid large-scale implementation presents significant challenges, as it increases the potential for important aspects of risk and uncertainty to remain concealed or inadequately addressed; There is not enough time or opportunity to identify and analyze problems, understand their causes, make necessary improvements, or even learn from mistakes.

3.1.1. Application of the precautionary principle

The potential for unforeseen interactions between technical risks in large-scale hydrogen infrastructure creates scientific uncertainty and the possibility of severe consequences. According to the EU's and SRA's interpretation of the PP, such situations warrant precautionary action.

3.1.2. Actor and action

According to the EU interpretation of the PP, a scientific assessment is required in order to determine whether or not precautionary measures should be implemented. However, relying on the results of risk assessments to justify the need for precautionary measures is problematic, as the principle is intended to support decision-makers in cases where such assessments are not able to produce information with the required accuracy. This is also the case for hydrogen scaling, where the uncertainties associated with the activities are to a large extent unquantifiable in the sense that we do not have any prior experience, and the uncertainty of any scientific predictive model is likely to be extremely large.

In contrast, the interpretation by SRA (2018) takes a more proactive approach by arguing that the PP should serve as a guiding principle for decision-making specifically when risk assessments cannot provide clear answers on what the potential consequences or outcomes could be.

Furthermore, the EU's interpretation prescribes that precautionary measures are the responsibility of policymakers and regulators, who base their decisions on scientific assessments. These actors must work collaboratively to ensure that risks related to hydrogen infrastructure are managed effectively. While the EU's interpretation provides a structured framework for the application of the PP, this approach relies on clear political strategies and a well-defined regulatory framework. In the context of hydrogen systems, where such strategies and frameworks are still in the early stages of development, such a reliance represents significant challenges.

According to SRA's definition, responsibility (actors) for precautionary actions is assigned to those directly involved in the system's operation or development, such as project developers and industry stakeholders. However, in the context of hydrogen systems and the broader energy transition, the responsibility for precautionary actions may extend beyond individual stakeholders to include society as a whole. This encompasses local governments, interest groups, citizens, legislators and other participants within the hydrogen value chain. Regulatory bodies play a crucial role, but the inclusive nature of hydrogen infrastructure requires a collective approach involving all relevant actors. Aligning the range of different values and concerns, and ensuring an effective and holistic implementation of the PP in such cases requires a high level of coordination and communication among the different stakeholders.

3.1.3. Quantum of action

The EU has outlined five principles for applying precautionary measures as outlined in section 2.

The first principle of proportionality is not applicable for the present case, as the large-scale deployment of hydrogen infrastructure lacks complete knowledge of all possible risks. Proposing less restrictive alternatives becomes difficult because the true nature of risks is uncertain, meaning that there is not sufficient data to distinguish between what constitutes "acceptable" and "unacceptable" risks. Additionally, since some risks may not manifest until much later, the PP may require immediate action to mitigate long-term harm, even without full scientific evidence. In this case, proportionality involves balancing precautionary measures with the uncertainties of long-term impacts. The second principle, Non-discrimination, is relevant here, as the specific risks of hydrogen systems are not yet fully clear; the regulation of hydrogen should treat its risks similarly to those of natural gas. The third principle, consistency with existing measures, is applicable as hydrogen infrastructure is planned to build on existing natural gas infrastructure. Lessons from natural gas infrastructure can be used in this context, which provides a basis for developing safety protocols that are aligned with past practices. The fourth principle, assessing the costs and benefits of action and inaction, is essential as it involves comparing the benefits of adopting hydrogen, such as reduced emissions and long-term sustainability, with the consequences of not acting, like failing to meet climate goals. However, while economic analysis is important, non-economic factors such as public health, safety, and environmental impact must also be considered. Society's willingness to accept higher costs for long-term health and environmental protection may justify investment in hydrogen infrastructure, even when the full costs are not yet clear. Furthermore, consideration must be given to the approaches and tools used to analyse the costs and benefits of action and inaction. Traditional cost-benefit analyses often rely on the use of expected values, which can be a poor metric in contexts where uncertainties are large, as in the case of hydrogen systems. The fifth principle, review and adjustment based on new information is highly relevant for this case, as the technologies of hydrogen systems are still developing. Continuous research and monitoring are required, and they must remain flexible and allow for rapid adaptation to new information, especially as risks become clearer through practical implementation.

SRA's interpretation suggests that the level of action required depends on the degree of scientific uncertainty. It argues that the PP should be applied in a context-dependent way. When scientific uncertainty is high such as when it is difficult to predict potential outcomes or model consequences precautionary measures should be implemented to minimize potential risk. However, prescriptive approaches for how to address these risks is not clearly defined in SRA's interpretation of the PP. This lack of information could create difficulties for stakeholders in taking action to manage these risks.

3.2. *Case 2: Safety and environmental risks from human errors*

Safety and proper handling of hydrogen technologies heavily depend on human involvement during installation, operation, maintenance, and decommissioning. Since hydrogen is different from more familiar fuels like petrol or natural gas, individuals working with these systems may not have the same level of knowledge and experience, and relying on experience with familiar fuels may be a disadvantage, as human bias and established procedures can lead to unsafe outcomes. In panic situations, solutions that were effective in those domains may be applied without thorough consideration, often resulting in counterproductive actions. The assumption that hydrogen systems will operate similarly to LNG or natural gas and that human resources and infrastructure from these domains can be easily replicated can also be misleading (Ricci et al., 2006).

3.2.1. *Application of the precautionary principle*

The potential for human errors represents high scientific uncertainties that are unlikely to be entirely eliminated, even when all factors are thoroughly considered from the outset. Furthermore, the potential consequences of human error in hydrogen systems can be severe, leading to fires, explosions or major environmental impacts. Additionally, such incidents could also undermine public trust in hydrogen as a safe and viable energy solution. Given these characteristics, the application of the PP is highly relevant for this type of scenario.

3.2.2. Actors and Actions

Both the EU’s and SRA’s interpretation of the PP offer guidance on who should be responsible for implementing precautionary measures.

The EU’s perspective emphasizes the role of policymakers, regulators, and scientific bodies in guiding and managing the application of the PP. These actors are responsible for conducting comprehensive risk assessments, and ensuring that all relevant risks, including those related to human errors, are adequately evaluated and handled. In the hydrogen context, this means establishing clear safety protocols, mandating specialized training requirements and ensuring compliance with relevant safety standards. The EC guidance on the operationalization (EC, 2000) can offer a structured procedure for such measures, allowing for a stronger consistency in the application of the principle and related safety practices. SRA’s perspective places greater responsibility on operators, developers, and industry stakeholders who work directly with hydrogen systems. The perspective acknowledges that the implementation of the PP is essentially determined by the values, concerns and priorities of these actors, and should be tailored to the specific context under consideration.

However, the rapid advancement of hydrogen infrastructure could pose significant challenges for both lines of interpretation. Accelerated development timelines could lead to gaps in operator training, incomplete or inaccurate safety protocols, and a rapid scaling of hydrogen technologies without sufficient data on human-system interactions. Furthermore, the transfer of human resources and infrastructure from LNG or natural gas operations to hydrogen systems could introduce biases and outdated practices. Operators and maintenance personnel could apply safety protocols and emergency responses that are inappropriate or ineffective for hydrogen-specific risks, leading to poor decision-making. Research is needed to understand better the risks associated with assumptions that hydrogen systems will operate similarly to LNG or natural gas and that human resources and infrastructure from these domains can be easily replicated (Martin et al., 2024). These assumptions may overlook the unique complexities and risks inherent in hydrogen systems.

3.2.3. Quantum of action

Determining how much training is sufficient remains a challenging question, as human error will always carry some level of risk.

Not all of the EU's quantum of actions are applicable in this situation. For example, finding measures proportional to risk and including less restrictive alternatives is quite tricky, as human error is hard to predict, and using less restrictive measures could increase the potential for unwanted outcomes. Similarly, the costs and benefits of action and inaction are difficult to implement in this case, as the costs associated with human error are difficult to quantify. There are uncertainties regarding the potential damage that could result from human errors, and the amount of training required remains unclear. As hydrogen systems become available, safety protocols and training programs can be updated to reduce the likelihood of human error. The prescribed action of non-discrimination can be misleading; because hydrogen has different properties and risks, it may be challenging to treat hydrogen the same as fuels we already know well, like natural gas or LNG. However, safety measures from natural gas or LNG provide a helpful foundation, but there is a need for a specialized protocol. Assuming that safety measures for other fuels are fully applicable to hydrogen may lead to overconfidence and an increased risk of human error. The prescribed action of consistency with existing measures, in this context, can be understood as applying lessons learned from natural gas systems, but adjusting these measures to the unique properties and risks associated with hydrogen systems. If the safety protocols are not adjusted, the human biases with these systems may lead to incorrect actions. For example, emergency procedures effective for natural gas might be applied to hydrogen without considering its specific hazards, which could make the situation worse. Finally, the EU emphasizes that the precautionary measures should be reviewed and adjusted as new scientific information becomes available. This guidance is particularly in this context; as more data from real-world applications of hydrogen systems becomes available, safety protocols and training programs can be updated to reduce the likelihood of human error.

SRA's interpretation suggests that the quantum of action depends on the level of scientific uncertainty. It suggests that the PP is context-dependent, which also highlights the distinction between scientific uncertainty and moderate uncertainty and argues that the principle should apply when scientific uncertainties are present. Moderate uncertainties can be dealt with through traditional risk assessments. SRA's interpretation, which suggests stopping activities when scientific uncertainty is high, may not apply here, as human error is inherently unpredictable and cannot be modelled with sufficient accuracy. Decisions regarding training requirements should be made on a continuous basis and adjusted as more information becomes available.

4. Discussion

Our analysis shows that both interpretations provide guidance under scientific uncertainty. Each has limitations in addressing the full scope of hydrogen system risks.

The EU interpretation provides a clear framework for determining the extent of precautionary measures. It specifies that measures should be proportional to the risk, include less restrictive alternatives, be consistent with similar past measures, and involve a cost-benefit assessment. Additionally, precautionary measures should be reviewed and adjusted as new scientific information becomes available. However, the EU's interpretation focuses on whether there is any scientific agreement and does not clearly cover the full specter of scientific uncertainty. It is difficult to apply ideas like proportionality and cost-benefit analysis. At this early stage of development, the ability to adapt measures as new information emerges is the most relevant aspect of the EU's approach to make a decision in the hydrogen context in Norway.

SRA's interpretation highlights the condition of scientific uncertainties as the main criteria for applying the PP. An important implication of this perspective is the acknowledgement that the principle is designed for risky situations where science cannot provide clear answers. This challenges the quality of decision support for informed decisions. Furthermore, it highlights the aspect that; what is considered scientific uncertainties is essentially a value judgment. Consequently, the application of the principle "depends on subjective decision-making, which is influenced by the values, preferences, and priorities of the decision-makers" (Aven, 2023). As these are all context-dependent, Aven (2016) argue that establishing precise recommendations and guidelines for application of the PP would be problematic. However, without clear guidance on the extent of necessary actions, decision-makers may struggle to implement appropriate measures.

Following the above discussion, it can be argued that both interpretations of the PP have strengths and weaknesses. However, as indicated in SRA's glossary (SRA, 2018), it's not always appropriate to converge upon one interpretation, and a polycentric reference to multiple interpretations representing different perspectives and aims, might represent the best way forward. The two interpretations can then complement each other to guide decision-making in the context of scaling hydrogen infrastructure.

4. Conclusion

The present paper focuses on the interpretation of the PP as given by the EU, as well as an alternative interpretation of the PP frequently referred to in risk and safety literature. We further evaluate these interpretations, focusing on two key case studies: the upscaling of the hydrogen energy system and human error related to hydrogen systems. Scaling hydrogen energy systems to meet ambitious global targets introduces unique challenges related to risk and safety. The PP becomes crucial given the scientific uncertainties surrounding hydrogen production and distribution. Human error is a significant source of uncertainty in hydrogen infrastructure.

Both the EU's and SRA's interpretation provide important insights into the application of the PP, but neither fully addresses the quantum of action required in the hydrogen case. The lack of clear guidance on the extent of precautionary measures poses challenges for stakeholders involved in hydrogen scaling. As hydrogen technologies continue to evolve, a more adaptive, context-specific approach to the PP will be essential for managing the risks associated with this emerging energy source. The application of precautionary measures must be dynamic, proportional to the level of uncertainty, and open to continuous reassessment as more data and insights become available.

The two interpretations of the PP complement each other and can in pair lead to more informed decision-making in the context of hydrogen energy systems in Norway.

Acknowledgement

The authors are thankful to the Norwegian Research Council and Consortium Partners in FME HyValue (Norwegian Center for hydrogen value chain research) for allowing them to publish this paper. RCN Project number: 333151.

References

Aldred, J. (2013). Justifying precautionary policies: Incommensurability and uncertainty. Ecological Economics, 96, 132–140.

Aven, T. (2011). On different types of uncertainties in the context of the precautionary principle. *Risk Analysis*, 31(10), 1515-1525.

Aven, T. (2016). Risk assessment and risk management: Review of recent advances on their foundation. European Journal of Operational Research, 253(1), 1–13.

Aven, T. (2023). A risk and safety science perspective on the precautionary principle. *Safety Science*, 165, 106211.

Cheng, C., van Greevenbroek, K., & Viole, I. (2024). The competitive edge of Norway's hydrogen by 2030: Socio-environmental considerations. International *Journal of Hydrogen Energy*, 85, 962-975.

De Smedt, K., Vos, E. (2022). The Application of the Precautionary Principle in the EU. In: Mieg, H.A. (ed.): The Responsibility of Science. Springer, Berlin, Germany.

Donati, A. (2021). The precautionary principle under European Union law. Hitotsubashi Journal of Law and Politics,49, pp.43-60

EC - European Commission. (2000). Communication from the Commission on the precautionary principle. https://op.europa.eu/ en/publication-detail/-/publication/21676661-a79f-4153-b984-aeb28f07c80a/language-en.

EU. (2021). European Climate Law. PE 27/2021/ REV/1.https://climate.ec.europa.eu/eu-action/european-climate-law_en

EU. (n.d.). Precautionary principle. EUR-Lex. https://eur-lex.europa.eu/EN/legal-content/glossary/precautionary-principle.html.

Flynn, R., Ricci, M., & Bellaby, P. (2012). Ambiguity, complexity and uncertainty surrounding the hazards of hydrogen and public views of emergent risks. *Journal of Risk Research*, 15(4), 373-387.

Gardiner, S. M. (2006). A core precautionary principle. Journal of Political Philosophy, 14(1), 33–60.

Goldner Lang, I. (2021). "Laws of Fear" in the EU: The Precautionary Principle and Public Health Restrictions to Free Movement of Persons in the Time of COVID-19. European Journal of Risk Regulation, 14(1): 141-164

Guo, L., Su, J., Wang, Z., Shi, J., Guan, X., Cao, W., & Ou, Z. (2024). Hydrogen safety: An obstacle that must be overcome on the road towards future hydrogen economy. *International Journal of Hydrogen Energy*, 51, 1055-1078.

Martin, P., Ocko, I. B., Esquivel-Elizondo, S., Kupers, R., Cebon, D., Baxter, T., & Hamburg, S. P. (2024). A review of challenges with using the natural gas system for hydrogen. *Energy Science & Engineering*, 12(10), 3995-4009.

Mossman, K. L., & Marchant, G. E. (2002). The precautionary principle and radiation protection. *RISK*, 13, 137.

Razmjoo, A., Kaigutha, L. G., Rad, M. V., Marzband, M., Davarpanah, A., & Denai, M. (2021). A Technical analysis investigating energy sustainability utilizing reliable renewable energy sources to reduce CO2 emissions in a high potential area. *Renewable Energy*, 164, 46-57.

Rechnitzer, T. (2022). Precautionary principles. In: Rechnitzer, T. (ed.), Applying Reflective Equilibrium: Towards the Justification of a precautionary principle (pp. 63–99). Springer International Publishing.

Ricci, M., Newsholme, G., Bellaby, P., & Flynn, R. (2006). Hydrogen: Too dangerous to base our future upon. Institution of Chemical Engineers Symposium Series, Manchester, UK.

Sandin, P. (1999). Dimensions of the precautionary principle. Human and Ecological Risk Assessment: An International Journal, 5(5), 889-907.

SRA - Society for Risk Analysis. (2018). Society for Risk Analysis Glossary.

Zuttel A., Borgschulte, A., & Schlapbach, L. (2008). History of hydrogen. In: Zuttel, A., Schlapbach, L., Borgschulte, A., & (eds.): Hydrogen as a Future Energy Carrier. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim.