



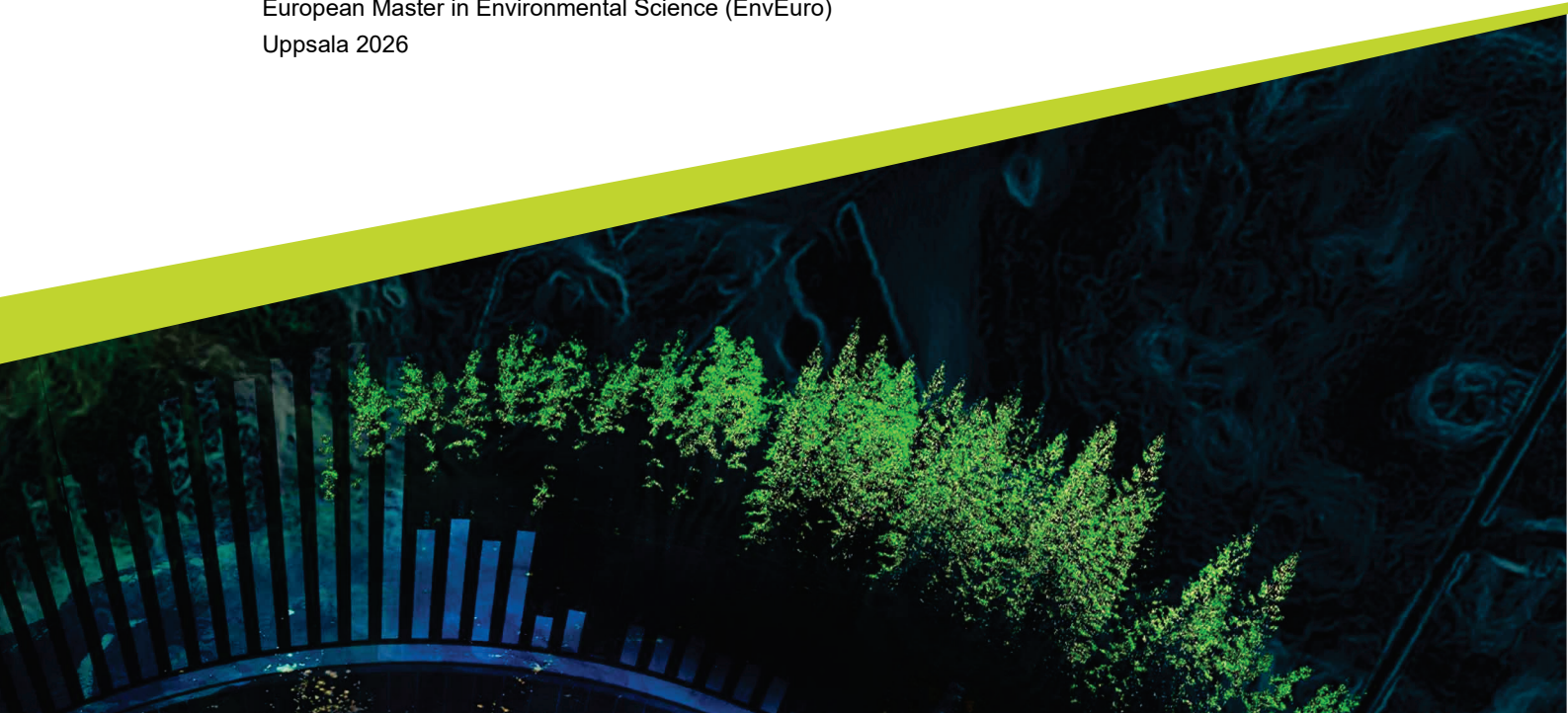
# **Understanding Responsibility in the Communication of Emerging Technologies:**

## The Case of Nuclear Fusion in Germany

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# Understanding Responsibility in the Communication of Emerging Technologies: The Case of Nuclear Fusion in Germany

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## Abstract

How emerging technologies are communicated shapes public understanding, political decisions, and ultimately the futures we collectively choose (Borup et al. 2006). Yet little is known about how the people involved in this communication understand their own responsibility. Existing research has examined how communication shapes technology expectations and public perception, but the role of individual communicators' understandings and responsibility practices has received considerably less attention. This master's thesis analyses how communicators involved in public communication understand and enact responsibility. To do so, nuclear fusion is used as a case, since it combines high public expectations with significant technological uncertainty and environmental risk, and is relevant to global sustainability transitions. To investigate this, eight semi-structured interviews were conducted with communicators from different professional backgrounds, including science journalism, parliamentary technology assessment advisory, and institutional communication, all embedded in the German public discourse on nuclear fusion. The findings were grounded in Hans Jonas's concept of responsibility, the responsible research and innovation framework, and science communication. The findings suggest that the role understanding of the communicating person plays a crucial role in how they perceive and enact responsibility in their communication, with notable differences between science journalists and science communicators. It also became clear that there are three operational levels of responsibility: ethical, political, and practical. Responsible communication requires engagement at all three levels simultaneously. By focusing on democratic values, the findings also suggest that there is a risk of placing too much responsibility on one person, ignoring that, in a democratic process, all involved stakeholders, as well as the public, should be part of it. This requires communication practices that are transparent, inclusive, and distributed across all involved actors, rather than placed on individual communicators alone. Emerging technologies such as nuclear fusion carry implications not only for future energy systems but also for ecological and societal conditions across generations. Understanding them, therefore, requires not only technological expertise but also a critical examination of how they are communicated and who bears responsibility for that communication.

*Keywords:* emerging technologies, environmental communication, nuclear fusion, responsibility, Responsible Research and Innovation, science communication, uncertainty

# Table of contents

|   |           |
|---|-----------|
| <b>List of tables</b> .....                             | <b>5</b>  |
| <b>List of figures</b> .....                            | <b>6</b>  |
| <b>Abbreviations</b> .....                              | <b>7</b>  |
| <b>1. Introduction</b> .....                            | <b>8</b>  |
| 1.1 Problem Statement .....                             | 9         |
| 1.2 Why is nuclear fusion a good case? .....            | 10        |
| 1.3 Research Question .....                             | 10        |
| <b>2. Nuclear fusion</b> .....                          | <b>12</b> |
| <b>3. Literature Review</b> .....                       | <b>14</b> |
| 3.1 Philosophical understanding of responsibility ..... | 14        |
| 3.2 Responsible Research and Innovation .....           | 16        |
| 3.3 Science communication and science journalism .....  | 18        |
| 3.4 Communicating under uncertainty .....               | 20        |
| <b>4. Material and method</b> .....                     | <b>22</b> |
| 4.1 Qualitative semi-structured interviews .....        | 22        |
| 4.2 Reflective thematic analysis.....                   | 24        |
| 4.3 Reflexivity and Role of the Researcher .....        | 25        |
| <b>5. Results</b> .....                                 | <b>27</b> |
| 5.1 Language use .....                                  | 27        |
| 5.2 Technological understanding .....                   | 30        |
| 5.3 Communication practice .....                        | 32        |
| 5.4 Communicator self-reflection .....                  | 37        |
| <b>6. Discussion</b> .....                              | <b>41</b> |
| 6.1 Practical level.....                                | 41        |
| 6.2 Ethical level.....                                  | 43        |
| 6.3 Political level .....                               | 45        |
| 6.4 Outlook and limitations.....                        | 46        |
| <b>7. Conclusion</b> .....                              | <b>48</b> |
| <b>AI Disclosure</b> .....                              | <b>49</b> |
| <b>References</b> .....                                 | <b>50</b> |
| <b>Popular science summary</b> .....                    | <b>55</b> |
| <b>Appendix 1 Interview Guideline</b> .....             | <b>57</b> |

# List of tables

|  |    |
|--|----|
| Table 1: Interview participants .....                    | 23 |
| Table 2: Summary of analysed themes and their codes..... | 27 |

# List of figures

Figure 1: Overview of the reflexive thematic analysis process, including ten initial codes and the emergent themes .....24

# Abbreviations

| Abbreviation | Description                         |
|--------------|-------------------------------------|
| RRI          | Responsible Research and Innovation |

# 1. Introduction

Technological innovations are often considered key solutions to the environmental crisis, including, but not limited to, sustainable energy systems, carbon capture and storage, or geoengineering. Technological innovations are not only shaped by scientific and technical advances, but also by expectations, visions, and promises about the future they might enable (Borup et al. 2006). Such expectations play an important role in the development of emerging technologies, as they might mobilise resources and sustain long-term research efforts (Brown & Michael 2003). This is particularly relevant for technologies whose practical utility has not yet been demonstrated, and which therefore rely on continued investment and societal support.

Expectations about technological futures are constructed and circulated through language use (Brown et al. 2000). The way in which these expectations, uncertainties, and hopes are communicated can affect public understanding of these technologies, as well as political decisions and funding (Borup et al. 2006). Expectations can thereby shape not only how technologies are understood but also how their development pathways are envisioned and supported. Furthermore, when technologies are in early stages of development, both the technological process itself and external factors create conditions of high uncertainty. In such situations, shared expectations can become particularly powerful in steering technological development in certain directions (van Lente 2012). The way such technologies are communicated might therefore influence public understanding as well as political decision-making and funding, which highlights the importance of reflecting on how emerging technologies are communicated, particularly with regard to handling uncertainty and the use of promises.

A prominent example of a technology strongly shaped by long-term expectations and future-oriented narratives is nuclear fusion. Nuclear fusion is the process in which two atomic nuclei form a heavier nucleus and release a huge amount of energy, which is said to help solve the world's energy problems and fossil fuel reliance (Sadik-Zada et al. 2024). This is the same process that powers the sun, which is why fusion is often described as “bringing the sun to Earth”, emphasising its potential as a future energy source. At the same time, nuclear fusion has been characterised by recurring delays and shifting timelines, as reflected in the often-cited remark that fusion is a technology that is “always 30 years away” (The Oxford Scientist 2022).

This coexistence of strong promises, persistent uncertainty, and delays makes nuclear fusion a particularly interesting case for examining the role of

communication in shaping technological expectations within environmental transitions. While communication about fusion often highlights the technology's transformative potential, it also requires addressing uncertainties about timelines and feasibility. This creates a tension between generating enthusiasm and maintaining realistic expectations.

While some research has examined the role of expectations and communication regarding emerging technologies, less attention has been paid to the perspectives of those who actively communicate them. People involved in communicating about nuclear fusion, for example, as science journalists, research institution communicators, or parliamentary technology assessment advisors, act as important intermediaries between scientific researchers and the public. Through their work, they help shape how fusion is understood and what expectations are associated with it.

This thesis analyses how fusion is communicated and described and takes a step back to focus on the actors involved in the process of communicating about nuclear fusion in Germany. Germany serves as a particularly relevant national context, as it has a long history of nuclear energy debate and an active fusion research landscape. This thesis aims to understand how these communicators perceive their own role and how they reflect on their responsibility for communicating a technology characterised by high promise and many uncertainties. Nuclear fusion is a useful example to understand how communicators position themselves with respect to expectations surrounding such technologies, as well as how uncertainties, risks, timelines, and benefits are communicated. Such analysis might also yield insights for the development of other upcoming technologies within environmental transitions that involve substantial uncertainties as well as multiple interests and stakeholders.

## 1.1 Problem Statement

A lot of research has examined the role of expectations in shaping technological development, particularly within the sociology of expectations and studies on technology hype and science communication (Brown & Michael 2003; Borup et al. 2006; van Lente 2012). Previous work has also highlighted the importance of responsible research and innovation as well as the role of communication in fostering responsible engagement between science and society (Owen et al. 2012; Stilgoe et al. 2013). Nuclear fusion as an emerging energy technology has received considerable attention in both scientific research and media reporting (Gi et al. 2020; Bustreo et al. 2024; Schultz 2025).

Despite this growing body of literature, less attention has been paid to how individuals involved in science communication themselves understand their role

and responsibility in shaping expectations about emerging technologies (for an exception, see Fischhoff et al. 2011 and Kueffer & Larson 2014). There is a limited empirical insight into how communicators navigate the tension between communicating technological promises and addressing scientific uncertainty.

Hopes for nuclear fusion are strongly tied to a sustainable, abundant future. This thesis considers these hopes and expectations as an outcome of societal communication processes, which are navigated by those engaging in public communication in their everyday practice. Focusing on the reflections, perceived roles, and reported activities of these communication professionals, this thesis contributes to environmental communication scholarship.

## 1.2 Why is nuclear fusion a good case?

Nuclear fusion offers a particularly suitable case study for examining these questions, as it combines high expectations with significant uncertainties. When research into nuclear fusion began, it was led and funded by various countries, such as the United States, Germany, and the United Kingdom. In recent years, both private investors and startups have entered the research field (ITER 2023). Consequently, there are many different stakeholders engaged with the topic of nuclear fusion, not only scientific researchers, but also private investors, politicians, and others. The issue is also highly relevant to the public, as there is hope that nuclear fusion could provide clean energy, which would be significant given future prospected energy needs.

## 1.3 Research Question

Building on the problem statement outlined above, this thesis addresses the following main research question:

How do communicators involved in the public communication of nuclear fusion understand and enact responsibility under conditions of high uncertainty in Germany?

To address this question, there are two sub-questions, leading the research:

1. How do people engaged in public communication of nuclear fusion see their own role in relation to responsibility?
2. What understandings of responsibility do communicators draw upon, and where do these reach their limits in practice?

This thesis is structured as follows. Section 2 provides background on nuclear fusion as an emerging technology. Section 3 presents the literature review and

conceptual framework, covering philosophical understandings of responsibility, Responsible Research and Innovation, science communication and science journalism, and communication under uncertainty. Section 4 outlines the methodological approach, including the qualitative semi-structured interview design, reflexive thematic analysis, and the researcher's positionality. Section 5 presents the empirical findings organised around four themes. Section 6 discusses the findings in dialogue with the literature, and Section 7 draws conclusions, addresses limitations, and outlines directions while emphasising the relevance of the thesis.

## 2. Nuclear fusion

The global primary energy demand is rising, with fossil fuels still supplying nearly 80% of the world's total energy consumption in 2024 (IEA 2025). Projections indicate that energy demand will continue to grow as populations and economies expand, with total energy use expected to rise between 8% (under stated policies scenarios) and 14% (under current policies scenarios) by 2035 (IEA 2025). Electricity demand is projected to grow faster than total energy use, accelerating the “age of electricity”.

Germany has set ambitious climate targets, aiming to reduce greenhouse gas emissions by 80–95% by 2050 compared to 1990 levels (Bundesministerium für Wirtschaft und Klimaschutz (BMWE) 2016). Germany has currently reduced its climate-damaging emissions by 48% and can still achieve the goal of reducing emissions by 65% by 2030 compared to 1990 levels. The energy sector plays a decisive role in reducing greenhouse gas emissions (Umweltbundesamt 2026).

Although most experts' assessments conclude that nuclear fusion will not contribute materially to meeting German climate targets by 2050 (Lerede et al. 2023; National Academy of Science and Engineering 2024; Wimmers et al. 2026), it is frequently presented as a potential energy source currently discussed in public and funded by German politicians (ntv Nachrichten 2024; Bundesministerium für Forschung, Technologie und Raumfahrt 2025).

Nuclear fusion seeks to harness the energy released when light atomic nuclei, typically isotopes of hydrogen, overcome their electrostatic repulsion within a high-temperature plasma (Köberle & Gehrke 2017; Girka 2019). To achieve and sustain the required conditions on Earth, which can reach temperatures of 100 million kelvin and higher, as well as, depending on the approach, high pressures, pose major engineering challenges. Two principal approaches dominate: the magnetic confinement (e.g., tokamaks such as the International Thermonuclear Experimental Reactor (ITER) under construction in southern France and stellarators such as Wendelstein 7-X (W 7-X) located in Germany) and the inertial confinement (e.g. laser-driven fusion at National Ignition Facility (NIF) located in California) (Merian 2024).

Despite important scientific milestones reached over the past 70 years, many questions remain unresolved regarding power-plant deployment. Key open issues include, among others:

1. Material and component lifetime: Reactor components must withstand extreme heat fluxes and intense neutron irradiation, which drive

displacement damage and helium embrittlement. Suitable materials remain under development (Landtag Nordrhein-Westfalen 2026).

2. Tritium fuel cycle and governance: Tritium occurs only in trace amounts naturally and must be bred from lithium within the plant. Managing a large tritium inventory raises technical, regulatory, and safety challenges. Tritium is radioactive (half-life = 12,3 years) and has military relevance (Landtag Nordrhein-Westfalen 2026).
3. Grid integration and operations: Future plants must be compatible with an increasingly renewables-based grid. Operational profiles and flexibility requirements remain an open design space (Grünwald 2024).
4. Waste and decommissioning: Fusion does not produce high-level spent fuel like fission, but it does generate activated structural materials that require conditioning, storage, and disposal (Girka 2019). The amount of low- and medium-level radioactive waste is greater in the nuclear fusion life cycle than in the nuclear fission life cycle (Grünwald 2024).
5. Proliferation and dual use: Overall proliferation risk is lower than in fission electricity, yet tritium has military relevance, and some knowledge and technologies could be dual-use (Grünwald 2024).
6. Economics and timelines: Development and capital costs are high, and commercialization timelines are uncertain. Fusion has progressed more slowly than anticipated in earlier projections (Dunlap 2021).

If future fusion reactors could generate net electricity, several benefits are often cited. Unlike nuclear fission, fusion does not rely on a self-sustaining chain reaction, which means the risk of runaway accidents, such as the one that occurred at Chernobyl, is considered to be significantly lower (Girka 2019; Sadik-Zada et al. 2024), the small amount of highly radioactive waste compared to nuclear fission and the potentially abundant fuel inputs of deuterium and lithium as well as the “low” carbon energy production (Lerede et al. 2023).

In addition to the potential technological benefits of nuclear fusion, other factors cast it in a positive light. These include, for example, the recent emergence of privately funded startups working on nuclear fusion, as well as the positive narratives employed by German policymakers, backed by substantial financial commitments. Germany has pledged over 2 billion euros by 2029 toward developing the world’s first nuclear fusion plant (Bundesministerium für Forschung, Technologie und Raumfahrt 2025). These aspects will be examined from a communicative perspective in the remainder of this thesis.

## 3. Literature Review

The following literature review provides important background information and theoretical foundations for this thesis. The literature search was conducted in various online databases, such as Boku Lit-Search, Primo, Scopus, and the Web of Science. In addition, the snowball sampling method was used to explore in greater depth and broaden the scope of the analysis.

### 3.1 Philosophical understanding of responsibility

Responsibility is often understood as “something that is your job or duty to deal with” (Cambridge Dictionary 2026), but in ethics and political theory, the understanding is richer and more differentiated.

Already in Aristotle’s works, we find a clear account of responsibility centred on the individual. In his *Nicomachean Ethics* III, he begins by distinguishing voluntary from involuntary action because, on voluntary passions and actions, praise and blame are bestowed, on involuntary, pardon (and sometimes pity) (Aristotle 350 AD). Responsibility for Aristotle rests on what is “up to us”. Actions that originate in the agent and are chosen to make the agent an appropriate target of praise or blame.

In 1957, the American philosopher Richard McKeon argued in his book “The Development and the Significance of the Concept of Responsibility” that there are three related dimensions to responsibility. (1) the external dimension of responsibility, which means the responsibility enforced by institutions and comes from the outside and is defined by laws, courts, and political systems. (2) the internal dimension, which refers to the personal moral reflection of a person. Here, the individual considers the consequences of their actions, and their decisions are guided by ethical principles and values. (3) the reciprocal dimension, which is a broader level of responsibility and exists within society and culture. Here, responsibility is shaped by the individual character as well as by the structures of society (McKeon 1957).

I will focus primarily on the concept of responsibility as articulated by the German-American philosopher Hans Jonas. In 1979, Jonas published the book “The Imperative of Responsibility – In Search of an Ethics for the Technological Age”<sup>1</sup>, in which he examines the concept of responsibility in an era marked by an emerging “global technological research dynamic” (Jonas 1979:9). Hans Jonas extends the idea by distinguishing retrospective responsibility (for what has been

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<sup>1</sup> Translations by the author from the German original.

done) from prospective responsibility (for foreseeable future consequences), arguing that technological power shifts the ethical burden toward long-range, institutional stewardship.

The rest of this chapter first outlines Jonas's account, then presents the Responsible Research and Innovation (RRI) framework as a practical operationalisation and finally connects these strands to current debates in science communication, with nuclear fusion as the case study.

Hans Jonas developed an ethics of responsibility for the technological age, in which humanity is expanding its power over nature. In his view, this fundamental shift in human action requires a new ethics. Under this framework, humans no longer bear only "ex post" responsibility for what has been done, but also "ex ante" responsibility, that is, for "the matter to which my actions lay claim" (Jonas 1979:174). This "ex ante" responsibility is determined by the extent of the power that an actor or institution holds over the well-being of others. This creates a "duty of power" (Jonas 1979:174). Overall, this means that responsibility extends not only to the agent's will but also to what is brought about by the object's vulnerability and plight. This may involve, for example, children, future generations, or nature (Nielsen-Sikora & Gordon 2017).

Jonas developed based on Kant's categorical imperative, a new "ecological" imperative that is appropriate for the new type of human behaviour and reads as follows: "act in such a way that the effects of your actions are compatible with the permanence of genuine human life on earth"<sup>2</sup> (Jonas 1979:36). Because technological interventions involve deep uncertainties and catastrophic downside risks, he proposes a "heuristic of fear" and the priority of the bad over the good prognosis: when forecasting is uncertain, plausible worst-case outcomes should weight more heavily than optimistic projections (Jonas 1979:63).

This understanding of responsibility is forward-looking, role-based, and precautionary, aiming to secure long-term human and environmental conditions rather than simply assigning blame after damage has occurred. In this sense, Jonas's account functions as a principle of stewardship for the future, extending moral considerations across generations and requiring that power over complex systems be exercised with disciplined foresight and restraint. A similar logic can be found in policy contexts, particularly in the European Union's precautionary principle. This principle allows preventive action in situations where scientific uncertainty exists and potential risks to human health or the environment are significant. As defined by the European Commission, the precautionary principle

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<sup>2</sup> Original: „Handle so, daß die Wirkungen deiner Handlung verträglich sind mit der Permanenz echten menschlichen Lebens auf Erden“.

is a principle that enables a rapid response to a possible danger to human, animal, or plant health, or to protect the environment (European Commission 2000). This demonstrates how Hans Jonas's philosophical approach can serve as a guiding principle for the current issues and decisions we must grapple with.

## 3.2 Responsible Research and Innovation

Responsible Research and Innovation (RRI) refers to the collaboration of diverse actors throughout the entire research and innovation process to align science and technology with societal values, needs, and expectations in the European Context (European Commission 2012). Its aim is to ensure that scientific research and technological development take into account their effects and potential impacts on the environment and society.

RRI is designed to align scientific advancement with societal values through inclusive, democratic, and transparent processes. Innovations should be socially desirable and therefore integrate ethical reflections early in their lifecycle to avoid long-term negative consequences (Owen et al. 2012; Stilgoe et al. 2013). This expresses the shift from "science in society" to "science for society", which is particularly relevant for innovations characterised by high uncertainty, such as nuclear fusion (Owen et al. 2012). Stilgoe et al. define responsible innovation as "taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al. 2013:4). This resonates with Hans Jonas's imperative of responsibility and its attention to distant, uncertain futures.

To implement responsibility in practice, Stilgoe et al. (2013) propose four interrelated dimensions: Anticipation, Reflexivity, Inclusion, and Responsiveness.

Anticipation encourages researchers to ask "what if...?" questions and explore plausible future pathways, because the future impacts of technologies are impossible to predict. This is especially relevant because emerging fields often carry highly optimistic promises of major transformation, requiring what is called an "ethics of promising" (Stilgoe et al. 2013:1571). Anticipation involves disentangling present hype from future reality.

Reflexivity involves systematic reflection by individuals and institutions on their own assumptions, values, limits of knowledge, and role responsibilities. Cultivating reflexivity expands role responsibility toward a broader moral responsibility, considering potential societal consequences, and makes reflexivity a public matter. It also asks the scientists to blur the boundary between their narrow "role responsibilities" and their wider "moral responsibilities" to society and citizens (Stilgoe et al. 2013:1568). This aligns with Hans Jonas "duty of

power”, where the persons wielding technical power must also accept the moral weight of its potential future impacts (Jonas 1979:174).

Inclusion seeks the meaningful participation of those who may be affected by innovation (Jakobsen et al. 2019). This can be done through multi-stakeholder partnerships, forums, citizens’ juries, as well as deliberative mapping and focus groups (Stilgoe et al. 2013). Here, the approach aims to ‘open the door’ for a participatory process. Moore summarised it as “the technical is political, the political should be democratic, and the democratic should be participatory” (Moore 2012:1). This indicates that technological innovations such as nuclear fusion should be part of a democratic and participatory process to align them with the RRI standard. An action plan issued by the German federal government emphasises that the public should be involved in implementing measures to help build the world’s first fusion plant in Germany (Bundesministerium für Forschung, Technologie und Raumfahrt 2025). Whether this constitutes a successful implementation of the dimension of inclusion will be further analysed.

Responsiveness entails the capacity to change direction considering new knowledge, public values, or emerging concerns. Responsiveness can be understood in two different ways: as the reaction to a previous situation or as a response. This requires openness, willingness to understand, and listening (Pellizzoni 2004). Achieving this requires situating innovation within a political economy of science that is attentive to both, purposes (why) and products (what) (Stilgoe et al. 2013).

The governance of emerging technologies is complicated by what Collingridge (1980) termed the “dilemma of control”. At early stages of technological development, when intervention is still feasible, the social consequences of an innovation remain largely unknown; yet by the time negative impacts become apparent, sociotechnical entrenchment makes change difficult and costly (Liebert & Schmidt 2010). RRI does not resolve this dilemma but offers a framework for navigating it more deliberately. By addressing the four dimensions of anticipation, reflexivity, inclusion, and responsiveness, RRI encourages proactive engagement with uncertainty before lock-in occurs, rather than waiting for harm to materialise.

This orientation shows a broader shift in governance thinking, from retrospective accountability – assigning blame after harm has occurred – toward prospective stewardship, or taking care of the future already in the present (Stilgoe et al. 2013; Stahl et al. 2017). This merging with Jonas’s “heuristic of fear” that counsels prudence in the face of potentially catastrophic, but uncertain consequences. In this spirit, responsibility is not just an internal scientific virtue, but a negotiated

relationship between practicing scientists and the broader public (Stilgoe et al. 2013).

In addition to the potential benefits of conducting the RRI methodology, several risks need to be considered. Owen and Stilgoe (2012) warn that RRI is becoming a “new label for business as usual”, used to acquire societal and ethical legitimacy for “precommitted policy objectives” rather than facilitating genuine transformation (Owen et al. 2012:757). This instrumental use often focuses on implementing a preselected technology pathway rather than choosing which pathway to follow, effectively turning RRI into a tool to smooth the path of innovation. RRI often targets individual technologies rather than the technological system. As a result, it often focuses on changes within the system rather than on changes of the system (Cuppen et al. 2019).

A significant risk is that RRI may moralise responsibility at an individual level, placing an unrealistic burden on scientists while again ignoring structural issues (Owen et al. 2013). Because modern innovation is a complex structure of many different actors, consequences are rarely attributable to a single actor, and focusing on individual accountability can lead to organised irresponsibility where the systemic drivers of risk remain unaddressed (Stilgoe et al. 2013).

It also shouldn't become the innovation governance for acceptance, rather than governance for critical reflection. Moore (2010) argues that this is problematic because the “technical is political” and should therefore be subject to authentic participatory democracy rather than instrumental “invited” engagement (Moore 2010:793).

Methodologically, RRI focuses heavily on identifying and mitigating unwelcome situations or adverse impacts. Scholten et al. (2016) point out that this negative framing can create a barrier to stakeholder absorption, making it difficult for the public to understand the broader technical complexities and social purposes of the research. To address these limits, they suggest that RRI should learn from science communication to develop more positive narratives that resonate better with the audience group. This should help to not just throw data on risk away, but to authentically collect and reflect on public values to modify research practice.

### **3.3 Science communication and science journalism**

Effective Science communication should enable people to make sound choices, conveying the benefits, risks, and other consequences of decisions (Fischhoff 2013). Its aim is not to force agreement but to foster a shared understanding of relevant facts. In democratic societies, the public has both a right and a need to engage with science because it shapes everyday life and underpins many public

and policy decisions (Durant et al. 1989). Communication in this domain is inherently interdisciplinary, drawing on social science, communication studies, and domain expertise, and it is embedded in broader cultural, political, and socio-economic contexts (Bucchi & Trench 2014).

In this thesis, I will focus on two professional fields of communication that are relevant in the discussion of nuclear fusion. On one hand, science communication through researchers, institutional communication leaders, and parliamentary technology assessment advisors. On the other hand, science journalism, which is a branch of journalism that reports on science in the public interest under editorial norms (e.g., accuracy, independence, etc.) and media logics (e.g., deadlines and audience) using formats such as articles, audio, and video (Bucchi & Trench 2014; Molek-Kozakowska 2016). Science journalists typically prioritise newsworthiness and accountability, especially within commercial media (Molek-Kozakowska 2016), whereas institutional communicators foreground relevance for stakeholder and organisational goals (Bucchi & Trench 2014). These differences shape how topics are framed, selected, and presented.

Framing is central to how audiences make sense of science. Frames allow the definition of problems, the attribution of responsibility, and the explanation of why the issues matter (Gamson & Modigliani). It is known that the framing of the news coverage influences the attention of the audience (Bubela et al. 2009). The usage of language and metaphors might influence how powerful the communication is. The responsible use of metaphors as well as the introduction of them is important to avoid hyperbole (Kueffer & Larson 2014). This is particularly relevant for emerging technologies such as nuclear fusion, where metaphors like “the holy grail” are often used in newspaper coverage. The usage of such metaphors presents nuclear fusion in a light of hope and could potentially build expectations, while ignoring uncertainties and risks.

Due to institutional and technological changes, science communication is becoming increasingly complex, as globally interconnected issues intertwine scientific, economic, and political dimensions, involving a wide range of stakeholders and giving rise to diverse expectations (Bubela et al. 2009). In the case of nuclear fusion, this includes long time horizons, technical uncertainties, and mixed stakeholder interests across public research and private investment.

Across both fields of communication practice, it is important to communicate science in accordance with good practice and ethical standards. This means reliance on peer-reviewed literature, transparent sourcing, and checking facts before using them (Kueffer & Larson 2014). Role conceptions help explain

variation in how communicators approach these tasks. Pielke (2007) distinguishes four ideal-typical roles for scientists in a policy context:

1. Pure Scientists (this means no engagement with policy; focus is solely on knowledge production)
2. Science Arbiter (answers specific factual questions posed by decision-makers)
3. Issue Advocate (narrows the range of options by promoting a preferred course of action)
4. Honest Broker (expands the range of options by clarifying alternatives and trade-offs)

While these roles are originally developed for scientists, they can also inform how professional communicators and science journalists position themselves.

In the context of nuclear fusion, the roles communicators ascribe to themselves likely influence how the technology is presented and debated. Risks and uncertainties play a crucial role in these presentations and will be discussed and presented in the following chapter.

### 3.4 Communicating under uncertainty

Building on the role conceptions outlined above, a central responsibility for science communicators and science journalists is how they characterise and convey uncertainty. Following Pielke, uncertainty arises when “more than one outcome is consistent with our expectations” in a given situation (Pielke 2007:55). For Keynes, something truly uncertain is something “we simply do not know” (Keynes 1937:214). For him, things like long-range geopolitical situations or long-term economic forecasts are truly uncertain.

For practical purposes in emerging technologies, three forms are especially relevant. First, epistemic uncertainty, which is uncertainty due to imperfect knowledge and can be reduced by gaining information (Abdo et al. 2017). Second, random processes, where each element has an equal chance to occur. Here, the uncertainty can be quantified but not reduced (Pielke 2007). Third, scenario uncertainty, which describes the uncertainty around external boundary conditions and future pathways for which there is no agreed probability distribution (Walker et al. 2003).

Because decisions must be made under uncertainty, communication becomes a mediating practice; which is discussed by Fischhoff and Davis (2014) in the beginning of their paper with: “All science has uncertainty. Unless that

uncertainty is communicated effectively, decision makers may put too much or too little faith in it” (Fischhoff & Davis 2014:1). They propose three linked tasks for communicators (a) characterising uncertainty (what is known, unknown, and why), (b) assessing its magnitude and implications (e.g., ranges, confidence, scenarios) and (c) conveying uncertainty in ways that afford decision makers the detail their choices warrant. Crucially, they distinguish between non-persuasive communication, which helps decision-makers identify choices that serve their own interests, and persuasive communication, which steers them toward choices others have already made. This distinction is particularly salient in the context of nuclear fusion, where science communication operates in a highly contested societal debate, and the boundary between informing and persuading is difficult to maintain.

Role conceptions imply different uncertainty practices. Issue advocates tend to emphasise confidence in preferred options and may downplay residual uncertainty. The honest broker presents alternative courses with associated ranges and trade-offs, while the science arbiters delineate what can and cannot be done in response to decision-makers' questions, and the pure scientists merely transfer knowledge about the uncertainties (Pielke 2007). In the context of fusion technology, where long time horizons, technical uncertainties, and mixed public and private interests come together, these roles might shape how risks, timelines, and expectations are publicly framed and presented.

## 4. Material and method

I adopt an approach that combines critical realism with social constructivism. Ontologically, I assume that nuclear fusion as a technology involves real physical mechanisms and limitations that are subject to the laws of nature. Epistemologically, our knowledge is fallible, incomplete, and theory-laden. Drawing on social constructivism and symbolic interactionism, I treat meanings as produced through language, symbols, and interaction (Mead 1934; Blumer 1969). The sociopolitical realities behind a technology, such as problem definitions, promises, risks, hopes, and governance, are constituted through ongoing communication among social actors. This does not deny material reality but rather emphasises that our reality is created through social interactions (Hallgren 2017).

As a researcher, my goal is to understand the various social constructions of meaning; therefore, I used qualitative interviews to capture different perspectives of social actors (Robson & McCartan 2016). To analyse them, I went through the interviews in an iterative process, searching for codes, themes, underlying meanings and understandings of reality. They are described in the following sections and subsequently discussed.

### 4.1 Qualitative semi-structured interviews

The data collection comprises eight semi-structured qualitative interviews. Therefore, I used an interview guide developed from a review of the literature on responsibility, science communication, responsible research and innovation, scientific journalism, and nuclear fusion projects in Germany (see Appendix 1). I had 7 overarching questions, which I divided into the following seven categories: Background and general information, Self-understanding, Uncertainty and expectations, Hype and Hope, Responsibility, Language use, Reflexivity, and Limits. For each of the seven main questions, I had prepared follow-up questions to ask as needed to dive deeper into the topic. Each interview lasted between 45 and 60 minutes and was conducted in German, as this was the native language of both the researcher and all interviewees. The interviews were transcribed in German, and the data were coded in German. Afterward, the used quotes were translated into English. When translation raised issues of meaning or nuance, I iterated between the German originals and the English versions and revised the translations accordingly.

The questions were formulated to allow the interviewee a considerable latitude in their answers, enabling the interviewer to probe for detail and explore nuances in

the participants' perspectives. In some interviews, the sequence of the questions was adapted to the flow of the conversation, and sometimes unplanned follow-up questions were introduced when they promised additional depth (Robson & McCartan 2016). As noted by Bryman (2012), semi-structured interviews are well-suited to eliciting what participants themselves consider relevant, which is possible while doing qualitative semi-structured interviews (Bryman 2012). This format enabled the interviewer to understand how the participants make sense of the topics and what they wish to communicate (Edwards & Holland 2013).

Participants were purposively selected to represent different stakeholder perspectives. To obtain a broad and detailed view of the topic, individuals with diverse professional backgrounds were included. A total of three interviews were conducted with science journalists working for public service broadcasting and one with a person working for a private media outlet. Two additional interviews were conducted with experts working in the field of parliamentary technology assessment, and one interview each was conducted with a communications officer from a research institution and a representative from a German environmental research institution.

All participants had professional experience in science communication and a connection to nuclear fusion. Potential participants were identified through stakeholder mapping and contacted via email. Zoom interviews were the most suitable method given the participants' geographical distribution and professional workloads. The platform's audio- and video-based format allowed the interviewer to observe nonverbal cues (e.g., facial expressions) and fostered a personal, conversational setting comparable to in-person interactions (Archibald et al. 2019). With informed consent, interviews were audio-recorded and subsequently machine-transcribed. The transcript was then corrected manually to verify its accuracy. The data were stored locally and will be deleted after the publication of the master's thesis.

*Table 1: Interview participants*

| Interviewee | Background   |
|-------------|--|
| SJ1         | Science journalist for public service broadcasting |
| SJ2         | Science journalist for public service broadcasting |
| SJ3         | Science journalist for public service broadcasting |
| J1          | Journalist for private media                       |
| C1          | Head of communication for a research institution   |
| PA1         | Parliamentary technology assessment advisor        |
| PA2         | Parliamentary technology assessment advisor        |
| S1          | Scientist at a research institution                |

## 4.2 Reflective thematic analysis

To analyse the interview data, I used the reflexive thematic analysis as outlined by Braun and Clarke (2006). Thematic analysis "is a method for identifying, analysing and reporting patterns (themes) within data" (Braun & Clarke 2006:4). The coding and theme development were guided by my analytical interest and the study's research question (Braun & Clarke 2006) and were neither purely inductive nor deductive. Accordingly, I adopted an abductive logic, which means that I iteratively moved between surprising or tension-filled observations in the interviews and relevant theoretical ideas in order to develop the most plausible interpretations (van Hulst & Visser 2024).

The analysis involved repeated cycles of different steps, based on the data analysis after Braun and Clarke (2006). The different steps are detailed in Figure 1.

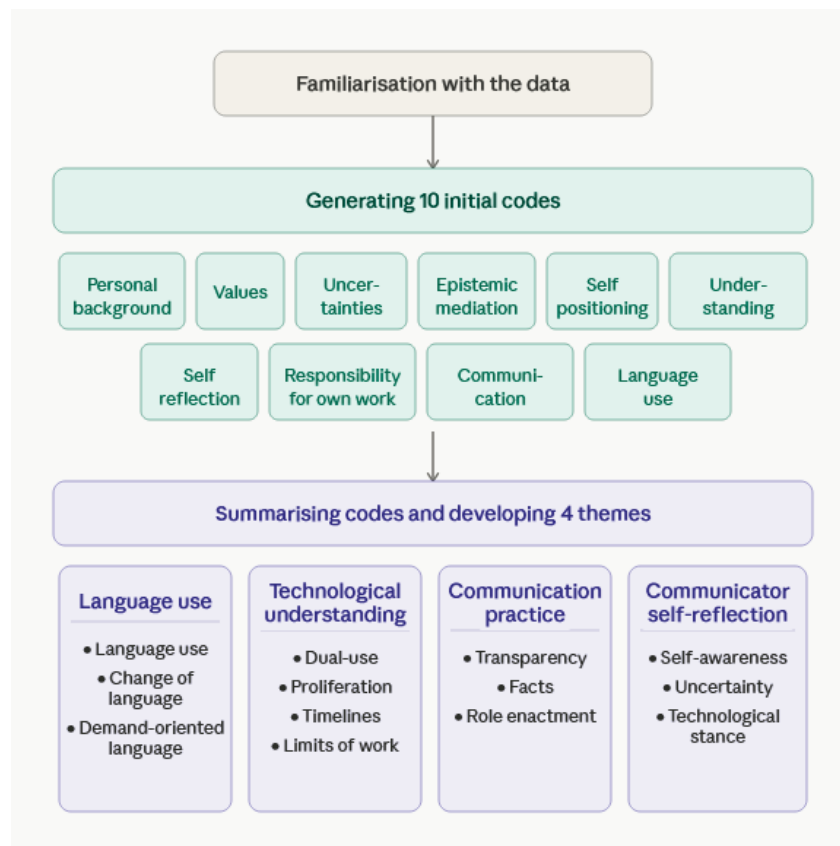


Figure 1: Overview of the reflexive thematic analysis process, including ten initial codes and the emergent themes

My initial coding was strongly informed by surprises and tensions that arose within and across interviews. I returned to the literature and relevant theoretical concepts, which in turn shaped subsequent cycles of coding and theme

refinement. This iterative “puzzling” from data to theory and back provided the basis for constructing the final set of themes (van Hulst & Visser 2024).

I started coding my data with 10 relatively broad codes to structure it in the first step. As Braun and Clarke (2006) note, writing should begin at the start of the analysis and continue throughout the data analysis process. Therefore, I wrote short texts for each code document, including quotes. This allowed me to identify tension and divergences between interviewees. Afterward, I decided on 4 themes with subthemes, as shown in Figure 1.

The results of the reflexive thematic analysis will be presented in Chapter 5 and subsequently discussed.

### 4.3 Reflexivity and Role of the Researcher

In this thesis, I examine how communicators understand their role and how they understand and enact responsibility in their communication. I assume their roles influence their understanding of the world. As a researcher analysing communication practice and the enactment of roles and responsibilities, I also occupy a role that influences my perspective and analytical choices. While reflecting on this, I acknowledge that “objectivity” is neither possible nor the aim of this study.

To engage with the “subjectivity” transparently, I used the reflexive thematic analysis approach developed by Braun and Clarke. This is a six-phase, iterative process that moves back and forth between data and my developing interpretations. This required a continual reflexive work, questioning my assumptions, discussing my interpretations, and keeping my theoretical and disciplinary background in mind. As Braun and Clarke argue, researchers cannot free themselves from their theoretical background; instead, they should articulate and reflect on it (Braun & Clarke 2006).

My disciplinary background is in natural science. Working with a social science approach was both challenging and “eye-opening”. My longstanding interest and experience in environmental ethics and ethics of responsibility informed my sensitivity to the concepts of “responsibility” and “uncertainty”. Because I am convinced that these terms are central to the analysis, I explicitly explain how I understand and use them in the thesis to promote clarity and a shared understanding of meaning. I initially approached this thesis with a primary focus on nuclear fusion as a technology. Through engaging deeply with the literature on responsible research and innovation, environmental communication, and the ethics of responsibility, my perspective shifted. I came to understand that nuclear fusion serves here as an empirical case rather than as the object of the study itself.

This shift from a technology-centred to a concept-centred perspective was one of the most significant developments in my thinking during this research.

The regular supervision throughout the thesis process helped me to engage and reflect on my data. The ongoing interaction with my fellow master students in the same field, as well as with those from different fields, helped me discuss my ideas and assumptions and reflect on my role as a researcher.

While reflecting on data generation, I considered how my sampling and recruitment decisions might shape the analysis. I focused on individuals who communicate publicly about nuclear fusion in Germany, where both publicly and privately funded research and development of nuclear fusion exist. I sought a range of perspectives by interviewing science journalists, communicators working at public and private institutions, and parliamentary technology assessment advisors. All interview participants identified themselves as male. Given the underrepresentation of women in public-facing fusion communication in Germany, I was unable to obtain a more gender-diverse sample. This might have implications for the study, as there may be differences in understanding and enacting responsibility and role positioning. Analysing these differences might be an interesting topic for further research.

As a researcher embedded in a European academic context, I am aware that my perspective, my choice of literature, and my interview partners reflect a predominantly Western understanding of nuclear fusion and its potential. This shapes the questions I asked, the frameworks I applied, and the conclusions I drew.

## 5. Results

Within the results section of this thesis, the four themes developed through coding will be analysed. The following table (Table 2) summarises the themes and their codes.

*Table 2: Summary of analysed themes and their codes*

|   | Theme                        | Codes  |
|---|------------------------------|--|
| 1 | Language use                 | Language use, change of language, demand-oriented language |
| 2 | Technological understanding  | Limits of work, timelines, dual-use, proliferation         |
| 3 | Communication practice       | Transparency, facts, role enactment                        |
| 4 | Communicator self-reflection | Self-awareness, uncertainty, technological stance          |

### 5.1 Language use

As already discussed in the literature review of this thesis, the use of language plays a central role in communicating science. Words, metaphors, and headlines are deliberately chosen to steer expectations and fears. Word choice is often tailored to the audience and responds to shifts in the public sphere, such as the emergence of fusion start-ups and increased political interest in nuclear fusion. The following section will analyse the language use by examining the codes: language use, change of language, and demand-oriented language.

Several interviewees noted that the use of certain terms, such as ‘breakthrough’, ‘future technology’, or ‘holy grail’, may paint ambitious visions of the future and fuel expectations. According to the interviewees, words are deliberately chosen either to dampen hype or to inspire hope. As PA2 notes, for him, a “breakthrough” would only exist when “something unforeseen happens, after which the world looks different than it did before”. He states that:

“Well, not every research achievement is a breakthrough on the path to an energy utopia. Not every tiny step forward is a world record, even if it might do something a little better than what was possible before” (PA2).

Accordingly, exaggerated metaphors such as “holy grail” and “bringing the sun down to Earth” are an “absolute taboo” (PA2). In contrast, SJ3 rejects a tabooing of certain terms and wants to “stay curious”. SJ3 uses language to foster openness rather than to de-hype the topic. This comparison shows that language can be used to pursue different goals and serve different interests.

PA1 states that he avoids the word “could” wherever possible, since it can lead to the assumption that “something could be the case – maybe that’s not so unlikely”. Using the subjunctive in this way makes it possible to sidestep thematising uncertainties, since ultimately everything “could be” (PA1). According to PA1, this, in turn, can result in certain issues, such as climate measures being postponed, because a technological solution to the problem is already assumed. This makes clear that the use of language can also be understood in a holistic context, where it is not only about generating or dampening expectations, but about far-reaching effects, such as the non-implementation of climate measures.

At the same time, it is argued that the non-use of certain terms can distort public discourse. SJ2 does not use designations such as “future technology” in his own language, but quotes them when his conversation partner uses them, because it would be “idiotic” not to use certain words when they are part of “public discourse”. By separating his own voice from others’ voices, he reflects the debate without actively amplifying these terms. By contrast, other interviewees report that they generally do not use these terms (e.g., PA2). This illustrates two different stances: on the one hand, mirroring the discourse by separating one’s own voice from quoted voices, and on the other, a precautionary de-hyping by avoiding such language. This, in turn, points to different approaches to responsibility and transparency.

As mentioned, economic and social changes influence communication. Several interviewees indicate that language and public communication have changed with the rise of privately financed start-ups and increased political interest in nuclear fusion. SJ2 states that communication “is completely different in the private sector”. This becomes evident through the following phrase:

“So they show me what they want to show me; they don’t show me anything else. And they bombard you, flooding you with PR jargon and glossy slides and pretty pictures they produce to raise capital. They’ve had some success, sure, but it’s not like they’re anything special. Some of them are successful, but there are also institutions that have pulled out” (SJ2).

This also critiques a lack of transparency in language and the attempt to use language for capital acquisition. This critique suggests that SJ2 sees himself as responsible for communicating transparently and for not uncritically reproducing statements. S1 also strongly criticizes start-ups’ communication and word choice. He reports that, in the context of an event at which one of the German fusion start-ups was invited, the German word “Reaktor<sup>3</sup>” had to be replaced by the English word “facility” and he was asked to avoid terms such as “nuclear waste” as well

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<sup>3</sup> „Reaktor“ is the German term for facility, here the interviewee needed to use the English word instead of the German one at a German-language event.

as “nucleus” (S1). This points to a deliberate language policy aimed at excluding associations with nuclear fission. Language is understood as a powerful instrument for steering expectations and interpretations. In contrast to SJ2 and S1, C1 assesses the changes in language and communication positively. He states that, in his role as a communicator for a research institution, he can communicate “more openly and freely”, since he can once more use terms like “nucleus” and “reactor”, which were previously not possible due to the strongly negative connotation of these terms (C1). From C1’s perspective, the communicative situation has changed such that clear naming has again become possible. These statements create a sense of tension: while some respondents criticise private-sector communication as driven by capital, others see an opening for direct language in the changed environment. Language is therefore perceived differently depending on the actor and the field of work, which also indicates differing perceptions of responsibility and transparency.

Decisions about phrasing and language use are often not made solely by the communicators but are strongly oriented toward the needs and expectations of the audience. This demand-oriented communication is particularly evident in journalism. Although the journalists interviewed report working largely autonomously, SJ1 and SJ2 emphasise the audience and the editorial office as a “control instance”. SJ3 states that his journalistic pieces are adapted according to “format and target audience” and receive “different emphases”. This shows that topics are presented differently depending on the expected target audience. J1, who describes himself as a more economic, but not scientific journalist – also the only one working for a private company –, describes his communication artifacts as “tailored to the audience”, with topic selection and presentation guided by “measurable reach”, and tone and headlines varying with the target audience. This makes visible that external conditions co-shape communication and that questions of responsibility shift from the individual to an interplay of roles, institutions, and economic factors.

This theme shows that responsibility is already visible in the handling of language. While some interviewees consciously avoided certain metaphors and terms, as well as the use of the subjunctive, others used language to foster openness toward technology. It also became clear that communicative decisions are not made by individuals alone but must be made within a political and economic context. The tensions observed suggest a situational approach to transparency and accountability, and they already indicate that responsibility cannot be attributed solely to the communicating individuals, which is one of the previously discussed risks of RRI, putting responsibility on the individual rather than addressing it to the whole system.

The following theme addresses limitations within work, timelines, and the understanding of responsibility in a context of dual use and proliferation.

## 5.2 Technological understanding

When discussing technological innovations like nuclear fusion, it is important to understand the technological context in which participants situate them.

Science communicators and science journalists repeatedly meet limitations within their activities. These arise from the complexity of the topics, but also from uncertainties within the technology. They include, for example, timeframes that cannot be estimated and potential risks of dual use and proliferation. It can be observed repeatedly that there is a discrepancy between statements by science journalists and science communicators, which becomes particularly apparent in more optimistic vs. more pessimistic views.

Some interviewees mark the limits of knowledge as a structural feature of their role. This applies mainly to science journalists, but also to the parliamentary technology assessment advisors. SJ2 states that journalistic knowledge is always only “half-knowledge”; PA1 states that he has “no independent competence in fusion research” and “has to rely on the knowledge of others”. In doing so, he does not classify himself as an expert on a specific topic, but rather as a translator and mediator of scientific findings. To handle limitations, SJ1 says he tries to “stretch” his knowledge as far as possible so that these boundaries are not reached. In this way, the capacity to act can be ensured even in complex topics, and the openness of outcomes can be maintained. Moreover, an overextension of one’s own remit is avoided and the risk of misjudgements reduced. Role-related boundaries create dependence on experts but promote interdisciplinary exchange and, under certain circumstances, ensure a reflective handling of knowledge.

Limits of knowledge appear not only regarding the abilities of communicators, but also with regard to the expected time horizon of fusion technology. This is repeatedly addressed, with assessments diverging. C1 states that, in the context of his work at a research institute, he indicates a period of at least “two decades” before they consider commercial use of fusion energy possible. Compared to other statements, this is a rather optimistic assessment. SJ2 speaks of a period of “40 years” until commercial use. SJ1 does not assume that there will be any practical application of fusion technology “in the foreseeable future” at all. SJ3 emphasises that fusion currently plays no role, but “perhaps in 25, 30 or 50” years. PA1 and PA2 also express scepticism about the actual use of nuclear fusion in the foreseeable future. S1 still considers:

“In any case, these are very complex machines that will likely be quite expensive, and it’s unclear whether they’ll reach the break-even point, compared to a PV system, which is very simple in how it works, or a wind turbine or something like that. They basically say that the economies of scale, with many plants, are somehow significantly lower than with other technologies because it’s so complex, so even if you build 100 power plants, you won’t really achieve a factor of 100 in terms of costs – maybe, if you’re lucky, a factor of 10 in cost reductions from the first plant to mass production – but there won’t be a solar and wind power miracle” (S1).

This breadth of time estimates and economic constraints underscores the uncertainties communicators face and the decisions they must make in their communication. These choices resonate with the dimension of anticipation in the Responsible Research and Innovation (RRI) framework, surfacing potential implications and responsiveness, adjusting communication to emerging concerns. PA2 also criticises communicative practices in which startups and politicians set the time horizon of fusion technology as follows:

“This is, so to speak, the result of years of – let’s say, and I’m deliberately exaggerating here – brainwashing through these articles, which leads people to believe that we’re somehow really close to achieving it and could now make current energy policy decisions differently than we otherwise would, since nuclear fusion is in the pipeline” (PA2).

This shows how expectations can be steered and also underlines once again the power of language use. Despite great uncertainty, optimistic time frames can influence perceptions and prioritisation, while it can be expected that research-oriented and sceptical voices will help dampen expectations. Divergent timelines push communicators to choose between reporting ranges, foregrounding preconditions, or declining to specify dates; these choices signal their stance on uncertainty.

The topic of dual use and proliferation is only addressed by some interviewees, with very different views and weightings. Here, a discrepancy between science communicators and science journalists could be found again. While SJ3 does mention the topic but classifies it as “not so important” and sees the immediate risk more in a “dirty uranium bomb” than in a “fusion weapon”, PA1, PA2, and S1 criticise a tendency toward under-communication. PA1 describes hydrogen bombs, which can be built with the help of fusion technology, as “significantly more powerful than uranium bombs”. He refers to the widespread framing of fusion as “clean and quiet”, with low safety and disposal risks, whereby the dual-use aspects are “hardly taken into account” (PA1). PA2 and S1 also see the risk of the potential weaponisation of fusion-related knowledge and material. PA2 says he has the feeling the risk is being “swept under the rug”. This supports the earlier observation that certain risks can be downplayed through communicative choices.

The political aspects of fusion technology are also addressed. S1 speaks of the risk of latent proliferation, for example, the covert production of weapons-grade materials, as well as the generation of dual-use knowledge “below the threshold where it becomes noticeable to other nations”. He criticises the lack of international “safeguards” to systematically monitor worldwide development (S1). The data show that actors close to the topic (PA1, PA2, S1) more strongly emphasise the need for governance and latent risks, while a science journalist (SJ3) relativises them. Possible explanations, such as different access to expertise and different perceptions of one’s own role, can be proposed, but can only be substantiated to a limited extent with the material available. What becomes clear, however, is that roles and framings shape which risks are visibly prioritised.

This theme underscores the various levels at which communicators are confronted when reporting on nuclear fusion. These extend across time horizons, dual-use and proliferation issues, and limits of knowledge due to limited scientific understanding of the technology. The following theme examines in more detail how communicators enact transparency and facts within their professional practice.

### 5.3 Communication practice

The theme interprets communication practice as an interactive process in which participants actively negotiate and construct what “transparency” means in a given context. Across interviewees, there are differences in how claims are produced, how certain they are, and how they enact roles under institutional and market constraints. The communication practice is analysed through the codes of transparency, facts, and role enactment, examining how communicators perform their roles within institutional and professional constraints.

As noted in the literature review, Kueffer and Larson (2014) argue that transparency is crucial to effective communication practice. Across interviewees, transparency is a part of their work. In their account, transparency takes three forms: (1) openness about personal interests and evaluative judgements; (2) clarity about the origin, quality, and limits of knowledge, and (3) disclosure of institutional roles and constraints that can enable or restrict openness. Two interviewees (S1 and PA1) mention the importance of inclusion – taking the public perspective into account in agenda-setting and decision-making – as part of responsible communication. S1 emphasises that he suggested inclusive processes with “workshops right from the start”. But this idea was then rejected due to the concern that only “troublemakers would show up” and that it wouldn’t get a “proper discussion at all”. PA1 mentioned that within the institution he is working for, they actively involve citizens in a “wide variety of processes, including

science communication”. For example, with “public dialogues in which citizens are explicitly encouraged to articulate their needs regarding research and science on specific topics”, these topics are then “predetermined”. This supports a “demand-driven” inclusive research orientation. With this approach, the audience is positioned as a stakeholder rather than a passive recipient. This inclusion can also be seen as alongside transparency and meta-knowledge, extending responsibility from disclosure to participatory sense-making.

PA1 emphasises that, based on scientific ethics, he is not authorised to include “personal opinions” in the discourse, unless he makes them explicit. This emphasises the distinction between his personal view and his professional responsibilities as a parliamentary technology assessment advisor, which he must not mix. He also stresses that this transparency helps the audience to “form their own understanding”, even if it differs from his advice (PA1). In addition, he highlights an economic dimension, “problematic aspects” of the research topic should be disclosed without fear of “losing research funding” (PA1). In my interpretation, transparency may be constrained by investor relations in the private sector context. While my data did not include startup actors, this points to a potential limit where funding risk transparency due to credibility and funding logic.

SJ2, a science journalist, points out that even if he strives for objectivity, his own views will likely “shine through”. For this reason, he considers it necessary to make it explicit and to disclose the provenance of the information he uses (SJ2). SJ3 directly addresses his own background and its possible influence on the reporting:

„Of course I’m a [technology] optimistic; I’m a physicist, and I won’t pretend that this couldn’t play some role, even if I would, of course, strongly deny it. But clearly, it can play a role“ (SJ3).

He appears to suggest that a physics background shapes his outlook on the world and that this influence should be signposted when communicating. Interestingly, SJ3 was the only one who explicitly mentioned the influence of his background as a physicist, even though several science communicators and science journalists have a background in physics (PA1, PA2, S1, C1).

In contrast, S1 does not foreground a personal background requiring transparency, but rather his professional background and the positioning of the institute he works for. Again, this highlights a contrast between personal and professional roles: while some interviewees, especially science journalists, emphasise transparency about their personal background and stance (SJ2, SJ3), science communicators tend to foreground their institutional and professional contexts

(PA1, S1). A reason for this might be the different professional norms. While the interviewed science journalists describe themselves as free in their work (SJ1, SJ2, SJ3) and discuss their texts with an editor just before publication, the science communicators are all working within institutional structures with clear role expectations and positions (PA1, PA2, S1, C1).

Beyond transparency about the origin of knowledge, the limits of one's responsibilities, and affecting backgrounds, several interviewees argue that "meta-knowledge" must also be communicated transparently. SJ3 understands this as disclosing sources and uncertainties; PA2 frames it as working in ways that do not mask uncertainty. PA1 articulates this explicitly:

"The knowledge that we scientists produce always includes meta-knowledge about the qualities of that knowledge. Those qualities include the uncertainties involved, the methodological background, which methods were used to find something out, the data that were used, possible data bias, and so on. All of this is part of that meta-knowledge" (PA1).

This connects directly to how uncertainty is handled in communication about nuclear fusion: PA1 advocates communicating these uncertainties openly. This also resonates with key dimensions of the Responsible Research and Innovation (RRI) framework, such as reflexivity (recognising and disclosing one's assumptions and limitations) and anticipation (making uncertainties and potential implications explicit).

Alongside transparency, several interviewees emphasise a fact-based approach. PA1 highlights: "We strive to work in a fact-based way and to approach things without any prejudice or preconceived results" (PA1). SJ3 underscores that journalistic work must be "fact-based" and should enable people to make "conscious and fact-based decisions"; at the same time, he warns of a tendency to "hide behind studies to some extent", instead of taking responsibility and making decisions. He adds that it is part of the job not only to state "the facts", but also to explain how they came about and where they may be abbreviated. This position links back to the "meta-communication" in which the limits of knowledge, as well as its origin, should be presented transparently.

While SJ1 stresses the existence of variable quantities like "numbers" and "energy balances" from which one should draw "sober" conclusions and criticises sloppy journalistic practice, such as "physical units (...) [that] are not correctly reported", J1 believes it is important not to present "any absolute numbers as facts", especially in the context of future projections. This difference could potentially arise from their respective roles and personal backgrounds: one is a science journalist, the other a general journalist who produces under high-pressure output to generate as many "clicks" as possible. It can be inferred that both interviewees

aim to present “correct facts” (J1) regarding nuclear fusion, but, due to external constraints, they achieve this aim through different paths.

The communication practice is also dependent on the role, the science communicator or science journalist may give themselves. As discussed in the literature review, Pielke (2007) distinguished four ideal-typical roles for scientists in a policy context. These roles help to describe roles that communicating persons – either journalists or communicators – may give themselves. PA1 described himself (without mentioning the roles of Pielke somewhere in the interview) as “an honest broker.” He states:

“When dealing with the information others provide us, this is where the role of the honest broker comes in – we must not allow ourselves to become advocates for specific positions (the alternative model would be that of an issue advocate), but rather first question what lies behind the position and statements of individuals, and I particular, where the certainty of expert claims ends, where uncertainties come into play, and above all, where value judgements come into play” (PA1).

This role enactment can be linked to the dimension of “anticipation” in RRI. The role enactment of PA1 reflects the ‘detangling present hype from future reality’ in the context of nuclear fusion, which can be interpreted as narrowing expectations for a future “sober” energy source through fusion technology.

S1 understands his work as doing “accompanying research” and “making corrections”. This means that he must uncover “wrong promises” and depict risks. He also sees it as essential to participate in critical “discussions” without excluding himself from them due to overly strong expressions of opinion. To prevent this from happening, he carefully considers his role within discussions, while always remaining committed to “scientific truth”. His self-understanding fits the role of the honest broker, even if the changing of different positions within discourses can lead to the assumption that he might understand himself within different roles. His statement clearly states that the role a person might give themselves may change, both consciously (to be able to participate in different discourses) and unconsciously. In the case of nuclear fusion, or any other emerging technology, it shows that communication practices are complex, involving different people acting in different roles.

While the science communicators mobilise an honest broker and potentially a science arbiter stance (PA1, S1), the science journalist SJ2 understands himself as an “explainer” who “narrows down” a topic, giving the audience “background” knowledge without prejudging the “outcome”. I return in the discussion on how this stance relates to the understanding of responsibility after Hans Jonas.

J1 feels a sense of “responsibility“ toward his readers. For him, fulfilling this responsibility means approaching statements critically, verifying information, and, when it comes to “controversial” topics, “presenting all arguments clearly”. Ideally, his communication is to “report only what actually happened” (J1). He sees himself as a facilitator of the readers’ understanding (J1). In my interpretation, laying out arguments for contested issues without interpretation might risk a drift toward both-sides presentation if evidential asymmetries are not explicitly calibrated. That, in turn, can lead to oversimplification of topics.

Whereas J1 draws a boundary around event-centric reporting, SJ2 and SJ3 articulate a meaning-making role. SJ2 describes his duty as understanding processes and situations from “as many perspectives as possible” and then to analyse them “transparently, comprehensibly, and critically” for the “general public”. In doing so, he sees it as his task not simply to “parrot” things but to “contextualise” and “question” them (SJ2). Similarly, SJ3 adopts a supporting role that involves researching “content”, providing “context”, and thereby enabling “informed and fact-based” decisions. This can be understood as trying to reach a meta-knowledge level, where it’s visible how interpretations are reached and how evidence is weighed, rather than just reporting events. This may deepen public understanding, but it also requires selective framing. Compared to J1, these narratives illustrate a tension in journalistic practice between procedural neutrality and constructive mediation.

Communication practice emerges as an enactment of transparency. Participants act transparency in different ways, reflecting role norms and constraints. Notably, journalists and science communicators diverge in how they implement their roles and what they foreground as “transparent” (e.g. personal stance vs. institutional context, event-focused reporting vs. contextualised analysis). In communicating about nuclear fusion, these different enactments have an influence. An event-anchored reporting approach protects against overclaiming but might risk a lack of audience understanding, while contextualised analysis helps audiences grasp timelines, preconditions, and uncertainties but might risk subjective influence through the communicator. The analysis of the communication practice has shown that transparency is not a fixed standard but a situationally enacted accomplishment, shaped by role norms, institutional constraints, and individual judgement. What remains to be examined is how communicators reflect on their subjectivity, their handling of uncertainty, and their understanding of the technology they communicate about. This will be presented in the following chapter.

## 5.4 Communicator self-reflection

To understand how communicators enact and understand responsibility under high uncertainty, it is important to examine how they reflect on their own subjectivity, their handling of uncertainty, and their technological stance.

PA1 emphasises that he isn't a "fusion researcher" and does not have "independent competence" in fusion research. He sees it as a privilege to work in scientific research, having the ability to "freely explore and investigate the unknown" (PA1). At the same time, he understands it as his duty to communicate knowledge "transparently" and disclose the limits of knowledge. This aligns with the goal of communicating transparently and fact-based, which was discussed in theme 3. In his conviction, he needs to be aware of:

"When I think about political consulting now, first and foremost, I want to be authentic—meaning I only advise on things I'm personally convinced of. Keywords here are scientific verifiability and transparency: the chains of reasoning, the data, and so on must support what's being said. So, as a scientist, I have to be authentic, let's say according to DFG guidelines, good scientific practice, or whatever you want to call it—it has to be justifiable" (PA1).

He does not consider himself "mandated" in his role to make "decisions with far-reaching social implications" that would lead to certain technologies being "shut out of society". In the case of fusion technology, this implies that only advice on matters he is personally convinced of. This positions him as a bridge between politicians seeking knowledge about nuclear fusion and scientists researching fusion technology. He legitimises his advisory role not through topic expertise but through methods and ethics. His rejection of a mandate to make far-reaching decisions functions as boundary work; it circumscribes his influence to advising, distancing him from advocacy and thereby protecting his legitimacy in politically sensitive terrains like nuclear fusion.

By citing public funding, C1 grounds his role in public accountability; he aims to "present facts while also fostering enthusiasm for research" and combines his duty to inform with recognition of publicly funded research. Here, the economic value of his work implies a sense of responsibility toward the communication practice. The pairing of "presenting facts" and "fostering enthusiasm" might also create latent tension, because conveying 'passion for research' can create tension over the disclosure of risks. It requires careful reflection to avoid the perception of promotional bias.

A key aspect of self-awareness is reflecting on the subjectivity someone brings to their communication practice. SJ1 believes that communication always involves a "judgement" on the part of the communicator – through the "weighting" of certain

arguments, the “selection of conversation partners”, and the “choice of topic” they address. Nevertheless, he strives to ensure that this degree of subjectivity does not lead to influencing readers (“this is good” or “this is bad”) (SJ1). SJ1 articulates a journalistic paradox: he recognises that subjectivity accompanies selection and framing processes, yet he tries to avoid directing the reader.

J1 layers ethical responsibility to the reader with legal accountability for published content; this dual frame encourages event-anchored reporting and caution with inference, which can protect against error while limiting contextual explanation. He also emphasises that it’s important for a journalist not to act as a “spokesperson” for certain opinions. From this, it can be concluded that J1 dual accountability pushes him toward cautious, event-based reporting that minimises inferential risks and avoids advocacy. Under high uncertainty, this stance enhances procedural credibility but may limit the provision of meta-knowledge, potentially reducing the audience's understanding.

Uncertainty, as an aspect of communicating emerging technologies, is part of the literature review of this thesis, as well as the research question, and was also raised by several interviewees. C1 claims that there will never be something “100% certain” in science; there will always be the risk of failure. For him, dealing with it means disclosing these uncertainties and risks openly. He claims that it is important to maintain a balance between “euphoria” and “too much scepticism”. From this statement, the question could arise: at what point does insecurity overreach the possibility of success? Following his understanding of uncertainty, everything could be possible, but the uncertainty and its associated risks need to be communicated openly. This frames uncertainty management as calibrating audience expectations rather than deciding for/against research.

PA1 also emphasises presenting uncertainties as an integral component of scientific quality. In addition to results, the „methodological background“, possible „data bias“ and the „limits of knowledge” should be disclosed; this again relates to the communication of meta-knowledge. He brings together uncertainties and the future in a more philosophical understanding.

“Over time, how should I put it, I’ve become increasingly sceptical about making definitive statements about the future. Or you could also say I’ve become much more positive about the idea of the future’s openness. I hold openness—as a positive space for shaping the future—in very high regard. And while elsewhere, openness is often equated with uncertainty, if we had certainty about the future, we wouldn’t have any room left to shape it” (PA1).

PA1 shifts from prediction to possibility and, as an ethical and epistemological stance, prioritises openness over certainty. In the context of nuclear fusion, this

approach promotes the communication of ranges and scenarios rather than fixed timelines, thereby avoiding excessive hype while preserving room for action.

Both science journalists, SJ3 and SJ2, connect the handling of uncertainties in communication with transparency. In the case of nuclear fusion, they state that they try to make “uncertainties visible” (SJ3) and convey facts, not only facts but also knowledge about the facts, which was discussed in theme 3 as meta-knowledge. This can be underlined by the statement of SJ2: “Well, it would be a poor form of realism to write about uncertain things as if they were very certain” (SJ2).

S1, in turn, problematise optimistic startup narratives that promise short timelines and climate solutions. He warns that inflated expectations can misdirect funding and incentives, and he actively discusses uncertainties and risks in public and with peers because, as he puts it, “without thinking and articulating uncertainties, you're really going to run into problems if you don't think this through from the start” (S1). Compared with other interviewees, this is a more interventionist role performance – seeking not only to disclose uncertainty but to reshape the discourse around it.

None of the interviewees recommended abandoning fusion. I interpret this as reflecting role boundaries (journalists/communicators avoid policy prescriptions) and/or a preference to manage expectations through transparency rather than to advocate for or against research.

To examine communicators’ technological stance, it is useful to consider their general orientation toward technology. C1 sees himself as a “technology-optimist” while emphasising that there is always a risk of failure, as already discussed at the beginning of this theme. This technological optimism may shape how he communicates about fusion – an invitational tone coupled with routine disclosure of uncertainties and failure modes. Also, SJ3 describes himself as a “technology-optimist”, but emphasises that this doesn’t mean that he:

“chasing every new trend and saying, – Oh, that’s great, it’s going to save the world, and we just need to be open to technology – then we won’t have to worry about anything (...). But it helps to approach this optimism by first taking an open look at the world and seeing what’s out there right now, what’s going on, and what ideas other people might have – ideas that might initially contradict the prevailing opinion” (SJ3).

He argues that “good science journalism” needs to find a balance between “curiosity” and “caution”. C1 and SJ3 can be seen as articulating a tempered techno-optimism, open to innovation but coupled with a stated resistance to hype. Finding the balance between curiosity/optimism and the prevention of hype

requires subjective judgement, which can introduce bias in selection and weighting unless explicitly managed.

PA2 describes himself as someone with a background in physics, finds the “topic itself fascinating”, and acknowledges the “outstanding research”, while emphasising that many open questions still need discussion and that transparent communication about the technology's potential risks and uncertainties is needed. J1 says that he is not “technophobic” but that he still has “serious doubts” about technology’s impact on the climate crisis. This can be interpreted as a scrutiny of effectiveness claims and policy dependencies over amplifying optimistic narratives.

These technological stances may serve as role anchors in uncertain contexts. Optimists may try to inspire without hyping, while disciplined, grounded actors may tend to translate open questions, staying ambivalent and resisting technology-solutionism. In the nuclear fusion context, these orientations will potentially shape communication choices – what is highlighted, how uncertainty is presented, and where boundaries are drawn between reporting and advocacy.

Responsibility in the public communication of nuclear fusion is neither a fixed attribute nor a defined obligation, but an ongoing practice present in various areas, such as language use, technological framings, communicative practices, and the communicator's self-reflection. All of them constitute where responsibility is enacted and where its limits become visible. The following chapter will discuss the results and relate them to the broader field of environmental communication.

## 6. Discussion

This discussion interprets the four themes developed in the results and situates them within the wider literature. It returns to the research question of how communicators engaged in the public communication of nuclear fusion understand and enact responsibility under high uncertainty, along with the two sub-questions concerning role understanding and pathways for enacting responsibility in communication practice. Working across the literature on RRI, Hans Jonas' concept of responsibility and environmental communication, in dialogue with the empirical findings from the interviews, three levels of responsible communication emerged: a practical, an ethical, and a political level. These levels serve both as an analytical framework and as a practical consideration for communicators. While some interview partners showed awareness of the practical and political dimensions of responsibility, the ethical dimension, such as obligations to future generations and long-term consequences, was rarely addressed explicitly. Importantly, the discussion also shows that responsible communication cannot be reduced to individual practice alone but requires structural conditions and inclusive processes that distribute responsibility more broadly. Although nuclear fusion serves as the empirical case, the three levels offer an analytical framework applicable to the communication of any emerging technology with uncertain environmental and societal consequences. At the end of this section, limitations and a possible outlook will be given.

### 6.1 Practical level

In the communication of nuclear fusion, language plays a decisive role. Some actors make promises about the future through positive metaphors and generate hype around fusion technology, while others deliberately try to prevent hype by actively avoiding certain metaphors, terms, and the subjunctive to avoid raising expectations. The responsible use of metaphors and their careful introduction are important to avoid hyperbole in science communication (Kueffer & Larson 2014), a challenge that is particularly salient for nuclear fusion, where terms such as the 'holy grail' or 'clean energy solution' are frequently used. This shows that communicators – whether working for institutions, in journalism, or in policy advising – are conscious that they do not only convey content but also enact different understandings of the technology.

There are different approaches to the role the interviewees occupy. The interview partners from policy advising are comparable to the "honest broker" role as defined by Pielke (2007). They prepare different courses of action and present consequences and risks transparently, while avoiding direct recommendations.

Science journalists more frequently emphasise event- and fact-oriented reporting, sometimes with contextualising framing, but without taking a position. Individual actors (e.g., S1) describe an interventionist practice in which their own evaluations become visible. I conclude that individual role understanding and the understanding of responsibility are connected. Those who understand neutrality as their role define responsibility differently from those who take an explicit position.

This also reflects distinctions established in the literature between science journalism, which prioritises newsworthiness and accountability under editorial norms, and institutional science communication, which foregrounds relevance for organizational and stakeholder goals (Bucchi & Trench 2014; Molek-Kozakowska 2016). According to Fischhoff (2013), successful science communication enables informed decision-making by equipping people with knowledge of the possible risks, consequences, and benefits of an action. Based on the roles described above, this becomes possible when the audience receives comprehensive and contextualised knowledge. This is the case in the honest broker role, which conveys knowledge and presents alternatives. However, the interventionist role can also meet Fischhoff's standard of successful science communication, as long as positioned statements are handled transparently.

These role understandings can be assessed on a normative level against the RRI dimensions of reflexivity and responsiveness. Reflexivity means making values, assumptions, and the limits of one's own position visible and reflecting on them, while responsiveness means adapting language to contexts (e.g., political agendas, formats) without distorting the evidence (Stilgoe et al. 2013). This does not mean that communicators should express personal recommendations, but rather that positions, uncertainties, and risks are explicitly marked, and that one's own voice is distinguished from quoted voices. Many of the interviewees state that they aim to communicate transparently and factually, which would meet the standard of responsiveness (Scholten et al. 2016). However, the interviews also reveal that individual understanding plays a role here. Science journalists, as well as journalist J1, indicate, as described in chapter 5.3, that they sometimes reach the limits of their knowledge when they can no longer fully understand the subject matter in depth, which, if not transparently marked, can lead to a distortion of information.

Fischhoff and Davis (2014) emphasise that effective communication under uncertainty requires communicators to characterise what is known and unknown, assess the magnitude of uncertainty, and convey it in ways that support informed decision-making. When communicators reach the limits of their knowledge without marking this transparently, the task fails not through individual

negligence alone, but through structural conditions that make deep engagement with complex technologies difficult. These structural limits do not only appear in the case of nuclear fusion. Environmental communication more broadly faces the challenge of communicating technologies whose consequences are uncertain, long-term, and scientifically complex, such as, for example, renewable energy systems, geoengineering, or carbon capture.

This points to a structural limit in responsibility practice, rather than merely individual failure, a distinction that is particularly important to recognise in the wider field of environmental communication. Emerging technologies are often highly complex, requiring a deep physical understanding to fully grasp how they work and what potential consequences may arise.

As the following section shows, only some interview partners address dual-use and proliferation risks, that is, the potential misuse of fusion technology for weapons development and the spread of nuclear materials, pointing to diverging understandings of what transparent communication entails.

## 6.2 Ethical level

Nuclear fusion energy has been researched for decades, yet it is not yet available for commercial use. Beyond technological uncertainties, unclear time horizons, and risks of dual use and proliferation, other risks arise. Communicating under these conditions is challenging and can take different forms.

The way communicators frame nuclear fusion's time horizons reveals fundamentally different understandings of communicative responsibility. While science communicators and parliamentary technology assessment advisors foreground uncertainty and avoid concrete predictions, individual science journalists and the institutional communicator frame commercial use as achievable within the next 25-50 years. This divergence is not merely a difference in opinion; it reflects different implicit assumptions about what responsible communication under uncertainty requires (Bubela et al. 2009). Those who frame fusion as near and achievable are, arguably, not practicing the anticipatory thinking that Stilgoe et al. (2013) describe as a core dimension of the RRI framework, nor the moral foresight that Jonas (1984) considers essential when dealing with technologies of uncertain consequences.

The varying visibility of dual-use and proliferation risks is also notable. While individual journalists and the institutional communicator address the topic only briefly, parliamentary technology assessment advisors and science communicators highlight the potential risks and governance gaps more clearly. The interviews do not provide a definitive answer for why this is the case; in my interpretation, it

may be due to a lack of knowledge and to different levels of subjective risk tolerance, which indirectly shape communication practice (Bubela et al. 2009). Connecting these findings to the RRI framework, the dimension of anticipation becomes particularly relevant. Stilgoe et al. (2013) describe anticipation as the systematic practice of asking ‘what if’ questions, a form of moral foresight that includes questioning what present actors owe to future generations.

This connects directly to Hans Jonas’ heuristic of fear, which prioritises the worst over the better prognosis and calls for a reflective approach to dual-use and proliferation dynamics. In his book “The Imperative of Responsibility: In Search of an Ethics for the Technological Age” (1979), Jonas also writes about the transformed possibilities of human action brought about by modern technologies, which expand human intervention in nature and can have consequences for future generations. Precisely because nuclear fusion has these characteristics, the heuristic of fear is particularly applicable here, despite the risks of proliferation and resource- and disposal challenges. Jonas understands responsibility toward future human beings as a moral imperative that should shape present action. According to this understanding, the heuristic of fear and Jonas’ concept of responsibility should find application in environmental communication and is also particularly relevant for communicating environmentally relevant technologies, such as nuclear fusion, which are often presented as solutions to the climate crisis before their consequences are fully understood. The heuristic of fear offers the opportunity to also focus on uncertainty and long-term risk, rather than just communicate through the lens of hope and opportunities.

When RRI dimensions and ethical considerations are transferred to communication practice, a risk of individualising responsibility arises. A consistent application in communication would place a great deal of responsibility on individual communicators, a responsibility that cannot always be enacted due to structural conditions, as several interview partners point out (editorial constraints (SJ3, J1), commissioned research (PA1, PA2), etc.). This raises the question of whether responsibility should already begin at the level of these structural conditions – that is, with institutions, politics, and public media – and can serve as a basis for further research.

The ethical imperative to anticipate risks and think ahead toward future generations finds its political counterpart in the EU precautionary principle and the question of how responsibility can be distributed across institutions, communicators, and the public. This will be discussed within the following chapter.

## 6.3 Political level

While the ethical level addresses the moral imperative to anticipate risks and think ahead, the political level addresses structural and institutional conditions to ensure that responsibility is not left to individual communicators alone. The EU precautionary principle provides one answer to this question. It implies that in situations of significant uncertainty and risk – for people and the environment – preventive measures must be taken at an institutional level. Jonas (1979) argues on the level of moral duty, the precautionary principle operates on the level of governance instruments. This is important when it comes to emerging technologies like nuclear fusion, but also to other technologies that might influence the climate crisis, whether positively or negatively, because they require not only political awareness but also political frameworks that make responsible practice and communication structurally possible. This also connects to the RRI dimension of responsiveness – the institutional capacity to adjust course when new knowledge or concerns emerge (Stilgoe et al. 2013). This responsiveness also requires that not only individual communicators adapt their practice, but that institutions create the conditions that make such adaptation possible.

However, the interviews reveal that structural conditions frequently constrain what individual communicators can enact in practice. Editorial frameworks (SJ3, J1) and commissioned research structures (PA1, PA2) limit the degree to which communicators can independently apply anticipatory or precautionary principles. This suggests that political and institutional frameworks must actively enable responsible communication, rather than assuming that individual communicators can bear this responsibility alone.

As described by the parliamentary technology assessment advisors, an ideal democracy would include citizens in both communication and decision-making. Also, citizens should be able to communicate their needs regarding research and science. Nuclear fusion involves many uncertainties, including timelines, resources, and dual-use. Inclusion presupposes that uncertainties are communicated transparently, a condition that Fischhoff also identifies for successful science communication (Fischhoff 2013). Environmental transitions never only affect some people, they are, by nature, affecting the whole planet. Therefore, inclusive processes in the communication of environmentally relevant technologies are not optional but structurally necessary.

As Durant (1989) writes, the public has the right and the duty to participate in scientific processes in a democratic society. This also implies that responsibility does not rest solely on individuals but involves everyone in a democracy, since, ideally, all citizens participate in decision-making. To make this possible,

participatory communication processes are needed, for example, citizen dialogues, the integration of diverse stakeholders, and the establishment of participation procedures. This is particularly urgent in the context of environmental transitions, where decisions about which technologies to develop and deploy have consequences that extend across generations and geographies. Inclusive communication processes are therefore not only a democratic ideal but a practical necessity for ensuring that environmental governance reflects the interests of those most affected.

If such inclusive processes were implemented in science communication, the risk of responsibility falling on individual communicators could be reduced. Such a participatory logic could have the further advantage of helping to avoid the Collingdrige dilemma, since informed participation and engagement with technologies could prevent them from becoming socially entrenched before their full consequences are understood.

While inclusion offers important opportunities for distributing responsibility in communication, questions remain about what equitable participation would look like in practice: who is asked, and how many people take part in the processes? Technologies such as nuclear fusion can have global implications, complicating participation formats and carrying the risk of developing Western-centric procedures.

Taken together, the three levels suggest that responsible communication practice regarding emerging technologies such as nuclear fusion operates simultaneously at the practical, ethical, and political levels. It requires not only individual communicators' reflexivity but also ethical foresight and political structures that distribute responsibility among all actors involved. This also applies to other areas of the communication of environmentally relevant technologies, which are often complex, new, and carry different risks and uncertainties. Communication about them is crucial and shapes not only public understanding but also democratic processes. After discussing the interviews embedded in the wider literature, it becomes clear that the practical, ethical, and political dimensions of communication must all be considered together.

## 6.4 Outlook and limitations

In summary, all interview partners perceive a responsibility for their communication, though this is strongly shaped by their respective understandings of their roles. While some interview partners see themselves as mediators and translators, others seek to present alternatives without prescribing a direction, and others again incorporate concrete recommendations into their communication.

Individual role understandings shape their approach and understanding of responsibility. Uncertainties are also perceived differently. While some interview partners see potential risks behind the uncertainties, such as proliferation and dual-use risks, as well as the postponement of climate action, others approach the innovations more openly and tend to highlight the potential opportunities (SJ3, C1, J1). There is also a recognisable difference between science journalists and science communicators, evident in their differing understandings of responsibility, their roles, and their communication under uncertainty.

Responsibility in the communication of nuclear fusion is not understood or enacted uniformly, but is context-dependent, role-bound, and structurally constrained. These findings point to broader challenges in environmental communication, in which diverse actors engage in discussions about technologies with uncertain consequences. This places responsibility on the communication and reflections of these actors, as they are increasingly central to public debate and democratic decision-making. In a democratic ideal, inclusive procedures would exist through which responsibility could be collectively shared.

These considerations point toward potential questions for future research. What influence can deliberative communication processes have on public engagement with technologies such as nuclear fusion and, more broadly, with emerging technologies that carry uncertain environmental consequences? This question is particularly relevant for the field of environmental communication, where inclusive and deliberative formats are increasingly discussed as opportunities for legitimate governance of environmental risks. The influence of institutional conditions on role understanding could also be examined in further research, given their strong impact on communication practice and the enactment of responsibility.

The limitations of this study include that only some stakeholders' perspectives were included; not all relevant stakeholder perspectives could be incorporated into the analysis. In total, eight people were interviewed; the findings are therefore not generalisable, which was not the aim of this study, but should nonetheless be noted as a limitation. As already mentioned, the sample consisted exclusively of male communicators. This may have influenced the understanding and enactment of responsibility reflected in the findings and therefore needs to be considered as a limitation.

## 7. Conclusion

This thesis examined responsibility in the communication of uncertain emerging technologies in a context where such communication might have an influence on the understanding and enacting with these technologies, a question with implications that reach beyond individual communication practice.

Answering the main research question, it became clear that communicators involved in the communication of nuclear fusion understand and enact responsibility under conditions of high uncertainty differently. As mentioned within the first sub-question of the research question, this depends on their role understanding, the institutional context, as well as the individual risk perceptions and the professional context. Often, responsibility is individualised in ways that exceed what a single communicator can realistically carry.

Addressing the second sub-question, the interviews revealed significant limitations in the communication. There is a tension between the normative frameworks, such as RRI, and structural realities that constrain the examination, including institutional background, editorial limits, and time constraints. This tension illustrates the existing limitations in communication, arising from external factors as well as personal limitations, such as limited knowledge and understanding of such complex technologies.

Drawing on eight interviews with communicators from journalism, science communication, and parliamentary technology assessment, this thesis showed that responsibility operates at three levels: ethical, political, and practical. It became clear that all communicators try to navigate all three simultaneously, often without explicit awareness of doing so, even if they have different professional and personal backgrounds and worldviews.

Since nuclear fusion is a technology that affects the environment and involves many uncertainties, its consequences might also affect future generations. These characteristics make it a relevant case for environmental communication scholarship, which is increasingly concerned with how uncertain and high-stakes technologies are framed, communicated, and governed. Communicating responsibly about uncertain technologies like nuclear fusion is not just an individual task; it requires structural conditions, inclusive processes, and frameworks that distribute responsibility among all involved actors.

## AI Disclosure

I have used Grammarly and Claude to correct language and grammar.

I wrote all texts in English myself and subsequently used the AI tool, primarily Claude to correct grammar, spelling, and awkward phrasing. I then revised the corrected text manually, as I find this helps me identify recurring mistakes and improve my vocabulary.

For sections that drew heavily on German-language sources, I used DeepL to translate key concepts and passages, which I subsequently revised and integrated into my own text.

I do not use AI to generate knowledge, information, or summaries of articles or books used in this thesis.

# References

- Abdo, H., Flaus, J.-M. & Masse, F. (2017). Uncertainty quantification in risk assessment - Representation, propagation and treatment approaches: Application to atmospheric dispersion modeling. *Journal of Loss Prevention in the Process Industries*, 49, 551–571. <https://doi.org/10.1016/j.jlp.2017.05.015>
- Archibald, M.M., Ambagtsheer, R.C., Casey, M.G. & Lawless, M. (2019). Using Zoom Videoconferencing for Qualitative Data Collection: Perceptions and Experiences of Researchers and Participants. *International Journal of Qualitative Methods*, 18. <https://doi.org/10.1177/1609406919874596>
- Aristotle (350 AD). *Nicomachean Ethics*. Internet Classics Archive. <https://doi.org/https://classics.mit.edu/Aristotle/nicomachaen.1.i.html>
- Blumer, H. (1969). The methodological position of symbolic interactionism. In: *Symbolic Interactionism: Perspective and Method*. University of California Press. 1–60.
- Borup, M., Brown, N., Konrad, K. & Van Lente, H. (2006). The sociology of expectations in science and technology. *Technology analysis & strategic management*, 18 (3–4). <https://doi.org/10.1080/09537320600777002>
- Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3 (2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Brown, N. & Michael, M. (2003). A Sociology of Expectations: Retrospecting Prospects and Prospecting Retrospects. *Technology Analysis & Strategic Management*, 15 (1), 3–18. <https://doi.org/10.1080/0953732032000046024>
- Brown, N., Rappert, B. & Webster, A. (2000). *Contested Futures - A Sociology of Prospective Techno-Science*. Routledge, Taylor & Francis Group. <https://www.taylorfrancis.com/books/mono/10.4324/9781315259420/contested-futures-nik-brown-brian-rappert> [2026-03-23]
- Bryman, A. (2012). *Social research methods*. Fourth edition. Oxford University Press. [http://bvbr.bvb.de:8991/F?func=service&doc\\_library=BVB01&doc\\_number=024466548&line\\_number=0001&func\\_code=DB\\_RECORDS&service\\_type=MEDIA](http://bvbr.bvb.de:8991/F?func=service&doc_library=BVB01&doc_number=024466548&line_number=0001&func_code=DB_RECORDS&service_type=MEDIA) [2026-01-08]
- Bubela, T., Nisbet, M.C., Borchelt, R., Brunger, F., Critchley, C., Einsiedel, E., Geller, G., Gupta, A., Hampel, J., Hyde-Lay, R., Jandciu, E.W., Jones, S.A., Kolopack, P., Lane, S., Lougheed, T., Nerlich, B., Ogbogu, U., O’Riordan, K., Ouellette, C., Spear, M., Strauss, S., Thavaratnam, T., Willemse, L. & Caulfield, T. (2009). Science communication reconsidered. *Nature Biotechnology*, 27 (6), 514–518. <https://doi.org/10.1038/nbt0609-514>
- Bucchi, M. & Trench, B. (eds) (2014). *Routledge Handbook of Public Communication of Science and Technology: Second edition*. second edition. Routledge. <https://doi.org/10.4324/9780203483794>

- Bundesministerium für Forschung, Technologie und Raumfahrt (2025). *Aktionsplan für das weltweit erste Fusionskraftwerk in Deutschland*.  
<https://www.bmft.bund.de/SharedDocs/Kurzmeldungen/DE/2025/10/011025-aktionsplan-fusion.html> [2026-03-19]
- Bundesministerium für Wirtschaft und Klimaschutz (BMWE) (2016). *Klimaschutzplan 2050*.  
<https://www.bundeswirtschaftsministerium.de/Redaktion/DE/Publikationen/Industrie/klimaschutzplan-2050.html> [2026-03-19]
- Bustreo, C., Ben Ayed, N., Biberacher, M., Bongiovi, G., Börcsök, E., Čadenović, R., Cok, V., Colucci, G., De Marchi, E., Dongiovanni, D.N., Ferencz, Z., Geysmans, R., Giacometti, A., Gracceva, F., Jones, C.R., Kembleton, R., Kenens, J., Lamut, U., Lechon, Y., Lerede, D., Lopes Cardozo, N.J., Meskens, G., von Müller, A., Olahne Groma, V., Oltra, C., Orlando, M.T., Povh, J., Prades, A., Savoldi, L., Stankiewicz, P., Trotta, A., Turcanu, C., Vitiello, S. & Ward, S.H. (2024). Socio economic perspectives on fusion power for a sustainable future energy system. *Fusion engineering and design*, 208.  
<https://doi.org/10.1016/j.fusengdes.2024.114679>
- Cambridge Dictionary (2026). *responsibility*.  
<https://dictionary.cambridge.org/dictionary/english/responsibility> [2026-03-04]
- Cuppen, E., Grift, E. van de & Pesch, U. (2019). Reviewing responsible research and innovation: lessons for a sustainable innovation research agenda? In: *Handbook of Sustainable Innovation*. Edward Elgar Publishing. 142–164.  
<https://www.elgaronline.com/edcollchap/edcoll/9781788112567/9781788112567.0015.xml>
- Dunlap, R.A. (2021). *Energy from Nuclear Fusion*. First edition. IOP Publishing.  
<https://iopscience.iop.org/book/mono/978-0-7503-3307-8>
- Durant, J.R., Evans, G.A. & Thomas, G.P. (1989). The public understanding of science. *Nature*, 340 (6228), 11–14. <https://doi.org/10.1038/340011a0>
- Edwards, R. & Holland, J. (2013). *What is Qualitative Interviewing?* Bloomsbury Academic. <http://www.bloomsburycollections.com/collections/monograph> [2026-02-26]
- European Commission (2000). *Communication from the Commission on the precautionary principle*. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52000DC0001> [2026-03-18]
- European Commission, D.-G. for R. and I. (2012). *Responsible research and innovation: Europe's ability to respond to societal challenges*. Publications Office of the European Union. <https://data.europa.eu/doi/10.2777/11739> [2026-03-11]
- Fischhoff, B. (2013). Sciences of science communication. *Proceedings of the National Academy of Sciences - PNAS*, 110 (Supplement 3), 14033–14039.  
<https://doi.org/10.1073/pnas.1213273110>
- Fischhoff, B., Brewer, N. & Downs, J. (2011). *Communicating Risks and Benefits: An Evidence-Based User's Guide*. <https://www.fda.gov/media/81597/download>

- Fischhoff, B. & Davis, A.L. (2014). Communicating scientific uncertainty. *Proceedings of the National Academy of Sciences*, 111 (supplement\_4), 13664–13671. <https://doi.org/10.1073/pnas.1317504111>
- Gi, K., Sano, F., Akimoto, K., Hiwatari, R. & Tobita, K. (2020). Potential contribution of fusion power generation to low-carbon development under the Paris Agreement and associated uncertainties. *Energy Strategy Reviews*, 27, 100432. <https://doi.org/10.1016/j.esr.2019.100432>
- Girka, I. (2019). *Nuclear Fusion: One Noble Goal and a Variety of Scientific and Technological Challenges*. <https://www.perlego.com/book/2026037/nuclear-fusion-one-noble-goal-and-a-variety-of-scientific-and-technological-challenges-pdf>
- Grünwald, R. (2024). Auf dem Weg zu einem möglichen Kernfusionskraftwerk - Wissenslücken und Forschungsbedarf aus Sicht der Technikfolgenabschätzung. <https://doi.org/10.5445/IR/1000177720> [2026-01-05]
- Hallgren, L. (2017). The role of social constructionism as a reflexive tool in environmental communication education. In: *Environmental Communication Pedagogy and Practice*. first edition. Routledge. <https://www.taylorfrancis.com/chapters/oa-edit/10.4324/9781315562148-8/role-social-constructionism-reflexive-tool-environmental-communication-education-lars-hallgren>
- van Hulst, M. & Visser, E.L. (2024). Abductive analysis in qualitative research. *Public Administration Review*, 85 (2), 567–580. <https://doi.org/10.1111/puar.13856>
- IEA (2025). *World Energy Outlook 2025*. <https://www.iea.org/reports/world-energy-outlook-2025> [2026-03-02]
- ITER (2023). *60 years of progress. ITER - the way to new energy*. <https://www.iter.org/fusion-energy/60-years-progress> [2026-03-18]
- Jakobsen, S.-E., Fløysand, A. & Overton, J. (2019). Expanding the field of Responsible Research and Innovation (RRI) - from responsible research to responsible innovation. *European planning studies*, 27 (12), 2329–2343. <https://doi.org/10.1080/09654313.2019.1667617>
- Jonas, H. (1979). *Das Prinzip Verantwortung - Versuch einer Ethik für die technologische Zivilisation*. Erste Edition. suhrkamp taschenbuch.
- Keynes, J.M. (1937). The General Theory of Employment. *The Quarterly Journal of Economics*, 51 (2), 209–223. <https://doi.org/10.2307/1882087>
- Köberle, P. & Gehrke, J.P. (2017). Kernfusion. In: *Moderne Physik*. Walter de Gruyter GmbH. 123–148. <https://doi.org/10.1515/9783110526233-008>
- Kueffer, C. & Larson, B.M.H. (2014). Responsible Use of Language in Scientific Writing and Science Communication. *BioScience*, 64 (8), 719–724. <https://www.jstor.org/stable/90006896>
- Landtag Nordrhein-Westfalen (2026). Das erste Fusionskraftwerk soll in Nordrhein-Westfalen stehen - Jetzt die Weichen für die Energieversorgung der Zukunft stellen. Parlamentsdokument.

- <https://www.landtag.nrw.de/portal/WWW/dokumentenarchiv/Dokument/MMST18-3414.pdf> [2026-03-04]
- van Lente, H. (2012). Navigating foresight in a sea of expectations: lessons from the sociology of expectations. *Technology Analysis & Strategic Management*, 24 (8), 769–782. <https://doi.org/10.1080/09537325.2012.715478>
- Lerede, D., Nicoli, M., Savoldi, L. & Trotta, A. (2023). Analysis of the possible contribution of different nuclear fusion technologies to the global energy transition. *Energy Strategy Reviews*, 49, 101144. <https://doi.org/10.1016/j.esr.2023.101144>
- Liebert, W. & Schmidt, J.C. (2010). Collingridge’s dilemma and technoscience: An attempt to provide a clarification from the perspective of the philosophy of science. *Poiesis & praxis : international journal of ethics of science and technology assessment*, 7 (1–2), 55–71. <https://doi.org/10.1007/s10202-010-0078-2>
- McKeon, R. (1957). The Development and the Significance of the Concept of Responsibility. *Revue Internationale de Philosophie*, 11 (39 (1)), 3–32. <https://www.jstor.org/stable/23940271>
- Mead, G.H. (1934). In: Morris, C.W. (ed.) *Mind, self, and society: From the standpoint of a social behaviorist*. University of Chicago Press. 253–260 and 325–328. <https://nbn-resolving.org/urn:nbn:de:0168-ssoar-50777-3>
- Merian, A. (2024). *Focal points in nuclear fusion*. Max-Planck-Gesellschaft. <https://www.mpg.de/25486262/focal-points-in-nuclear-fusion> [2026-03-02]
- Molek-Kozakowska, K. (2016). Pragmalinguistic Categories in Discourse Analysis of Science Journalism. *Lodz Papers in Pragmatics*, 11. <https://doi.org/10.1515/lpp-2015-0009>
- Moore, A. (2010). Beyond participation: Opening up political theory in STS. *Social Studies of Science*, 40 (5), 793–799. <https://doi.org/10.1177/0306312710383070>
- Moore, A. (2012). Following from the front: Theorizing deliberative facilitation. *Critical policy studies*, 6 (2), 146–162. <https://doi.org/https://doi.org/10.1080/19460171.2012.689735>
- National Academy of Science and Engineering (2024). Nuclear Fusion Research: Academies Evaluate the Status Quo. *acatech - National Academy of Science and Engineering*. <https://en.acatech.de/allgemein/nuclear-fusion-research/> [2026-03-02]
- Nielsen-Sikora, J. & Gordon, J.-S. (2017). Hans Jonas. Zur Diskussion seiner Denkwege. <https://doi.org/10.30819/4452> [2026-03-09]
- ntv Nachrichten (2024). *Merz trotz Kritik für Alternative: Ist Kernfusion statt -spaltung sichere Energiequelle?* [https://www.youtube.com/watch?v=\\_3AZQj6FNn8](https://www.youtube.com/watch?v=_3AZQj6FNn8) [2026-03-19]
- Owen, R., Bessant, J.R. & Heintz, M. (2013). *Responsible innovation: managing the responsible emergence of science and innovation in society*. first edition. John Wiley & Sons Inc. <https://doi.org/https://ebookcentral.proquest.com/lib/slub-ebooks/detail.action?pq-origsite=primo&docID=1166329>

- Owen, R., Macnaghten, P. & Stilgoe, J. (2012). Responsible Research and Innovation: From Science in Society to Science for Society, with Society. *Science and Public Policy*, 39, 751–760. <https://doi.org/10.1093/scipol/scs093>
- Pellizzoni, L. (2004). Responsibility and Environmental Governance. *Environmental Politics*, 13 (3), 541–565. <https://doi.org/10.1080/0964401042000229034>
- Pielke, R.A. (2007). *The honest broker: making sense of science in policy and politics*. first edition. Cambridge Univ. Press.
- Robson, C. & McCartan, K. (2016). *Real World Research - A Resource for Users of Social Research Methods in Applied Settings*. fourth edition.
- Sadik-Zada, E.R., Gatto, A. & Weißnicht, Y. (2024). Back to the future: Revisiting the perspectives on nuclear fusion and juxtaposition to existing energy sources. *Energy*, 290. <https://doi.org/10.1016/j.energy.2023.129150>
- Scholten, V., van den Hoven, J., Cuppen, E. & Flipse, S. (2016). Science communication and Responsible Research and Innovation. How can they complement each other? *Journal of Science Communication*, 15 (6), C04. <https://doi.org/10.22323/2.15060304>
- Schultz, I. (2025). Record-Breaking Fusion Lab More Than Doubles Its 2022 Energy Breakthrough. *Gizmodo*. <https://gizmodo.com/record-breaking-fusion-lab-more-than-doubles-its-2022-energy-breakthrough-2000604093> [2026-01-07]
- Stahl, B.C., Timmermans, J. & Flick, C. (2017). Ethics of Emerging Information and Communication Technologies: On the implementation of responsible research and innovation. *Science and Public Policy*, 44 (3), 369–381. <https://doi.org/10.1093/scipol/scw069>
- Stilgoe, J., Owen, R. & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research policy*, 42 (9), 1568–1580. <https://doi.org/10.1016/j.respol.2013.05.008>
- The Oxford Scientist (2022). How close are we to fusion power? *The Oxford Scientist*. <https://oxsci.org/how-close-are-we-to-fusion-power/> [2026-03-18]
- Umweltbundesamt (2026). *Treibhausgasdaten zeigen: Klimaschutz braucht neuen Schub*. Umweltbundesamt. <https://www.umweltbundesamt.de/presse/pressemitteilungen/treibhausgasdaten-zeigen-klimaschutz-braucht-neuen> [2026-03-19]
- Von Dering, C., Wimmers, A., Böse, F., Kemfert, C. & Krauß, J. (2026). DIW Wochenbericht 8.
- Walker, W., Harremoës, P., Rotmans, J., Sluijs, J., Asselt, M.B.A., Janssen, P. & Kraus, M.P. (2003). Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support. *Integrated Assessment*, 4. <https://doi.org/10.1076/iaij.4.1.5.16466>
- Wimmers, A., Böse, F., Kemfert, C., Krauss, J., Reschlitz, J., Steigerwald, B. & Von Hirschhausen, C. (2026). *DIW Berlin: Kommerzielle Energieerzeugung mit Kernfusion nicht absehbar – Anwendungsforschung entwickelt sich dynamisch*. DIW Berlin. [https://doi.org/10.18723/diw\\_wb:2025-13-1](https://doi.org/10.18723/diw_wb:2025-13-1)

# Popular science summary

Nuclear fusion is often called the ‘holy grail’ of energy, a technology that could provide power without greenhouse gas emissions. As the world searches for solutions to the climate crisis, technologies like nuclear fusion are increasingly discussed as part of a sustainable energy future, but decades of research later, it remains unavailable for practical use, and many of its risks are still poorly understood. But how do those who communicate about this technology understand their own responsibility, and where are the limits of what they can communicate? To answer these questions, it is important to understand how scientific topics, such as nuclear fusion, are communicated and how communicators perceive themselves in their roles, because communicators influence how a technology is presented and how risks and benefits are demonstrated and discussed.

To explore these questions, I spoke with eight people who professionally communicate about nuclear fusion in Germany, including science journalists, journalists, policy advisors, and institutional communicators. Through these conversations, I gained insight into how they perceive their roles, where they see their responsibilities, and what limits they encounter in practice.

Through this approach, I found that responsibility operates on three levels: practical, ethical, and political. This means that not only does an ethical understanding of responsibility matter, but also the practical opportunities to act responsibly. Overall, there is a political component that influences how responsibility is implemented and what final decisions are made. A science journalist, for example, may understand responsibility as reporting facts accurately – the practical level. At the same time, they are influenced by editorial decisions about which topics get covered and how much space they receive – the political level. And underlying all of it, philosophical questions appear, for example: what do we owe to future generations when communicating about a technology whose consequences are not yet fully understood – the ethical level. Alongside this, the understanding and enactment of responsibility depend strongly on the role understanding of the communicating person and are limited by professional backgrounds, knowledge gaps, and a lack of technological understanding. A parliamentary technology assessment advisor, for instance, may want to communicate all risks transparently, but institutional constraints or the complexity of the technology itself may limit what they can say. This creates a gap between what responsible communication would ideally look like and what is actually possible.

Nuclear fusion is often described as a future green energy technology. This might affect political decisions and awareness of potential risks, such as potential military applications, material demands, and disposal difficulties arising from radioactivity. It is important to understand how communicators understand and enact responsibility when they communicate about nuclear fusion, because communication shapes how societies understand and respond to emerging technologies.

Nuclear fusion is one example, but these questions arise whenever emerging technologies with uncertain environmental consequences enter the debate about sustainable transformation. Renewable energy, carbon capture or geoengineering, all carry, sometimes more or less, uncertainties and risks that need to be communicated responsibly. Environmental communication plays a crucial role in shaping how societies understand these technologies and what futures they consider possible.

Responsible communication in this context would be transparent, inclusive, and shared across all actors involved, to contribute to informed, democratic decision-making about the future.

# Appendix 1 Interview Guideline

Interview guideline – translated into English:

## **Background and general information:**

1. Could you tell me something about your background?
2. When did you begin engaging with emerging technologies such as nuclear fusion?
3. Why do you choose to communicate about nuclear fusion / What situations and occasions lead you to communicate about nuclear fusion? What personal or institutional motives play a role in this?

## **Role understanding:**

4. When you communicate about nuclear fusion, how would you describe your role?
5. Follow-up: Informing? Explaining? Contextualizing? Taking a position/advocating? Mediating?
6. Do you tend to have an optimistic or pessimistic view of new technologies? Does this influence your communication, or do you remain neutral?

## **Uncertainties and expectations:**

7. Nuclear fusion has been discussed as a promising technology since the 1970s. Today, more than 50 years later, it still does not exist in a form we can practically use, despite significant progress. Many uncertainties regarding this technology remain. Which uncertainties do you encounter most frequently, and how do you deal with them?
8. What strategies do you use to communicate these uncertainties?
9. If political influence is relevant: What role does your political efficacy play in communicating uncertainties?
10. Have there been situations in which you had to adapt your way of communicating? If so, why and how?
11. How much uncertainty do you make visible in your communication? (explicitly, for example, through percentages or ranges)

12. If journalist: Do you believe that public reporting on nuclear fusion can create unrealistic expectations among readers? If so, do you see this as a real risk?

**Hype and Hope:**

13. Nuclear fusion is often associated with a great deal of hope, particularly regarding future energy security. How do you professionally deal with this hype in your communication?
14. Is the political debate about nuclear fusion changing as a result of private investors entering fusion research?

**Responsibility:**

15. In your opinion, what constitutes good communication about nuclear fusion?
16. Can you describe the role you take on in your communication?
17. What responsibility do you see in communicatively anticipating possible long-term consequences even today?
18. Do you see limits in your communication?
19. Who bears responsibility for future narratives: individual researchers, institutions, or society as a whole?

**Reflexivity and limits:**

20. Are there narratives, frames, or formulations that you consciously use or avoid when talking about nuclear fusion? Why?
21. Do you see a change in narratives as a result of private investors entering fusion research, and if so, how do you assess this?
22. How do your own values, opinions, or assumptions influence the way you communicate?
23. How would you assess the current public communication about nuclear fusion in Germany? Is there anything you would change?
24. Do you see the public more as an addressee of science communication or as an active co-creator?
25. What challenges do you currently see and foresee in the future for the communication of new technologies such as nuclear fusion?

**Question relating to a publication and closing:**

26. Could you tell me something about the process of creating XXX and what goal you pursued with it?
27. Is there anything important regarding the responsible communication of new technologies that we have not yet addressed, or anything you would like to add?

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