Policy Responses to Hydrogen Import Challenges in the Netherlands

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Preface

This thesis marks the completion of my Master's programme in Complex Systems Engineering and Management at Delft University of Technology. Over the past months, I have had the opportunity to explore a topic of growing importance within the energy transition: the role of policy interventions in shaping hydrogen import strategies for the Netherlands. Conducting this research has been both intellectually challenging and highly rewarding. As a qualitative study grounded in expert interviews, it allowed me to engage with a wide range of perspectives from professionals and policymakers at the forefront of the hydrogen sector. Their insights have been invaluable in shaping the findings presented in this work.

In addition to these conversations, visiting hydrogen-related events and completing my graduation internship at Statkraft significantly enriched the process. These experiences not only deepened my knowledge but also made the work highly enjoyable and motivating. Writing a thesis can at times be a solitary process, but the interaction with professionals in the sector turned it into a far more dynamic and engaging process. These interactions provided me with valuable market insights and strengthened my enthusiasm for the industry.

In particular, I would like to thank my supervisor, Toyah Rodhouse, for her constructive feedback, thoughtful input, and for thinking along with me when I lost the overview. Her enthusiasm and insights helped me move forward multiple times. I also thank Aad Correljé for his guidance, both during this thesis and throughout the Master's programme. His engaging energy courses have sparked my interest in the energy sector, and I've learned a great deal from him over the past two years.

A special thanks goes to Rob Smit for offering me the opportunity to conduct my thesis research at Statkraft's Hydrogen department. This made the process significantly more valuable and enjoyable, allowing me to apply theoretical insights from my studies in a real-world setting at a leading company in the sustainable energy sector. I look back on a valuable and enjoyable internship period where I was able to learn from professionals with years of experience in the field. This gave me not only knowledge but also energy and motivation to continue pursuing a career in this sector. I also extend my thanks to the rest of the hydrogen team at Statkraft, as well as to Max Tönis for sharing his expertise on green ammonia projects.

Finally, I would like to thank all the experts who generously shared their time and knowledge during the interviews. Their openness and insights were central to the depth and relevance of this research.

I genuinely hope this thesis contributes in a small but meaningful way to the broader discussion on sustainable energy systems and the development of effective policy frameworks for the emerging hydrogen import systems. I have learned a lot about this complex and dynamic sector, and perhaps I have had the chance to apply the theory of Complex Systems Engineering in a real-world context. One thing has certainly become clear: this research is about a very complex system!

Doris Brasser
Delft, August 2025

Executive Summary

The Netherlands aims to play a leading role in the European hydrogen economy by developing international hydrogen import chains, which are considered essential to complement domestic production and meet long-term decarbonization goals. As a highly industrialized country with limited potential for large-scale renewable energy expansion, the Netherlands will need to import green hydrogen to meet its climate and industrial goals. Although government strategies acknowledge this need, commercial-scale hydrogen imports have yet to materialize.

This research explores the extent to which current policy instruments effectively address the key challenges associated with early-stage hydrogen import chains, with a focus on green ammonia.

A qualitative embedded case study approach was used to examine how institutional and regulatory differences expose distinct challenges in hydrogen import chains, along with the policy responses needed to overcome them. The overarching case focuses on the Dutch hydrogen import landscape, with two embedded case studies serving as comparative subunits:

- Case 1: A potential green ammonia import value chain between the United Kingdom and the Netherlands.
- Case 2: A potential green ammonia import value chain between Norway and the Netherlands.

Although both countries are not members of the EU, Norway is part of the European Economic Area. It therefore operates within a regulatory framework that is more closely aligned with the EU than the United Kingdom. This contrast allowed the study to compare context-specific challenges and explore how institutional differences shape appropriate policy responses. The involvement of Statkraft in green ammonia projects in both countries facilitated access to key stakeholders and practical insights.

The research combined policy document analysis with 18 semi-structured interviews across sectors, including industry, government-affiliated organizations, infrastructure providers, and research institutions. Two complementary theoretical frameworks guided the study. First, the Product Life Cycle theory explains how emerging sectors such as green hydrogen evolve through phases, from development to maturity. It highlights the type of policy support needed at each stage. Second, transition failure frameworks from Weber et al. (2012) and Bolhuis (2024) were used to categorize systemic challenges that arise during shifts from conventional to sustainable systems. Together, these frameworks supported a structured interpretation of both the market's developmental stage and the nature of the challenges it faces, providing a foundation for evaluating the adequacy of current policy interventions.

This study reveals that a complex and interdependent set of challenges challenges the development of green ammonia import chains to the Netherlands. These are not isolated technical or regulatory issues, but system-wide challenges that span multiple domains. Based on policy analysis and stakeholder interviews, the following key findings emerge:

- Disruptions in one area of the import value chain can cause cascading effects throughout the entire chain. Stakeholders consistently recognized this systemic complexity and stressed that progress requires coordinated, parallel development.
- Political targets for hydrogen imports are often set without realistic pathways or supporting instruments. While ambitions are high, the underlying policies lack credibility in the eyes of stakeholders, which weakens investor confidence and slows project momentum.
- RED III mandates for the industry and transport sectors are seen as strong drivers for import development. The Netherlands has not translated these EU-level ambitions into enforceable national frameworks, creating uncertainty for project developers. H2Global is also widely regarded as promising in both interviews and policy documents, but its effectiveness depends on scaling up. The European Hydrogen Bank's international pillar is still under development and should be linked to H2Global to improve access to funds for third countries.

- In Norway, especially, local concerns about ammonia safety and green energy-based export products create challenges. These concerns reflect broader societal unease rather than opposition from transition ”losers.” This form of resistance is currently underrepresented in transition failure theory, but proves to be a crucial factor in practice.
- The UK’s position outside the EU and EEA introduces friction in aligning certification schemes. The absence of a bilateral agreement between the Netherlands and the UK further complicates project development.
- In the UK, where the case projects are relatively mature, challenges are primarily operational. In Norway, by contrast, the main challenges are structural and societal, due to limited political prioritization and public hesitation.

This research contributes to the literature on energy transition policy by offering a system-level perspective on the development of hydrogen import chains, specifically green ammonia routes from the UK and Norway to the Netherlands. While previous studies have focused mainly on domestic hydrogen production, this research highlights challenges related to the development of international hydrogen import value chains, such as the UK’s export subsidy uncertainty and Norway’s societal resistance. By using qualitative system mapping, the study reveals how interdependent challenges create system-wide uncertainty. A theoretical contribution of this research is the identification of public legitimacy as a distinct transition challenge that is currently underrepresented in existing transition failure typologies [75, 7]. Particularly in the case of green ammonia, public acceptance emerged as a crucial factor not only in the Netherlands but also in exporting countries like Norway. These findings suggest that insufficient societal support can act as a structural challenge to transition, highlighting a gap in current theoretical models.

In conclusion, achieving the Netherlands’ hydrogen import ambitions requires an approach that balances ambition with realism. A stable and adaptive policy framework, grounded in system thinking and tailored to the developmental stage of the market, is essential to facilitate investment, foster international cooperation, and support the broader energy transition.

Contents

Nomenclature

Abbreviations

Abbreviation	Definition
DMP	Data Management Plan
CBAM	Carbon Border Adjustment Mechanism
EEA	European Economic Area
EBN	Energie Beheer Nederland
EHB	European Hydrogen Bank
EU	European Union
LOHCs	Liquid Organic Hydrogen Carriers
MoU	Memorandum of Understanding
MS	Member States
PLC	Product Life Cycle
RED	Renewable Energy Directive
RFNBO	Renewable Fuels of Non-Biological Origin

Symbols

Symbol	Definition
CO_2	Carbon dioxide
H_2	Hydrogen
LH_2	Liquefied hydrogen
NH_3	Ammonia

1 Introduction

The urgent challenge of climate change has led nations around the world to improve efforts to reduce greenhouse gas emissions [14]. The European Union (EU) aims to achieve climate neutrality by 2050 [27], a target that requires the Netherlands, a highly industrialized country with limited renewable energy potential, to adopt a diverse mix of renewable technologies [13]. Although expanding wind and solar power is essential, constraints such as limited land availability and grid congestion complicate their large-scale integration. This underscores the need for versatile and scalable energy carriers to complement renewable electricity and replace natural gas [43].

Green hydrogen, produced via water electrolysis using renewable electricity, is expected to play a pivotal role in this transition. It can accommodate intermittent renewable energy generation [9] and has various applications, particularly in decarbonizing industries, heavy transport, and hard-to-electrify sectors [43, 34]. However, the Netherlands faces challenges in establishing a hydrogen economy due to limited land for renewable energy expansion and grid congestion. Consequently, domestic production alone will not suffice to meet future hydrogen demand, particularly given the country's energy-intensive industrial base. To address this, it is necessary to establish reliable and cost-effective hydrogen import supply chains from regions with abundant renewable resources, which will be essential for the energy transition and industrial competitiveness [13, 59]. Hydrogen imports can complement domestic production, improve supply diversity, and potentially reduce costs [31].

The Dutch government has recognized the importance of securing hydrogen imports to complement domestic production. Despite growing global interest in hydrogen trading, large-scale imports have not yet occurred. Current estimates suggest that approximately 12 million tons of hydrogen could be available for export worldwide by 2030, based on announced projects. However, a significant portion (7 Mt hydrogen per year) of potential export has not yet been committed to customers, indicating that while hydrogen imports are widely viewed as a necessary step in the energy transition, commercial agreements and supply chains remain underdeveloped [36]. This discrepancy underscores the need for enhanced policy support to foster the development of a hydrogen import market.

Government policy plays a crucial role in shaping the early development of emerging green industries [42]. The Netherlands, with its strategic location as a European energy hub and a well-developed chemical industry, is well-positioned to become a key player in the European hydrogen economy. Its existing gas infrastructure presents an opportunity to repurpose it to support the storage and transportation of hydrogen [67]. Although interest and policy activity around hydrogen are increasing, the European hydrogen market still faces regulatory uncertainty and related challenges. This uncertainty discourages investment and threatens progress towards the EU's 2030 decarbonization goals. EU regulations and national strategic choices shape Dutch hydrogen policy. While the EU sets direction and provides financial support through initiatives such as the EU Hydrogen Strategy, the REPowerEU Plan, and the European Hydrogen Bank (EHB), Member States develop their import strategies independently [28].

The Netherlands aims to position itself as a key player in the European hydrogen import market [67]. To support the Netherlands' ambition to play a leading role in hydrogen imports [67], it is essential to assess how current policy interventions address existing challenges and where gaps and misalignments persist. This study contributes to this effort by mapping the current policy landscape, identifying key challenges and perceptions of current policy effectiveness based on stakeholder insights, and exploring the additional interventions needed to support the development of hydrogen import chains in the Dutch context.

The report is organized as follows: Chapter 2 provides essential background information on hydrogen imports, with a particular focus on green ammonia. Chapter 3 presents the theoretical framework that underpins the analysis. Chapter 4 describes the methodology, detailing the combination of policy analysis and stakeholder interviews. Chapter 5 examines the main transition challenges identified through both documents and interviews. Chapter 6 assesses how current policies address these challenges and identifies key gaps or misalignments that still exist. Chapter 7 presents a broader perspective on the findings and offers broad policy recommendations. Finally, Chapter 8 synthesizes the answers to the research questions and presents the main conclusions of the study.

Link to CoSEM Master's Program

This thesis aligns with the Complex Systems Engineering and Management Master's program by focusing on hydrogen import value chains as complex socio-technical systems. These value chains span multiple countries and sectors, involving the integration of technical infrastructure (including production, transportation, storage) with a dynamic institutional environment shaped by policies, regulations, international cooperation, and stakeholder interests. Its complexity stems from the interaction between various actors, including governments, industry, and infrastructure operators, as well as the dynamic and emerging nature of hydrogen markets. This research investigates the relationship between policy measures and stakeholder needs, as well as broader system challenges. Therefore, this thesis supports the CoSEM program's goal of understanding complex, real-world systems with multiple actors through a research-based approach.

1.1. Motivation for Research Topic

This section provides a synthesis of academic literature relevant to hydrogen import developments in the Netherlands. The purpose of the synthesis is to describe the current state and to identify the research gap that will be addressed in this study. The literature selection process and the selected literature are detailed in the Appendix.

The European Union views renewable hydrogen as a crucial component of its strategy to achieve climate neutrality by 2050 [12]. Hydrogen imports are expected to play a vital role in this, particularly for countries like the Netherlands, which have limited domestic production potential.

A recent report by Elzenga, Eggink, and Joode [19] examines the progress of Dutch initiatives related to the production and import of green hydrogen. The report highlights that challenges exist in different parts of the green hydrogen value chain. These challenges hinder market development, resulting in slow momentum and a failure to meet key policy objectives. The main reason cited for the delay in the development of hydrogen (carriers) imports is the uncertain Dutch demand and the delayed construction of pipelines to transport hydrogen and ammonia to the industry cluster Chemelot and Germany. However, despite the challenges mentioned in the report by Elzenga, Eggink, and Joode [19], there is little discussion about the specific policy interventions required to stimulate import development. The report by Rooij et al. [65] confirms this: although importing green hydrogen could make an essential contribution to the energy transition, it currently receives relatively little attention from the perspective of national regulations and subsidies.

Zooming out to the European level, EU policy plays a central role in setting the rules for hydrogen trade. However, some parts of this policy may unintentionally cause delays. Talus, Pinto, and Gallegos [71] argues that the EU's strong focus on renewable fuels of non-biological origin (RFNBO) with strict qualification criteria makes it harder to get projects off the ground. This narrow definition aims to ensure sustainability, but limits flexibility in the early phase of hydrogen market development.

Previous research has explored hydrogen trade policies in Germany and the wider EU framework, but there remains a limited understanding of how Dutch hydrogen import policies interact with private investment conditions [61, 78, 70, 77, 4]. For example, Quitzow, Nunez, and Marian [61] show that Germany's international hydrogen strategy focuses on the formation of bilateral partnerships, yet often lacks concrete agreements. This makes it difficult for private companies to invest. Similarly, International Energy Agency [36] discusses the hydrogen trade strategy in Northwest Europe, noting that despite ambitious EU targets, formal agreements remain largely undefined. Unlike established energy markets, the hydrogen sector is still in its developmental phase, requiring government intervention for financial support and to incentivize demand off-take [42]. In line with this, Steinbach and Bunk [70] highlight the crucial role of government policies in developing hydrogen trade markets. They suggested adapting regulatory structures from the natural gas market to create clearer trading mechanisms for hydrogen. However, they also point out that the natural gas market is a mature and well-established system, which differs significantly from the current early-stage development of the hydrogen market. As such, applying similar regulatory approaches may not be appropriate at this stage.

Despite these insights, there remains limited knowledge about how the Dutch hydrogen import policy influences private investment. Hasankhani et al. [33] explores this gap and identifies structural problems in the Dutch domestic hydrogen system. These include unclear rules, delays in permits, and poor coordination between different levels of government. The stakeholders interviewed in the study state that these issues lead to project delays and make it harder for private parties to commit.

The Dutch hydrogen strategy is outlined by Stam, Linde, and Stapersma [67], who describes plans for infrastructure and international cooperation. However, their analysis does not address the question of how policy challenges affect private investment. Hasankhani et al. [33] go further by showing that poor communication between government and industry slows progress. They stress the need for clearer rules and simpler procedures to attract long-term investment.

Hydrogen import policies in the Netherlands and the EU are still evolving, but challenges such as complex regulations, financial risks, and infrastructure gaps continue to slow progress. Although much of the existing research addresses broad policy frameworks, there is limited attention to which specific policy instruments could help overcome these challenges and support the development of hydrogen import value chains in the Dutch context.

Although policy research on Germany and the European Union is more developed, dedicated studies focusing specifically on the Netherlands remain limited. Given the Netherlands' ambition to become a key hub for hydrogen imports, it is important to gain a clearer understanding of the specific challenges encountered by stakeholders at this stage of the import value chain development. Additionally, it is crucial to clarify the government's role and identify the necessary policy interventions to address these challenges and enable the sector to move forward. This research aims to fill that gap by examining the policy actions necessary to address current challenges and facilitate the development and scaling of hydrogen imports in the Netherlands.

1.2. Research Gap and Main Research Question

The literature covers hydrogen policies, but lacks a focused examination of how Dutch hydrogen import policy interventions can be optimized to address key challenges and facilitate scaling. Dedicated research on the Netherlands remains scarce, with most studies providing broad overviews [67] or focusing on hydrogen market regulation at the EU level [4]. As the Netherlands aims to establish itself as a key hub for importing hydrogen, it is essential to identify and address challenges in the early-stage development of hydrogen import chains.

Thus, the central research question emerging from this gap is:

To what extent does Dutch policy effectively respond to the key challenges in developing hydrogen import value chains?

1.3. Sub-Research Questions

To address the main research question, four sub-questions have been identified:

1. *What challenges hinder the development of hydrogen import chains in the Netherlands?*
2. *What are the current Dutch and EU policy instruments governing hydrogen imports?*
3. *How do stakeholders perceive the effectiveness of current policy interventions in addressing hydrogen import development challenges?*
4. *What additional interventions are needed to effectively support the development of hydrogen imports in the Dutch context?*

The first research question aims to identify challenges that could hinder the development of hydrogen import chains.

Research specific definitions

This research defines **challenges** as systemic obstacles and uncertainties that impede the development of the hydrogen import value chain.

The concept of **policy instruments** refers to the actions intended by governments to address these challenges, indirectly or directly. This includes instruments such as financial support strategies, regulation, directives, and bilateral and multilateral partnerships and platforms directly or indirectly related to hydrogen import developments.

These challenges will be identified through a combination of practical insights from semi-structured stakeholder interviews and a document analysis of relevant policy and policy-related texts. To ensure a structured analysis, the identified challenges will be grouped into different categories of transition failures identified by Weber and Rohracher [75] and Bolhuis [7]. These different types of transition challenges will be explained further in Chapter 3, which outlines the theoretical framework of the investigation.

The second research question explores the current policy instruments that shape the hydrogen import landscape in the Netherlands. The policy landscape will be identified using the same policy document analysis and semi-structured interviews as in Question 1. The combination of these sources will provide insight into which instruments are most prominent in formal policy and which are most emphasized in practice. This dual approach helps assess the alignment between policy design and stakeholder attention, as well as which instruments are perceived as the most relevant in shaping the import value chain.

Based on this analysis, the third research question investigates how stakeholders perceive the effectiveness of these existing policy instruments in practice. The effectiveness of policy interventions depends not only on their content but also on how well they align with the current state of market development. This question focuses on assessing whether current interventions adequately address previously identified challenges and how effective these measures are considered to be in supporting import development. Stakeholders involved in different parts of the hydrogen value chain will reflect on the practical impact and limitations of the policy landscape. This question will therefore provide insight into how policies translate into actual progress.

Finally, the fourth research explores what additional interventions may be necessary to enable the scaling up of hydrogen import chains. Drawing on the perceived limitations identified in Question 3, this question seeks to provide policy-relevant insights into how the Dutch government and its partners can strengthen their approach to hydrogen imports.

1.4. Research Flow Diagram

The research flow diagram (Figure 1.1) visually represents the structured approach of this study. It serves as a guide to understanding how each research phase builds upon the previous one to address the research questions systematically.

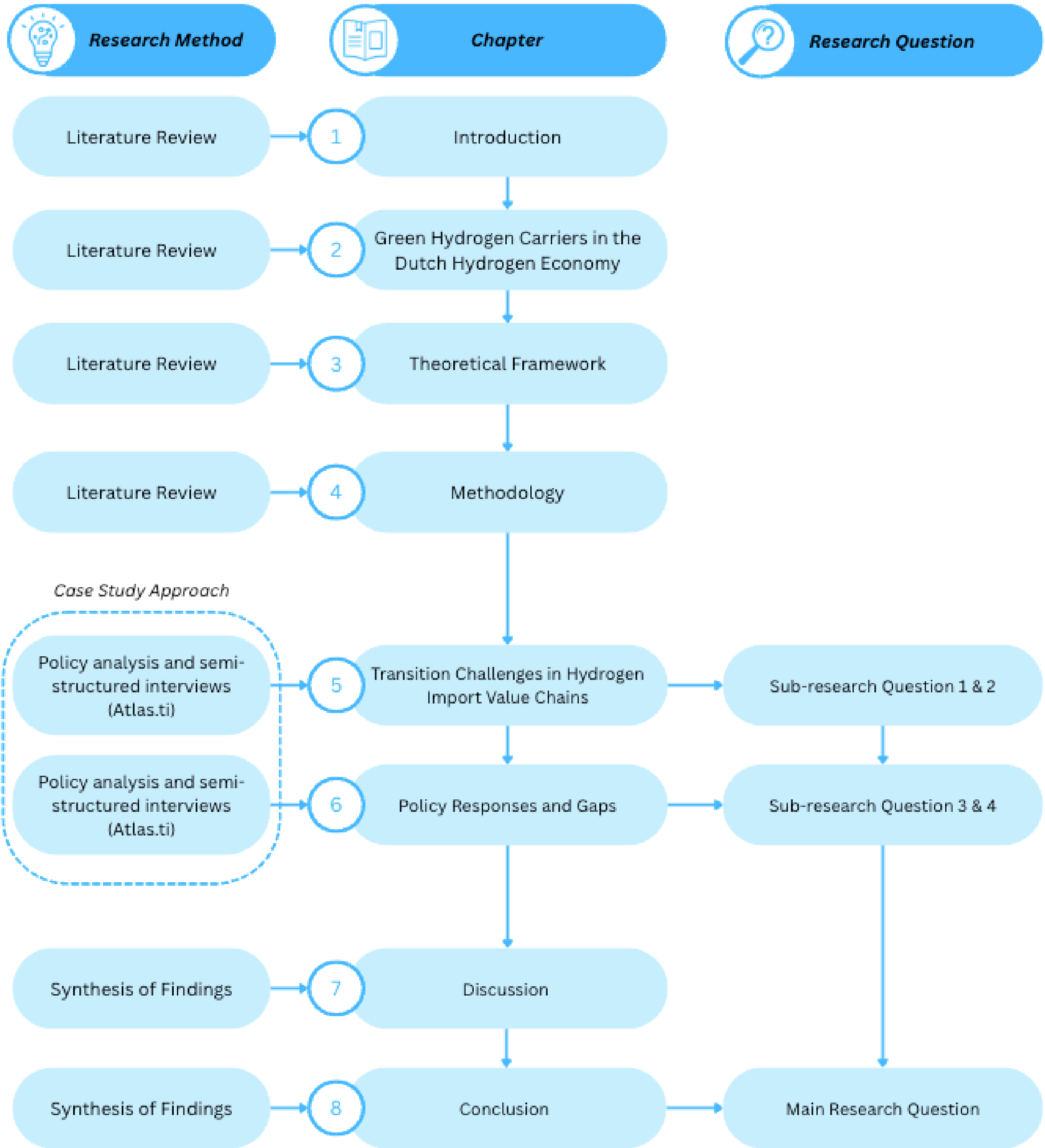

Figure 1.1: Research Flow Diagram

2

Green Hydrogen Carriers in the Dutch Hydrogen Economy

This chapter outlines the current state of hydrogen imports in the Dutch energy system. It begins by examining the role of hydrogen in achieving national climate goals, enhancing energy independence, and strengthening industrial competitiveness. Consequently, it explains why domestic production alone will be insufficient, making large-scale imports essential. Subsequently, the chapter outlines the rationale for the focus on ammonia as a hydrogen import carrier. Finally, the Dutch government's vision on ammonia is introduced. This chapter provides background knowledge for the analysis of implementation challenges in the following chapters.

2.1. The Role of Hydrogen Import in the Dutch Energy Transition

Hydrogen is increasingly recognized as a crucial element in the Dutch energy transition. Its strategic relevance stems from its potential to support multiple objectives: strengthening energy independence, allowing deep decarbonization of sectors that are difficult to eliminate, enhancing the flexibility of the energy system, and facilitating international trade in renewable energy [50, 19].

A persistent dependence on energy imports marks the current structure of the Dutch energy system. This ”import gap”, the difference between domestic production and energy demand, is expected to remain substantial even in future low-carbon scenarios. Figure 2.1, developed by the ”Dutch Energy Management” (in Dutch: Energie Beheer Nederland (EBN)), visualizes the anticipated trajectory of domestic production versus primary energy demand, highlighting the continued need for energy imports, including hydrogen.

Although the Dutch government aims to reduce its dependency on energy imports, the structural nature of this dependency cannot be overlooked. This should also be considered in the context of hydrogen: while domestic hydrogen production can reduce reliance on energy imports, it will be insufficient to meet growing demand.

Estimates from Netbeheer Nederland’s II3050 scenarios suggest that 40–60% of the Dutch hydrogen supply will need to come from imports by 2035, rising to 40–70% by 2040 when including transit volumes [44, 52]. The research of CE Delft projects that the demand from the industry and transport sectors alone could reach 60 to 100 PJ by 2030 [40]. These projections confirm that hydrogen imports are essential and not merely supplementary.

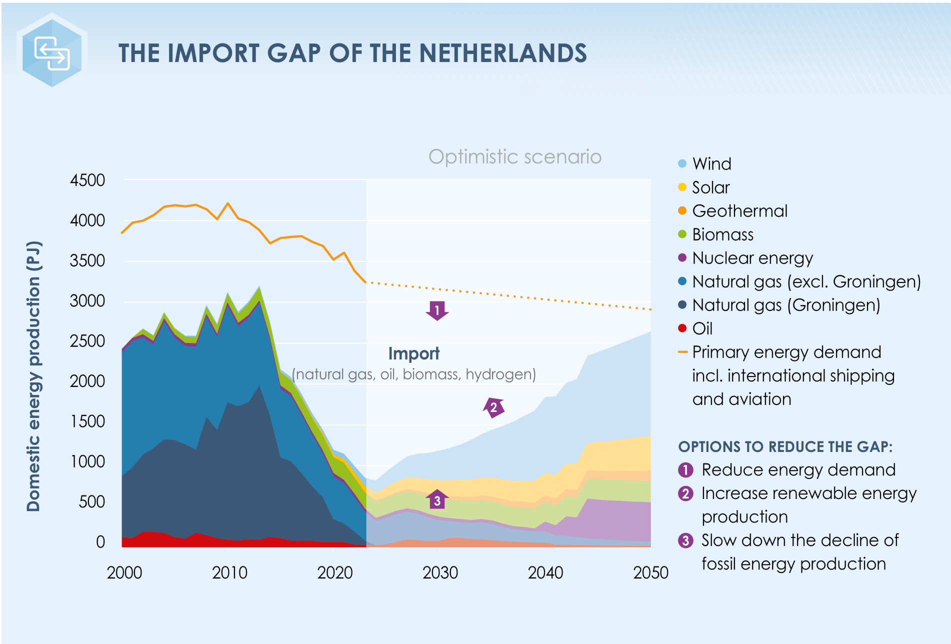

Figure 2.1: The import gap of the Netherlands: future scenarios for domestic production and projected demand (source: EBN)

This becomes even more evident when considering the sectoral breakdown of energy consumption. Figure 2.2, also published by EBN, provides an overview of energy flows in the Netherlands, from the source to the final use. It shows the predominance of the industrial and mobility sectors in total energy demand. These sectors are challenging to electrify and likely to depend on molecules such as hydrogen for decarbonization.

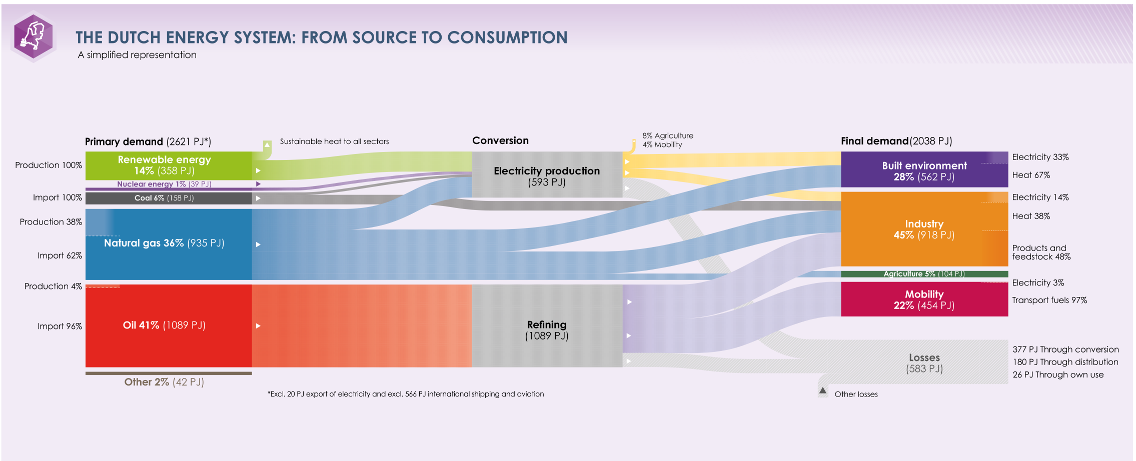

Figure 2.2: The Dutch energy system: from source to consumption (source: EBN)

Hydrogen offers a flexible and scalable alternative to fossil fuels in these sectors, as highlighted in the introduction. Moreover, unlike fossil energy resources, green hydrogen can be produced in a wider range of countries with abundant renewable energy, allowing the Netherlands to diversify its supply chains and reduce geopolitical risks [34]. This spatial flexibility represents a strategic advantage in building resilient import pathways, especially in the context of previous over-reliance on suppliers such as Russia.

Imports also reinforce the Netherlands' ambition to serve as a central energy hub for northwest Europe. By allowing import, transit, and re-export of hydrogen and its derivatives (e.g., ammonia, methanol, LOHCs), the Netherlands aims to maintain and expand its logistical relevance [50]. The current phase is viewed as a critical window for establishing the necessary infrastructure and international partnerships [44].

2.2. Hydrogen Import Technologies

The main hydrogen import technologies discussed in the literature include ammonia (NH_3), liquefied hydrogen (LH_2), liquid organic hydrogen carriers (LOHCs), methanol, and green gaseous hydrogen transported via pipelines. Each carrier presents specific trade-offs in terms of energy efficiency, infrastructure compatibility, safety, maturity, and scalability [1, 31].

- **Ammonia (NH_3)** is synthesized via the Haber-Bosch process by reacting hydrogen with nitrogen. It can be transported as a liquid at $-33°$C or at 10 bar, offering a high volumetric hydrogen density (107–120 kg/m^3). It benefits from a well-established global infrastructure. However, cracking ammonia back into hydrogen requires high temperatures (850–950°C), and its toxicity necessitates strict safety measures during transport and storage [73, 64].
- **Liquefied hydrogen (LH_2)** involves cooling hydrogen to $-253°$C to significantly reduce its volume. LH_2 offers high purity and is used in specialized applications such as aerospace. Nonetheless, the liquefaction process is energy-intensive and subject to boil-off losses during transport and storage [1, 73].
- **LOHCs (Liquid Organic Hydrogen Carriers)** chemically bind hydrogen to a carrier liquid. They can be handled using existing fuel infrastructure and offer improved safety. However, dehydrogenation requires high temperatures, and the hydrogen density is relatively low (6–7% by weight) [1, 73, 39].
- **Methanol** is a carbon-based liquid fuel widely used in industrial applications. It can be produced using green hydrogen and sustainable carbon sources, offering potential for carbon-neutral or negative fuels. Methanol is easy to store and transport, but the availability of sustainable carbon feedstock remains a key limitation [1].
- **Gaseous hydrogen** transported via pipelines is highly efficient for intra-European transport, offering minimal energy loss and leveraging well-established technology. However, the cross-border

pipeline infrastructure is still in development and is expected to be operational by 2032 [19].

This research focuses specifically on green ammonia as a carrier technology for import. Conventional ammonia, which is derived from fossil fuels, is already widely produced, traded, and stored globally, with a well-established international supply chain and port infrastructure. The Netherlands has existing infrastructure for importing and storing ammonia, including several large-scale tanks in Rotterdam and planned capacity expansions, such as a proposed 60,000-tonne facility in Europoort [40]. The rationale for this focus is also based on the strategic relevance of Statkraft, which is actively involved in green ammonia initiatives in both the United Kingdom and Norway and is exploring potential export routes to the Netherlands.

However, there are also several challenges to the import value chain of green ammonia. Ammonia is toxic and presents safety concerns in the event of leaks or accidents, which can limit its acceptance in densely populated areas. Both the synthesis and cracking of ammonia are energy-intensive processes. In particular, ammonia cracking remains an immature technology, with no full-scale commercial facilities currently in operation. This introduces uncertainty about its cost and performance. In addition, ammonia leaks can contribute to environmental problems such as acidification and formation of particles [44, 1].

According to Leguijt et al. [40] and Ministerie van Economische Zaken en Klimaat [44], green ammonia imports are expected to be the dominant mode of international hydrogen transport in the short term. The short-term export potential is identified in Scandinavia, Spain, Portugal, and Scotland [40, 44, 29]. These countries offer short transport distances and opportunities for accelerated supply chain development. Although long-term volumes may come from outside Europe, the establishment of intra-European import relationships is considered strategically important [40, 44].

When green ammonia is used directly, as a feedstock in fertilizer and chemical production or as a marine fuel, the need for energy-intensive reconversion to hydrogen is eliminated, reducing both costs and complexity [1, 39]. In such cases, imported ammonia may be more cost-effective than domestically produced hydrogen or ammonia, due to the high capital and operational costs of local hydrogen production [19].

2.3. Green Ammonia Import Value Chain

The establishment of a functioning green ammonia import value chain requires the coordination of multiple components in both the exporting and importing countries. Inspired by Guidehouse Netherlands [31], this section analyses the value chain through three interdependent domains: (1) physical infrastructure in exporting countries, (2) non-physical trade arrangements, and (3) physical infrastructure within the Netherlands 2.3. Each part must be aligned and developed simultaneously, as any gaps in one segment can compromise the viability of the entire chain.

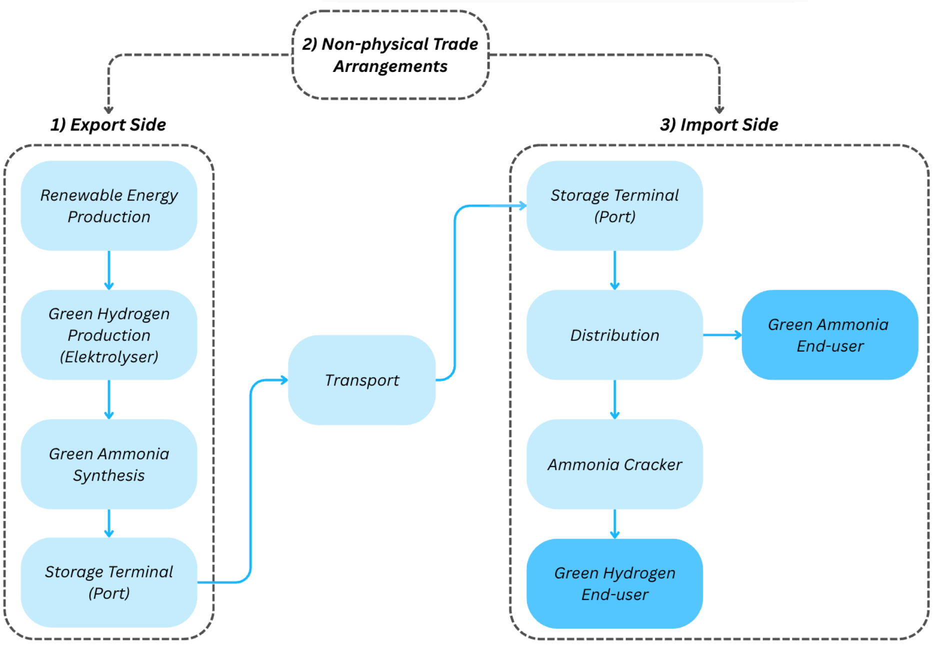

Figure 2.3: Overview of the green ammonia import value chain

On the export side, the value chain begins with the production of hydrogen using renewable electricity. The technologies required for renewable electricity generation, such as solar and wind energy, are mature. However, faster deployment is often constrained by supply chain bottlenecks and lengthy permitting procedures [1]. Consequently, renewable electricity is used to produce green hydrogen through the electrolysis of water, a process that splits water molecules into hydrogen and oxygen using an electric current. The technical maturity of electrolyzer manufacturing is considered mature, although ongoing technology improvements are still being made [36]. Hydrogen production itself via electrolysis is improving rapidly, and no technical bottlenecks are expected. Despite the low technical risk, the cost competitiveness of green hydrogen production largely depends on capital cost reductions for hydrogen production facilities and reductions in the cost of renewable power [29].

Ammonia synthesis is a mature and globally applied technology. Developers are currently working on designs that integrate renewable electrolysis with ammonia synthesis to increase system-level efficiency [1]. The storage and transport of ammonia by ship are similarly mature, with existing international trade routes and handling infrastructure in place. Ammonia is routinely stored in large cryogenic tanks. It is shipped worldwide in specialized tankers, indicating that the infrastructure in this segment can be largely scaled up from existing capabilities [1, 40, 55].

The second domain, non-physical trade flows, includes the regulatory and institutional frameworks that support and enable the physical movement of hydrogen. It includes elements such as certification systems, financial arrangements, trade agreements, and tariffs. One central aspect is compliance with the EU's RFNBO criteria. Certification systems must verify that the hydrogen used in ammonia production meets requirements such as additionality, temporal matching, and greenhouse gas reduction [44]. Challenges in this area can discourage investment in export and import infrastructure or divert hydrogen trade flows away from the Netherlands.

On the import side, the Netherlands has existing infrastructure for ammonia handling, which may facilitate its role in future hydrogen supply chains in northwest Europe. Currently, five large-scale ammonia storage tanks are located in industrial port areas, each with a capacity of 15,000 tons. A 60,000-ton tank is also planned at the OCI terminal in Europoort [40]. In Dutch ports, thirteen terminal development plans have been identified, although details on expected capacities are not yet available for all projects. Several major ports, including Rotterdam, Amsterdam, North Sea Port, and Eemshaven, have expressed ambitions to expand their import infrastructure. These combined plans represent a potential import capacity of approximately 650–700 PJ per year, equivalent to approximately 65-70 GW of electrolyzer output [40, 44]. Although these ambitions are substantial, the feasibility and timeline of their realization remain uncertain. Projects are at various stages of development and often encounter administrative and logistical complexities.

Ammonia transport within the Netherlands is expected to rely primarily on barge logistics. Although a direct ammonia pipeline to the German border is being considered, a widespread network of ammonia pipelines is not anticipated due to safety concerns and decentralized demand [39].

One critical component still in development is ammonia cracking, the process of converting ammonia back to hydrogen. Although technically feasible and demonstrated on the pilot scale, no commercial-scale facilities are currently operational. This limits the short-term application of imported ammonia to sectors that can utilize ammonia directly, such as fertilizer production, maritime fuel use, or electricity generation in port locations [1, 39].

The green ammonia import value chain includes mature and emerging technologies. The Netherlands may serve as a gateway for green ammonia in Europe, pending further technical development and international coordination.

3 Theoretical Framework

This chapter presents the theoretical frameworks used to analyze the development of hydrogen import value chains in the Netherlands. The Product Life Cycle (PLC) theory, as described by Levitt [42], explains how emerging markets evolve through distinct phases. This framework helps identify the current state of the hydrogen sector, specifically its development stage and the desired future stage. The transition between these stages presents various challenges. To better understand these challenges, the concept of transition failures is used, as described by Bolhuis [7] and Weber and Rohracher [75]. Their frameworks will provide information on challenges that arise when shifting from conventional to sustainable systems and will help justify the role of government in addressing them. Together, they provide a framework for analyzing the key challenges in developing hydrogen import value chains in the Netherlands.

3.1. Hydrogen Market Phases

The market for hydrogen and its derivatives needs to be developed along the entire value chain. Reaching a fully developed market with the necessary infrastructure and regulatory framework requires progressing through multiple stages [42, 77]. Understanding these phases of market development is essential, as each phase presents distinct demands on the stakeholders involved. The PLC Theory, introduced by Levitt [42], provides a structured framework for understanding how markets evolve through distinct phases: market development, growth, maturity, and decline. In the development stage, new products or industries face high levels of uncertainty, which necessitate demand creation, technological refinement, and supportive policies. As markets grow, competition intensifies, leading to efficiency improvements and cost reductions. Eventually, the market matures, becomes stable, and is widely adopted. Applying this framework to the development of the hydrogen market clarifies the progressive nature of adoption and highlights the strategic interventions needed at each stage to ensure sustained industry growth [42]. The market phases will not have clear boundaries, but will gradually transition over time. This evolution will continue until the hydrogen market reaches a mature state. As the hydrogen market consolidates, it will become more transparent and fluid, and prices will eventually be determined by global supply and demand [70, 75].

3.1.1. Market Development

The development phase, which represents the current stage of the hydrogen market, is where first-movers commercialize hydrogen and its derivatives [42]. To meet climate goals, hydrogen must be introduced rapidly under competitive conditions. However, demand for hydrogen at this stage remains uncertain, and it needs to be actively created. The government plays a crucial role in this process by implementing policies and incentives that make hydrogen a viable alternative to conventional energy sources [70, 77]. The hydrogen landscape is expected to develop through localized "hydrogen islands," where production, transportation, and consumption occur in close proximity. In these early markets, bilateral and long-term contracts will dominate to provide investment security. Currently, gray hydrogen is produced directly at its application sites, mainly concentrated in Germany and the Netherlands [70]. As a result, Europe's hydrogen infrastructure remains underdeveloped. In addition to infrastructure limitations, a significant cost gap exists between low-carbon hydrogen and conventional energy sources, rendering it less economically competitive. This further adds to demand uncertainty, as industries may hesitate to transition without financial incentives or regulatory support. Building a hydrogen economy requires substantial capital investment, but the high uncertainties in this phase increase investment risks. Risks such as price volatility, uncertain future demand, and competition between domestic and imported hydrogen must be effectively managed. The government plays a crucial role in mitigating these risks by establishing clear regulatory frameworks, providing financial incentives, and promoting infrastructure development. By providing stability and mitigating investment risks, government intervention can accelerate market development and encourage private sector participation [77].

3.1.2. Market Growth

The development phase is followed by the market growth phase. According to Levitt [42], this stage is characterized by rapid demand and market expansion. In this growth phase, hydrogen logistics and infrastructure must be further developed to support the increasing demand for hydrogen and its derivatives [77]. Small-scale pilot projects will be expanded to large industrial electrolyzers, enabling the mass production of hydrogen. However, despite these advances, significant investment is still needed in all stages of hydrogen production and supply. As technology improves and production increases, costs will decrease, making hydrogen investment more attractive. To provide investment security and ensure a reliable hydrogen supply, the market growth phase will still be characterized by long-term contractual relationships. As investment and production capacity increases, industrial hydrogen clusters will start to form and the first import corridors will gradually develop [77]. However, to fully support this expansion, import logistics, including ports, ships, storage facilities, and pipelines, must also be developed further. At the same time, EU-wide standards for transportation and regulations for cross-border trade will be essential to ensure an efficient and coordinated hydrogen market [70]. As the hydrogen market expands, reliable storage infrastructure will become increasingly crucial for balancing supply and demand. Storage facilities near consumption sites will act as buffers, ensuring a stable supply even when continuous hydrogen deliveries are not yet fully developed or guaranteed [77].

3.1.3. Market Maturity

From the market growth phase, the market evolves into the market maturity phase. The maturity phase, according to Levitt [42], is characterized by market growth stabilization, demand reaching a steady level, the infrastructure being fully developed, and competition shifting toward efficiency, cost reduction, and service differentiation. In this phase, the hydrogen backbone is established at the transmission and distribution levels, and hydrogen will be utilized in all relevant hard-to-decarbonize sectors. Responsibilities, market roles, and liability issues have been defined, and commercial risk mitigation has been standardized. Market consolidation will drive the hydrogen market to become more transparent and liquid, with prices ultimately determined by global supply and demand in the long term Steinbach and Bunk [70] and Westphal et al. [77]. The stage of market decline in Levitt's theory is not relevant to the hydrogen market because it will be a key component of a green energy system, securing its long-term role.

Levitt's framework provides insight into the current phase of the hydrogen market and outlines the stages required to develop a fully established and effective hydrogen market. In each phase, stakeholders have different roles, with the government playing a crucial role in initiating and supporting market development. Its involvement is essential to stimulate growth, reduce uncertainties, and create the conditions for a more competitive, transparent, and liquid free market. This is especially relevant for this research because it helps identify the key challenges to hydrogen imports at each stage of development and to understand what policy interventions are needed to facilitate their growth.

3.2. Transition Challenges

Progress in establishing the hydrogen import value chain is currently lagging behind the pace necessary to achieve the target capacity. If the Netherlands fails to establish an effective hydrogen import value chain, it will undermine the transition of the energy system and hinder the achievement of the energy goals and the broader climate policy objectives [31, 19]. [75] integrates insights from the innovation system and multi-level perspective frameworks into a comprehensive 'failures' framework. This framework expands upon the traditional classifications of market and system failures by introducing a new category: transformational system failures.

Transformational system failures occur when socio-technical systems are unable to adapt or transform in response to emerging societal needs and challenges. These failures result from ineffective policy mechanisms, a lack of stakeholder engagement, rigid institutional structures, and a lack of strategic direction. Weber and Rohracher [75] outlines four key types of failure that can hinder transformational change, namely: directionality failures, demand articulation failures, policy coordination failures, and reflexivity failures.

Bolhuis [7] builds upon the typology of transition failures introduced by Weber and Rohracher [75], offering a more detailed classification by distinguishing ten categories of systemic failures that can hinder transitions to sustainable systems. This research adopts a synthesized framework based on both contributions to structure the analysis of hydrogen import value chains. Although both studies use the term "failures", this study opts for the term "challenges", as this choice of terminology reflects a more constructive and solution-oriented approach.

Table 3.1 provides an overview of the different types of transition challenges that will be used to structure the analysis of the challenges in the development of hydrogen import value chains identified in the policy analysis, as well as the results of semi-structured interviews conducted with stakeholders involved in the hydrogen import value chain.

Type of Transition Challenge	Description
Demand articulation	Insufficient articulation of market demand limits coordinated investment and innovation, particularly under conditions of uncertainty and interdependence among supply chain actors. Public coordination is often necessary to stimulate synchronized market activity.
Inadequate physical infrastructure	The development of essential infrastructure is hampered by long investment horizons and low short-term returns, despite its vital coordinating role in facilitating systemic transitions.
Insufficient policy coordination	Incoherence or contradiction between policies at different governance levels obstructs systemic change and undermines actors' ability to respond effectively to transition incentives.
Lack of shared directional vision	The absence of a collective vision or long-term goal hampers alignment among actors, delaying coordinated action and perpetuating uncertainty in the transition pathway.
Lack of ecosystem-wide financing	Fragmented or insufficient financial instruments prevent simultaneous investment across actors within a value chain, leading to under-investment in system-wide transition activities.
Lack of knowledge and resources	Deficits in technical knowledge, competencies, and productive resources inhibit actors' capacity to engage in or adapt to transformative innovation processes.
Incomplete or outdated institutions	Existing institutional arrangements and regulatory frameworks discourage or inhibit necessary behavioral change, often being misaligned with the objectives of sustainable transitions.
Limited reflexivity and learning capacity	Actors fail to monitor, learn, and anticipate effectively, leading to delayed or ineffective responses to transition developments.
Opposition from transition losers	Actors expecting to incur losses actively resist change, which can slow systemic progress.

Table 3.1: Overview of transition challenges based on Weber (2012) and Bolhuis (2024).

As with market and system failures, transformational failure serves as a rationale for government intervention Weber and Rohracher [75]. Thus, from a broad policy perspective, the advance of hydrogen import through targeted interventions can be justified, as it plays a crucial role in preventing transformational failure and supporting the achievement of energy and climate goals.

However, a policy intervention is only justified if it effectively addresses the challenges faced by market participants. Additionally, the policy intervention should align with the current development phase of the import value chain, as outlined in the previous section. When a challenge in the development of hydrogen imports can be linked to a transition challenge, intervention can be justified. The next step is to determine whether this challenge can be addressed with current or expected policy interventions or if additional policy is required. Additionally, it should be evaluated whether the policy intervention aligns with the phase of market development [75, 31]. For example, market regulation, which is typically suitable for mature and liquid markets, may pose challenges in the current nascent market for hydrogen imports.

Figure 3.1 illustrates how the transition challenges outlined in 3.1 combine with PLC theory of Levitt to form the theoretical framework for this research. The purpose of this framework is to support a structured analysis of the findings; it is not intended to validate the underlying theories empirically.

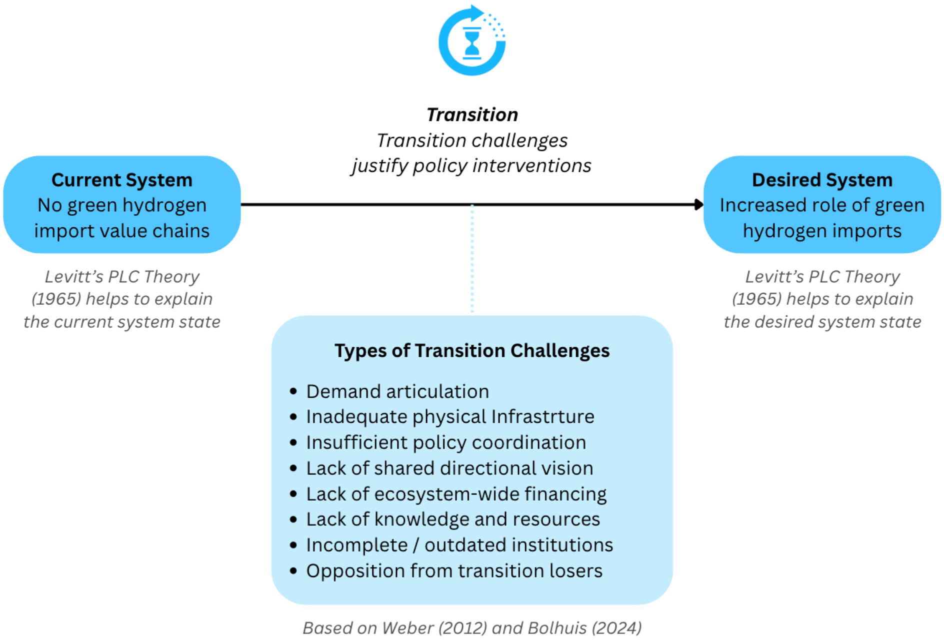

Figure 3.1: Diagram illustrating how the theoretical background [42, 75] guides the analysis of the transition from the current system (no green hydrogen imports) to the desired system (increased green hydrogen imports).

4

Methodology

This chapter outlines the main research approach and methodology used in this study. It begins by introducing the overall case study design and explaining the rationale for focusing on import value chains from potential export countries, the United Kingdom and Norway. The chapter then describes the two primary research methods: a policy analysis and a series of semi-structured stakeholder interviews. It explains how relevant documents and interviewees were selected, how the data were collected and coded, and how findings were analyzed. Finally, it discusses how these two methods were integrated to provide a coherent understanding of the challenges and policy dynamics involved in developing hydrogen import chains to the Netherlands.

4.1. Main Research Approach

This study employed a qualitative and descriptive case study approach to investigate how Dutch hydrogen import policy interventions can address key challenges in the development of hydrogen import value chains. A case study approach, as described by Yin [80], facilitates the study of real-world phenomena where the boundaries between the phenomenon and its context are not clearly defined. Given the evolving nature of international hydrogen markets, this approach enabled a comprehensive and practical understanding of policies and stakeholder perspectives.

This research aimed to gain a detailed understanding of the Dutch and European policy landscape concerning hydrogen imports. The theoretical framework described in Chapter 3 provided a structure and guidance for analysis; however, the primary goals were to describe and interpret the practical challenges associated with developing hydrogen import value chains. Therefore, the research was classified as descriptive case research, as it aimed to provide a detailed understanding of the Dutch hydrogen import context and the challenges involved in its development [5].

The study used an embedded case study design. As described in Yin [80] and elaborated by Baxter, Jack, et al. [5], an embedded case study includes a primary case with multiple subunits of analysis. This design was considered appropriate because it allows for a more detailed examination of different aspects within the same overall case. In this study, the overarching case examined hydrogen import chains from European countries that are not members of the European Union to the Netherlands. Within this broader framework, two specific case studies were examined:

The embedded cases were:

- **Case 1**: A potential value chain of green ammonia imports between the United Kingdom and the Netherlands.
- **Case 2**: A potential value chain of green ammonia imports between Norway and the Netherlands.

The use of an embedded design was suitable for this research because it made it possible to compare different national contexts within the same general theme. Although both countries are not members of the EU, Norway is part of the European Economic Area (EEA). It therefore operates within a regulatory framework that is more closely aligned with the EU than the United Kingdom. This difference allowed the study to explore how variation in institutional and regulatory settings can influence the development of hydrogen import chains.

The embedded case study design also had consequences for the analysis and results. It allowed for the identification of both case-specific challenges and more general patterns across cases. This improved the ability of the research to conclude common challenges and possible policy interventions, while also showing where context-specific approaches may be needed. The design thus contributed to a more structured and comparative analysis of hydrogen import policy.

Additionally, the rationale for selecting these case studies was based on data availability, as Statkraft is involved in green ammonia projects in these regions, thereby ensuring better access to relevant sources of knowledge.

To analyze the alignment between current policy and stakeholder needs, this research employed two primary methods: policy analysis and semi-structured interviews. The policy analysis was based on official policy documents from the UK, Norway, the Netherlands, and the European Union, as well as strategy papers and position papers. Semi-structured interviews were conducted with stakeholders active in the hydrogen import value chain, including policymakers, industry actors, infrastructure providers, and researchers. These interviews were used to collect qualitative data on perceived challenges and the extent to which existing policy interventions supported the development of hydrogen import chains. Both methods are explained in more detail in the following section.

The case studies served as a basis for identifying gaps and misalignments in current hydrogen import policy interventions, providing practical insights into key regulatory challenges. Policy analysis helped develop clearer and more relevant questions for stakeholder interviews by linking them to real policy gaps. These interviews then helped confirm and expand on the initial findings, strengthening the overall analysis by connecting theory with practical issues in hydrogen deployment.

4.2. Research Methods

This section outlines the primary research methods used to investigate the challenges and policy responses related to hydrogen imports to the Netherlands. It combines a policy document analysis with qualitative insights from semi-structured expert interviews and sector observations.

4.2.1. Policy Analysis

This section explains the approach used to analyze selected policy documents. Together with the semi-structured expert interviews, this policy analysis forms one of the two primary research methods in this study.

The analysis serves a dual purpose (see Research Method 1 in Figure 4.1): first, to identify key challenges related to the development of hydrogen import chains; and second, to map the current policy landscape that addresses these challenges. By comparing the difficulties identified with existing policy instruments, the analysis aims to highlight areas where policies are effective, where they are insufficient, and where significant gaps remain.

Document Selection

The selection of documents for this policy analysis followed a targeted approach. The primary objective was to identify documents that provide insight into current policy developments, challenges, and institutional circumstances related to the import of hydrogen and hydrogen carriers into the Netherlands. Two complementary steps guided the selection of documents:

1. **Identification by experts:** Internal consultations with hydrogen experts at Statkraft were carried out to select documents considered influential or relevant to understanding the landscape of hydrogen import policy.
2. **Stakeholder-focused scan:** A systematic search was carried out on the websites and publication portals of key stakeholders.

To ensure the analysis reflects the most recent policy developments, only documents published after November 2022 were included, except for The Norwegian Government's Hydrogen Strategy, as no updated version has been published since 2020. This date corresponds to the publication of the latest updated Dutch National Hydrogen Strategy [50], which builds on the previous version from 2020. Documents published before this update were excluded to avoid relying on outdated assumptions or policy frameworks.

Although all selected documents discuss hydrogen policy, not all focus exclusively on hydrogen import. In those cases, only the relevant sections were analyzed.

The final sample comprised 20 documents, including government policy letters, strategic road maps, consulting reports, parliamentary publications, and international monitoring studies (see Table 4.1).

#	Title	Publisher	Type of Document	Year
1	Study on the Necessity of Government Involvement in Scaling Up Hydrogen Import Chains	Guidehouse	Consultancy research report	2023
2	Parliamentary Committee Debate on Hydrogen, Green Gas, and Other Energy Carriers	NVDE	Debate summary	2024
3	National Hydrogen Programme Roadmap	National Hydrogen Roadmap	2022	
4	Parliamentary Letter: Energy Diplomacy and Hydrogen Imports	Ministry of Climate and Green Growth	Governmental policy letter	2023
5	Northwest European Hydrogen Monitor	International Energy Agency	Research report	2024
6	Production, Import, Transport and Storage of Hydrogen in the Netherlands	Environmental Assessment Agency (PBL)	Research report	2024
7	Hydrogen Policy in the Netherlands	CIEP	Research paper	2024
8	Background paper: Rollout of international hydrogen trade for the EU	International Energy Agency	Research paper	2022
9	RED III – Directive (EU) 2023/2413	European Parliament and Council	EU directive	2023
10	The EU's industrial policy on renewable hydrogen	European Court of Auditors	Discussion paper	2024
11	The Economics of Decarbonising Europe's Ammonia Industry	Oxford Institute for Energy Studies	Discussion paper	2025
12	Mobilizing Europe's Full Hydrogen Potential	Fraunhofer ISI, RIFS Potsdam, dena	Discussion paper	2023
13	Challenges and Opportunities Posed by the EU's 42% Renewable Hydrogen Target by 2030	Oxford Institute for Energy Studies	Discussion paper	2025
14	Renewable Hydrogen Import Routes into the EU	Oxford Institute for Energy Studies	Discussion paper	2023
15	Assessment of Hydrogen Policy Developments	CE Delft	Research Report	2024
16	In-depth Assessment Document on Hydrogen Carriers	Ministry of Climate and Green Growth	Government report	2024
17	Realizing Scotland's Hydrogen Potential: A Plan for Exports	Scottish Government	Government report	2024
18	Hydrogen Strategy Update to the Market: December 2024	UK Government	Government report	2024
19	Norway's Internal and External Hydrogen Strategy	Scottish Government	Discussion Paper	2023
20	The Norwegian Government's hydrogen strategy	Norwegian Government	Government report	2020

Table 4.1: Selected policy and advisory documents on hydrogen import chains (2022–2025)

Coding and Analysis

The policy analysis was carried out using Atlas.ti software and followed a structured three-phase approach.

Phase 1: Inductive First-Order Coding

The first phase involved an open and exploratory reading of the selected policy documents. Text fragments were manually coded in Atlas.ti. Each fragment describing a challenge or a policy instrument was assigned a short, descriptive label that captured its content independently of a theoretical framework. Examples of challenge codes include 'lack of demand certainty', 'hydrogen backbone delay', or 'complex RFNBO criteria'. Similarly, policy instruments were labeled with codes such as 'H2Global' or 'RED III RFNBO obligations'.

As a result, this phase produced two outputs:

1. A list of identified challenges, and
2. a list of policy instruments and regulatory frameworks relevant to the development of hydrogen import chains to the Netherlands.

Phase 2: Deductive Second-Order Coding

In the second phase, the first-order challenges were grouped into broader categories, using the transition challenges described in Chapter 3 to structure the analysis.

Phase 3: Policy Landscape Assessment

The third phase analyzed the relationship between identified challenges and selected policy instruments using the ”code co-occurrence” function in Atlas.ti. This function identifies overlaps between different codes within the same text segments, allowing for a clear understanding of where policy instruments and transition challenges are discussed together, suggesting a potential relationship. Once the coding process was completed, the function was used to examine where these two categories of codes appeared in close proximity within the same segment of text.

Atlas.ti’s code co-occurrence tool generated a matrix where rows and columns represent specific codes, and intersecting cells indicate their co-occurrence in the data. In this context, the matrix provided an overview of where policy instruments (e.g., subsidies, regulatory obligations) were linked to recurring challenges, such as infrastructure uncertainty or demand articulation. Although some connections were more frequent than others, the matrix was not used to quantify importance, but to systematically identify potentially meaningful relationships in the data.

This step helped identify instances where a policy instrument was discussed in direct relation to a specific challenge. Code co-occurrence function enabled pattern identification in how challenges and policy instruments are presented in policy documents and stakeholder interviews. For example, if the coded challenge ‘lack of reliable demand’ and the instrument ‘RED III RFNBO obligations’ co-occur in a segment, Atlas.ti registers this as a link. This suggests a relationship between the instrument and the challenge. Such links helped determine whether instruments actively address challenges or if challenges appear without corresponding policy responses, indicating potential policy gaps.

It is important to note, however, that such code co-occurrence does not necessarily indicate a meaningful or intentional relationship. Some links may result from coincidental proximity in the text, without reflecting an actual connection between the identified challenge and the policy instrument. These cases were examined in more detail in subsequent qualitative analysis to assess the relevance of the connection.

In addition to revealing such patterns, the code co-occurrence function also introduced a degree of transparency and consistency into the analytical process. It ensured that relationships were grounded in systematically coded text segments. However, identifying a code co-occurrence was not considered sufficient to assess the effectiveness of a policy response. For each identified link, a subsequent qualitative assessment was carried out to examine the nature of the relationship in more detail. This involved reviewing the code co-occurring text segments to determine whether the policy instrument in question offered a concrete solution, partially addressed the issue, or merely referenced the challenge without substantive response. This step was essential for evaluating not only the presence but also the relevance and quality of policy responses in supporting the development of the hydrogen import value chain.

4.2.2. Semi-structured Interviews

In addition to the policy analysis, semi-structured interviews with key stakeholders are conducted to obtain qualitative in-depth information on the challenges they face in establishing hydrogen import routes. The semi-structured method enables a structured exploration of challenges while maintaining the flexibility to adapt questions based on expert insight [68]. The overarching aim of the interview is to gather insights from stakeholders and experts who are actively involved in the development of hydrogen imports or are closely connected to this field. As large-scale hydrogen imports are still in an early stage, stakeholders with experience in the broader green hydrogen transition are also considered relevant.

The interviews address two main research objectives: (1) identifying challenges and (2) evaluating the effectiveness of existing policy measures. To achieve the first objective, the interviews focus on the challenges encountered by stakeholders in the UK-to-Netherlands and Norway-to-Netherlands hydrogen import chains. Stakeholders provide information on how these challenges affect the feasibility of establishing hydrogen import value chains and whether they can be addressed through market mechanisms or require government intervention. For the second objective, the interviews assess the perceived effectiveness of current policy measures in addressing these challenges within the context of case studies. These insights help determine whether current policies align with the practical needs of market participants or whether adjustments are necessary to facilitate the import of hydrogen better.

Selection of Interviewers

To ensure a broad and representative understanding of the policy and practical dimensions of hydrogen import development, interviewees were selected from a range of stakeholder groups involved in or closely related to the hydrogen import value chain. These groups include government agencies, research institutes, infrastructure providers, industry actors, and industry associations. This diversity enables the inclusion of perspectives from stakeholders with diverse roles and responsibilities within the emerging hydrogen import system.

A total of 18 interviews were conducted for this study. Although additional interviews could provide further nuance, this number aligns with similar research in this field [48]. An overview of the conducted interviews is presented in Table 4.2.

Stakeholder group	Organisation	Date of interview (2025)	Interview Reference
Research Institute (RI)	CE Delft	April 16	RI01
	Planbureau voor de Leefomgeving (PBL)	April 29	RI02
Government (GV)	Energie Beheer Nederland (EBN)	April 18	GV01
	Ministerie van Klimaat & Groene Groei (KGG)	April 25	GV02
	Rijksdienst voor Ondernemend Nederland (RVO)	April 14	GV03
Industry Association (IA)	Nederlandse Vereniging Duurzame Energie (NVDE)	April 14	IA01
	NLHydrogen	April 22	IA02
Industry Actor NO (INO	Statkraft Norway (1)	April 9	INO01
	Statkraft Norway (2)	April 24	INO02
Industry Actor UK (IUK)	Statkraft United Kingdom (1)	April 13	IUK01
	Statkraft United Kingdom (2)	April 29	IUK02
Industry Actor NL (INL)	Statkraft Netherlands	April 25	INL01
	Essent	May 14	INL02
	Air Liquide	April 22	INL03
	YARA	May 6	INL04
Infrastructure Actor (I)	Gasunie	May 1	I01
	Port of Rotterdam	April 15	I02
	VOTOB	May 6	I03

Table 4.2: Overview of stakeholder interviews conducted for the hydrogen import policy analysis (2025)

Interview Guide and Informed Consent Form

The interviews focused on five core areas: (1) the interviewee's role in the hydrogen value chain, (2) key challenges encountered in establishing import routes, (3) impact of these challenges, (4) views on the effectiveness of current Dutch and European policy, and (5) recommendations for future policy improvements and support measures. This structure enabled comparability between interviews, while the semi-structured format also allowed the collection of specific information based on the role of the interviewee within the sector. Before each interview, participants received an informed consent form that outlined the study's scope, purpose, and data handling procedures. At the beginning of each interview, a brief introduction was provided, followed by a short explanation of the research context and the specific objectives of the interview. Verbal consent was then obtained before the audio recording began. Both the interview guide and the consent form are located in Appendix B.

Data Handling and management

This research is based on primary data collected through recorded interviews. A Data Management Plan (DMP) was developed and approved by the Data Support Staff of the Technical University of Delft before the start of data collection. The interviews were recorded using Microsoft Teams after obtaining verbal consent and were securely stored in TU Delft OneDrive storage. Company names are included in this thesis unless specifically requested. In such cases, stakeholder group descriptions were used in place of company descriptions. Personal data, such as names and contact details, was used solely for administrative purposes and is deleted upon completion of the project. The signed consent forms are stored separately and securely in accordance with the TU Delft data retention policy.

Analysis of Interviews

Atlas.ti software is utilized to structure and facilitate the analysis of interview transcripts. This approach follows the same three-phase structure outlined in the previous section.

Since the interview guide is designed to explicitly ask stakeholders about their perceived challenges and their views on relevant policy responses, the coding and analysis process was more straightforward and focused. Aligning the interview analysis with the policy analysis approach enables the integration of findings. It facilitates comparison between the challenges and policy instruments identified in the policy documents and those discussed by stakeholders (see Research Method 2 in Figure 4.1).

4.2.3. Hydrogen Sector Events and Meetings

In addition to the policy analysis and semi-structured interviews, several hydrogen-related events were attended to gain a better understanding of the hydrogen sector. These events provided valuable opportunities to observe ongoing market developments and to engage in informal conversations with industry actors. The following events and meetings were visited:

- **E-World Energy & Water Exhibition, Essen (February 12, 2025)**
  This is a leading European trade fair focused on the energy transition, with attention given to hydrogen. The event provided valuable insights into the current state of the hydrogen market and facilitated direct interaction with key stakeholders.
- **World Hydrogen Summit & Exhibition, Rotterdam (May 21, 2025)**
  Informal conversations were held with representatives from the hydrogen sector. The exhibition layout was organized into national pavilions, which facilitated targeted networking with actors involved in the Norwegian and United Kingdom hydrogen sectors and helped validate the challenges encountered by stakeholders during the interviews.
- **H2A Symposium on "Achieving Breakthroughs in Hydrogen Imports", Amsterdam (June 19, 2025)**
  This event was directly aligned with the research focus, addressing challenges to the development of hydrogen import chains and exploring integrated value chain solutions. Discussion panels and presentations were delivered by organizations such as Gasunie, Deloitte, the Port of Amsterdam, the Ministry of Climate and Energy Policy, and network operator Alliander.
- **Statkraft weekly online international hydrogen meetings**
  Weekly internal hydrogen update meetings were attended at Statkraft, covering ongoing developments across the company's hydrogen teams in Norway, the United Kingdom, Sweden, Germany, and the Netherlands. While information from these meetings was not used in the thesis due to confidentiality constraints, the sessions were instrumental in deepening my contextual understanding of the sector.

4.3. Integration of Research Methods

The results of this study are presented in two complementary parts, each drawing on insights from both policy analysis and stakeholder interviews. By combining findings from these two sources, the research ensures a more complete and nuanced understanding of the challenges and policy dynamics surrounding hydrogen import chains to the Netherlands. This integrated structure supports a more robust interpretation of the findings and strengthens the overall validity of the analysis (see Figure 4.1).

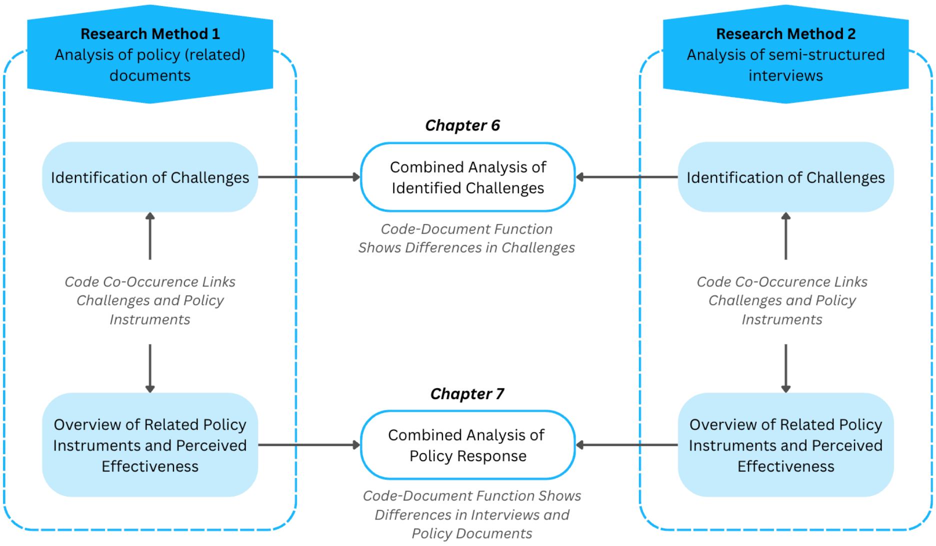

Figure 4.1: Overview of the research process and data analysis steps based on document analysis and interviews.

Transition Challenges in Hydrogen Import Chains

Chapter 5 outlines and categorizes the key systemic challenges that may hinder the development of hydrogen import chains. These challenges are derived from the results of the policy analysis and the interview analysis.

For the analysis of the integrated results, the Code-Document Analysis function in Atlas.ti is used. This function analyzes which coded challenges are mentioned in specific document groups. The following nine document groups were established:

- **Dutch and European government**: Transcripts of interviews with Dutch governmental and semi-governmental representatives were analyzed alongside official policy publications on hydrogen and import regulations issued by both the Dutch and European governments. This group comprises documents from the European Commission. The EU and the Dutch government are combined in one group because European policy frameworks have a significant influence on the Dutch hydrogen policy context.
- **Government of United Kingdom**: Policy documents issued by the UK Government. As no UK officials were interviewed, this document group consists of two policy documents only.
- **Norwegian government**: Policy documents issued by the Norwegian Government. As no Norwegian officials were interviewed, this document group consists of only two policy documents.
- **Dutch industry**: Interviews with Dutch industry stakeholders on importing green ammonia.
- **United Kingdom industry**: Interviews with British industry stakeholders on exporting green ammonia to the Netherlands.
- **Industry associations**: Interviews with representatives of hydrogen-related trade associations and their published position papers.
- **H_2 infrastructure actors**: Interview with port operator, terminal representative, and infrastructure operators involved in hydrogen and green ammonia transport and storage.

- **Research institutes**: Interviews with experts from research institutes and relevant academic publications on hydrogen import and the broader hydrogen economy.

The Atlas.ti Code-Document Analysis function provides insight into which coded challenges appear within each document group by generating a frequency matrix that shows how often specific codes occur across predefined stakeholder categories. This enables the identification of challenges that are shared across different groups, as well as those that are specific to particular types of actors or case studies. Unlike co-occurrence analysis, which identifies links between codes within single text segments, code-document analysis focuses on the distribution of individual codes across various sources. As such, it functions as a clustering tool that highlights patterns in how often, and by whom, particular challenges are raised. This allows for a structured understanding of general, stakeholder-specific, and case-specific challenges in the development of hydrogen import chains, and offers insight into the relative importance different actors assign to specific issues.

The combined use of code co-occurrence and code-document analysis strengthens both the validity and depth of the overall analysis. While co-occurrence analysis helps uncover how policy instruments and challenges are framed in relation to each other within a single source, code-document analysis reveals which challenges are emphasized by which types of stakeholders. Together, these tools provide both relational insight (how policy and challenges are connected) and distributional insight (who raises which challenges).

Beyond analytical complementarity, the structured application of both functions is particularly important given the scope of the analysis. A total of 38 documents were included in the integrated analysis, covering a diverse range of sources across government, industry, infrastructure, and research. In such a context, the use of systematic and transparent coding tools ensures that the findings are not only grounded in the data but also traceable and reproducible. The code-book of coding phase 1 and 2, including code label definitions and rules, is presented in Appendix C. This contributes to the overall rigor of the study by making the analytical process explicit and verifiable. It allows readers to evaluate how conclusions were drawn, thereby enhancing the credibility and interpretive clarity of the results.

Policy Responses and Gaps

Chapter 6 analyzes the responses to the policy and potential policy gaps. This analysis is carried out in two main steps. First, a code co-occurrence analysis is performed within each method to link the identified challenges to specific policy instruments. The results are then integrated to provide a comprehensive overview. Second, the code-document group function in Atlas.ti is used to compare the presence and interpretation of these instruments in the interview data with the policy documents. This comparative analysis identifies which instruments are considered relevant by market parties and practitioners, as well as which instruments are primarily discussed in policy documents but not addressed in the stakeholder interviews. This clarifies which instruments are recognized by stakeholders actively involved in implementation, as opposed to instruments that mainly appear in policy discourse but lack significant resonance or visibility among practitioners.

By synthesizing the results of both research methods, this chapter aims to provide an integrated analysis of the policy response. The findings on code co-occurrence provide insight into how instruments relate to the identified challenges, and the code-document group analysis indicates where the perspectives between policy documents and market parties diverge.

4.4. Case Study Contexts

This section offers a more detailed description of the selected case studies. Statkraft is involved in hydrogen activities in both countries and is exploring potential export opportunities. The green ammonia project in the UK is situated in the Shetland Islands, while the Norwegian project is located in Narvik. At the beginning of this research, both projects were in the early stages of development; however, the UK project is somewhat more advanced.

Figure 4.2: Potential hydrogen imports from the United Kingdom and Norway to the Netherlands.

Both Norway and the United Kingdom are ranked among the top ten countries in the Hydrogen Export Competitiveness Index [34]. This index measures a country's potential for hydrogen export based on factors such as resource availability, the policy and regulatory environment, financial conditions, and industrial capabilities. Norway and the UK score particularly high in the latter three areas, reflecting solid institutional frameworks and advanced sector development. While it is expected that significant hydrogen imports will come from outside Europe in the long run, establishing short-term supply relationships within the continent is considered necessary. European trading partners can benefit from shared regulations, close geographical proximity, and access to EU financial support. In this context, both Norway and the UK present promising early opportunities for ammonia-based hydrogen trade with the Netherlands [44, 40].

4.4.1. United Kingdom Hydrogen Context

The United Kingdom is actively developing its hydrogen economy through national and regional strategies. The 2021 Hydrogen Strategy and the more recent Hydrogen Production Delivery Roadmap (2023) outline a pathway toward 5 GW of low-carbon hydrogen production capacity by 2030 [15, 72]. This goal is backed by the Hydrogen Business Model, which offers financial incentives to producers through Contracts for Difference [3]. In addition, the Scottish administration is actively advancing its hydrogen plans, with a strong focus on exporting green hydrogen and its derivatives, such as ammonia, to European markets [29]. This regional initiative highlights the UK's ambition to export green ammonia [3].

International and EU policies continue to shape the UK's approach to decarbonizing ammonia production, despite its departure from the EU. Regulations such as RED III, FuelEU Maritime, and ReFuelEU Aviation generate external market signals for renewable fuels, including green ammonia. These frameworks create both pressure and incentives for the UK to align with evolving European standards [3].

However, the UK's current regulatory landscape lacks specific measures targeting the decarbonization of ammonia. There are no binding emission reduction targets or dedicated incentives focused solely on low-carbon ammonia production. Instead, support is provided more broadly through initiatives aimed at hydrogen deployment [3].

4.4.2. Norwegian Hydrogen Context

Norway has a long tradition in ammonia production and benefits from a nearly fully decarbonized electricity system based on hydropower. The country's Hydrogen Strategy (2020) outlines a technology-neutral approach (both green and blue hydrogen) focused on enabling industrial projects, hydrogen hubs, and pilot initiatives [56, 66]. This differs from the green Europe approach. However, the government's 2020 strategy was criticized for being merely a description of the status quo rather than a full-fledged action plan with specific goals; it was also noted that no new policy measures were proposed [66]. In response, the Norwegian government published a hydrogen roadmap in 2021, supported by increased state funding for hydrogen research and industry projects.

The main sectors that have been prioritized are the maritime sector and energy-intensive process industries. Hydrogen and ammonia are deemed most suitable for large, long-distance vessels [66]. Norway's geographical proximity and formal political relations with the Netherlands, as evidenced by the 2024 MoU on cooperation in the field of hydrogen and CCS, create favorable conditions for bilateral cooperation in the development of the hydrogen value chain [64].

5

Transition Challenges in Hydrogen Import Chains

This chapter presents an integrated analysis of the challenges identified through the semi-structured interviews and policy document review. The chapter is structured as follows. First, a general overview of the main challenges is provided. This is followed by a detailed discussion of each challenge, organized according to the categories of transition challenges outlined in Table 3.1. Finally, the chapter reflects on the broader implications and potential impact of these challenges on the development of hydrogen import chains.

5.1. Results of Code-Document Analysis

The challenges identified across the 39 analyzed sources, including both interview transcripts and policy-related documents, were systematically reviewed and manually coded. As outlined in Chapter 4, the Code-Document Group Analysis function in Atlas.ti was used to explore which challenges were raised by different stakeholder groups.

This analysis produced a matrix that indicates how frequently each group mentioned each challenge. The matrix cells show the number of times a challenge was referenced within the documents belonging to a particular stakeholder group. As this research is qualitative in nature, the results are influenced by the selection of interviewees, the composition of the document set, and the researcher's interpretation. While the use of Atlas.ti enabled a more structured and transparent analysis of the qualitative data; the frequency counts themselves are not statistically significant. However, the relative frequency with which a challenge appears across documents can still provide meaningful insights into its perceived relevance or urgency among different stakeholder groups.

To visualize these patterns, a symbolic scoring system was applied (see Table 5.1). For each group, a ratio was calculated by dividing the number of documents that mention a given challenge by the total number of documents in that group. These ratios were then translated into qualitative frequency symbols based on the following scale:

Symbol	Interpretation	Ratio Range
–	Not mentioned	0
+	Mentioned occasionally	$0 < r \leq 0.33$
++	Mentioned regularly	$0.33 < r \leq 0.66$
+++	Mentioned frequently	$r > 0.66$

Table 5.1: Legend for interpreting frequency of challenge mentions per stakeholder group

Table 5.2 presents the results of this analysis, providing a qualitative overview of how different stakeholder groups perceive and prioritize the identified challenges.

5.2. Broader Interpretations of Results

The first set of challenges involves articulating demand, which was identified by all stakeholder groups as a significant issue for hydrogen import chains and, consequently, for green ammonia trade (see Table 5.2). There is a lack of reliable demand signals, an absence of long-term off-take agreements, and uncertainty surrounding cost developments and the timelines for demand and supply. These factors make it difficult for stakeholders to commit to final investment decisions. What stands out clearly from the interviews and documents analyzed is that demand articulation challenges were widely discussed and recognized across stakeholder groups. Stakeholders commonly emphasized that if a sufficient and reliable future demand for hydrogen were established, it could trigger the development of the hydrogen value chain, and by extension, stimulate hydrogen import flows.

However, it also became evident from the interviews that resolving demand-related challenges alone does not automatically lead to the successful development of import chains. For instance, in the absence of appropriate infrastructure, the supply of hydrogen cannot reach areas of demand. This underscores that overcoming individual challenges in isolation is insufficient. The real complexity lies in the strong interdependencies between these challenges. If one part of the chain fails to progress, it has ripple effects throughout the entire system. Stakeholders showed a high level of awareness of these mutual dependencies.

This systemic nature of the transition is further confirmed by the findings in Table 5.2, which show that most challenges are not confined to specific stakeholder groups. Contrary to expectations that stakeholder perspectives would be fragmented, with certain groups identifying unique challenges, the data reveal that most challenges were identified by multiple, if not all, groups. There are few challenges that were mentioned exclusively by a single group. One example is the issue of subsidy-based export uncertainty for green ammonia, which was raised only by UK-based industry actors. This challenge refers to the lack of clarity on whether UK-produced green ammonia, derived from subsidized hydrogen, can be exported to EU countries, a concern not yet addressed in policy documents and largely unknown to other actors.

Another example is the challenge of limited urgency for green hydrogen exports, mentioned only by Norwegian industry representatives. This reflects the specific context in Norway, where the urgency to develop green hydrogen export chains is perceived as low due to the country's existing low-carbon electricity system and its strategic focus on blue hydrogen.

Infrastructure-related challenges were recognized consistently across all stakeholder groups, indicating their widespread relevance to the development of import chains. The absence of a physical infrastructure complicates the alignment of supply with demand, resulting in delays throughout the value chain. Certain aspects of this group of challenges are more tied to specific contexts. For instance, stakeholders from the Netherlands have highlighted the uncertainty surrounding the regulation of hydrogen integration into existing gas systems, particularly in relation to the evolving EU gas and hydrogen regulatory framework. Additionally, the issue of permitting delays has been predominantly highlighted by Dutch stakeholders. This observation highlights a more significant structural challenge within the Dutch energy transition, where complex and protracted permitting processes have consistently hindered the prompt development of energy infrastructure.

Challenges related to policy coordination were largely emphasized by stakeholders on the import side. Differences in policy approach between EU Member States and limited alignment between the Netherlands and its neighboring or exporting countries were primarily raised by Dutch actors. A particularly specified issue is the coordination of RFNBO compliance with third countries. This challenge is unique to the UK case, given the country's non-EU status and its separate certification system.

In the context of hydrogen imports, stakeholders in the Netherlands have particularly emphasized the lack of a clear import vision supported by a realistic roadmap. Additionally, a misalignment exists between policy and market perspectives regarding hydrogen carrier options, particularly in relation to ammonia. This divergence was highlighted by participants involved in the Dutch import environment.

Issues related to financing show a mixed pattern. Limited subsidy budgets were seen as a general challenge. However, the lack of funding for ammonia conversion infrastructure and the immaturity of cracking technology were raised primarily by stakeholders from the import side, given that these facilities are situated downstream in the supply chain.

Institutional challenges also show both general and case-specific aspects. Complex certification requirements for green hydrogen and ammonia were cited by nearly all stakeholders, underscoring their relevance across the value chain. However, regulatory uncertainty around whether subsidized hydrogen in the UK can be used to produce ammonia for export to the Netherlands is a specified challenge for the UK case study. This issue is currently under development and has not yet been formally reflected in policy documents.

The Norwegian situation is marked by specific contextual challenges. Stakeholders in Norway frequently highlight the public and political sensitivity surrounding electricity exports, which is influenced by rising electricity prices and increasing industrial demand. Additionally, there is a limited sense of urgency for developing green hydrogen in Norway, partly because the country already has a low-carbon electricity system and because it maintains a national hydrogen strategy that is also focused on blue hydrogen. As a result, there is a diminished perception of the immediate need for green ammonia exports.

Lastly, societal concerns about the safety of green ammonia production and transport were mentioned across various stakeholder groups and locations, making this a broadly relevant issue. While such concerns may vary in intensity, they have implications for the spatial planning and permitting of infrastructure throughout the value chain.

Overall, while certain challenges are more evident in specific segments of the value chain or within particular national contexts, these challenges are often interconnected. When progress is hindered in one area, whether due to uncertainty, regulatory misalignment, or a lack of infrastructure, it can delay or negatively impact advancements in other areas, understanding these systemic interactions is crucial for creating effective interventions that promote the coordinated development of hydrogen and green ammonia import chains.

Description of Challenge	Government NL/EU	Government UK	Government NO	Industry Norway	Industry UK	Industry NL	Industry Assoc.	Infrastructure	Research Inst.
Demand Articulation									
Gap between the green cost premium and WTP	+++	+++	+++	+++	+++	+++	+++	+++	+++
Lack of reliable demand (stimulation)	+++	++	++	+++	+++	+++	+++	+++	+++
Uncertainty about future cost developments for green H_2	++	-	-	-	+++	-	++	-	+++
Uncertainty about future demand and supply volumes and timelines	+++	-	-	+++	+++	+++	+++	+++	+++
Inadequate Physical and Knowledge Infrastructure									
H_2 infrastructure delays and uncertainties	+++	++	-	++	++	+++	+++	+++	+++
Lack of clarity on H_2 integration into existing systems	+	-	-	-	-	-	+	++	++
Permitting delays for critical infrastructure	+++	-	-	-	-	-	+	++	+
Insufficient Policy Coordination									
Difference in policy approach between MS	+++	-	-	-	-	+++	-	+++	++
Policy alignment NL - neighboring and exporting countries	+++	-	-	-	+	-	-	+	+
RFNBO compliance coordination with third countries	+	+++	-	+	+++	-	-	-	-
Lack of Shared Directional Vision									
(Geo)political instability undermines transition momentum	+	-	-	++	++	+	+	++	+
Lack of a well-substantiated general H_2 roadmap	+	-	-	-	+++	+++	-	++	-
Lack of a specific vision for H_2 import	+	-	-	-	-	+	++	+++	+
Unclear Industrial Vision Undermines H_2 Development	+++	-	-	++	+	-	+++	+++	++
Misalignment between policymakers and market actors on H_2 carrier vision	+++	-	-	-	+	-	+	++	+
Lack of Ecosystem-Wide Supply-Side Financing									
Limited subsidy budgets	+++	-	-	-	-	+	++	+++	+++
Lack of financial support NH_3 cracking facilities	++	-	-	-	-	+++	+++	+	-
Lack of Relevant Knowledge, Skills, and Resources									
Immature large-scale NH_3 cracker technology	++	-	-	-	+++	-	+	-	++
Conflicting or Incomplete Institutions and Rules									
Complex certification requirements for RFNBO	+++	+++	++	+++	+++	+++	-	+	+++
Subsidy-based export uncertainty for green NH_3	-	-	-	-	+++	-	-	-	-
Opposition from negatively impacted actors	+	-	-	-	+	++	+	+	++
Political and public sensitivity to energy exports	-	-	++	+++	++	-	-	-	-
Limited urgency for green H_2 exports	-	-	-	+	-	-	-	-	-
NH_3 societal acceptance concerns (safety)	+++	+++	-	+++	+	++	+++	+++	+++

Table 5.2: Overview of challenges identified across different stakeholder groups

5.3. Development Challenges in Hydrogen Import Chains

Whereas the previous section outlined a broad system analysis of the results, this section provides an in-depth explanation of the main challenges identified in Table 5.2 and links these challenges to the transition challenges described by Bolhuis [7] and Weber and Rohracher [75], thereby structuring the analysis.

5.3.1. Demand Articulation

One of the transition challenges outlined by Bolhuis [7] and Weber and Rohracher [75] is the lack of articulation of the demand. This refers to situations where market actors experience insufficient or unclear demand signals, making them reluctant to invest in or adopt new technologies. In the case of green hydrogen and its derivatives, many companies are uncertain about the future size and timing of demand. This uncertainty is driven by factors such as policy ambiguity, uncertain price developments, and competition with conventional fuels.

Without reliable demand signals, actors are unlikely to commit to large-scale investments in infrastructure or production. This section discusses challenges related to demand articulation that were identified in the policy and interview analysis and explains how they directly or indirectly affect the formation of hydrogen import value chains.

One of the most evident indicators of weak demand articulation in the hydrogen market is the absence of long-term off-take agreements. These contracts play a crucial role in providing producers and investors with the confidence needed to develop large-scale hydrogen projects (Interview GVO1 & GVO2) [37, 44]. Without such agreements, it becomes challenging to secure financing and make final investment decisions. Early adopters of renewable hydrogen are likely to face higher costs than those using conventional hydrogen due to the limited scale and technological maturity. To ensure market uptake despite this disadvantage, targeted government support is necessary to reduce the cost gap and make long-term off-take financially viable for end-users [37].

An industry representative emphasized the practical challenges of securing long-term off-take agreements for hydrogen projects. He highlighted the lengthy lead times associated with developing these projects and the difficulty in finding buyers willing to commit to fixed volumes and prices over extended periods. This uncertainty in demand at an early stage complicates investment and project planning decisions. Consequently, a deadlock arises: producers are cautious about investing without guaranteed demand, while potential buyers are hesitant to commit without reliable supply and pricing conditions (Interview UK01).

The absence of long-term contracts is not just an isolated issue; it reflects deeper structural problems within the hydrogen market, particularly on the demand side. These challenges include uncertainties in cost, unclear regulations, and a limited willingness or ability among buyers to pay a premium for green hydrogen. The following sections will delve into these specific challenges in more detail and explain how they contribute to the overarching issue of demand articulation.

Gap Between Green Cost Premium and Willingness to Pay

A significant challenge in establishing reliable demand for green hydrogen and its derivatives is the considerable price gap compared to conventional fossil-based alternatives. As a Norwegian industry representative highlights:

> *"The financial gap between cost and willingness to pay is simply too large to close without external support." (Interview IN01)*

As shown in Table 5.2, this issue is recognized by all stakeholder groups, making it a central obstacle to the adoption of a hydrogen economy. It directly affects the development of hydrogen import value chains in the Netherlands. This challenge is crucial because it is linked to various uncertainties that can increase or exacerbate the cost difference. For instance, unexpected increases in green hydrogen production costs, the lack of reliable demand creation and stimulation, and geopolitical instability all contribute to heightened perceived risks. These uncertainties lead to increased risk premiums and financing costs, which can further widen the price gap between green and conventional hydrogen. As this gap widens, it becomes increasingly uncertain whether government financial support will be adequate to bridge it. While some of these issues will be explored in more detail later, it's important to note that they are all interrelated.

This challenge is particularly pronounced in internationally competitive sectors, such as basic chemicals and fertilizers, where profit margins are slim, and product prices are determined by global markets. In these circumstances, companies cannot simply pass on higher input costs to their customers, leaving them with little ability to absorb a green premium (Interview RI01, [40]).

Uncertainty about future cost trajectories for green hydrogen

Uncertainty surrounding the future costs of green hydrogen and ammonia weakens clear demand signals. Early forecasts anticipated significant price declines; however, actual cost reductions have consistently fallen short of expectations. The high capital costs of electrolysis plants persist, and inflation, along with rising interest rates, has increased the financing costs for hydrogen projects. This situation further widens the cost gap between hydrogen and conventional alternatives [1, 40].

An industry representative expressed concerns about these uncertain price developments during an interview:

> *There has been a large price increase for green hydrogen carriers. Then we can ask: How much further should prices for these carriers be expected to increase? How will this progress further, and what does it mean for demand? (Interview GV01)*

Additionally, global supply chains for electrolysis plants and critical components remain vulnerable, and interruptions or delays can hinder projects and drive costs even higher [1].

Uncertainty About Future Demand and Supply Volumes and Timelines

Another challenge that emerged from the interviews and policy documents, related to demand articulation, is the uncertainty about future demand and supply volumes and timelines. The European Union has introduced green hydrogen obligations for the industrial and transport sectors in the Renewable Energy Directive III to establish long-term market signals. However, market participants emphasise that, since these mechanisms have not yet been implemented at the national level, they do not provide adequate certainty regarding future demand timelines (Interview IUK01 & I01).

The uncertainty on the demand side is paralleled by similar challenges on the supply side. Exporting countries face long project lead times and capital-intensive investments. Without coordination between demand and supply trajectories, and lacking mutual confidence in synchronized scaling, players on both sides of the value chain are hesitant to make commitments [37].

Although both the Dutch and EU strategies support a combination of imports and domestic production, the precise role of imports remains uncertain. This lack of clarity affects exporting countries, which are reluctant to invest without clear import targets [31]. In the absence of clear and timely signals on future demand, investments in import terminals, transport infrastructure, and contractual trade routes are delayed or avoided altogether.

5.3.2. Inadequate Physical Infrastructure

A well-functioning hydrogen economy depends on an adequate infrastructure for transport, storage, and distribution. It functions as a backbone that links supply and demand across [7]. However, infrastructure projects are characterized by long lead times, high capital requirements, and relatively low returns, which discourages investment and leads to structural underinvestment ([75]). When infrastructure lags behind market needs, it hinders actors' ability to coordinate and commit to large-scale operations. In the case of hydrogen imports, these delays directly affect the ability to connect the international supply with the domestic demand.

Hydrogen Infrastructure Delays

A common theme highlighted in expert interviews is the ongoing chicken-and-egg dynamic between public infrastructure and private investment. These delays are consistently seen as a critical bottleneck across stakeholder groups (see Table 5.2). Market participants are reluctant to make FIDs due to the holdups in hydrogen infrastructure projects, such as the Delta Rhine Corridor and the Dutch Hydrogen Backbone. An interviewee noted:

> *We were shocked as a sector when we heard that the Delta Rhine Corridor would be delayed by four years. (Interview IA02)*

And an infrastructure actor noted:

> *It's very complex. We are all waiting for each other, and everything needs to happen at once. (Interview I02)*

The interviewees also raised concerns about the alignment of infrastructure development with EU targets, especially the 2030 and 2035 benchmarks set by RED III. The Dutch national backbone is currently scheduled to be completed in full by 2032, raising doubts about the feasibility of meeting intermediate demand targets (Interview IA02).

At the EU level, the absence of synchronized infrastructure planning between Member States is another challenge. Without coordinated development of transnational pipelines and terminals, particularly in regions with a hydrogen shortage, such as the Benelux and Central Europe, the expected import volumes from regions with a surplus, such as Iberia, Scotland, and Scandinavia, may not be realized [10, 2].

The complexity of import-oriented infrastructure is further enhanced by the need for specialized facilities such as ammonia cracking units, which are capital-intensive and technologically complex. Even when subsidies are available, their effect is muted in the absence of physical infrastructure according to Leguijt et al. [40].

5.3.3. Insufficient Policy Coordination

The development of a hydrogen economy depends on well-aligned policy efforts across multiple governance levels and sectors. In the case of international hydrogen supply chains, such alignment is crucial, as these involve coordinated decisions on infrastructure, demand incentives, regulation, and cross-border cooperation.

Insufficient policy coordination refers to situations where different levels of government or institutions pursue unaligned or only partially integrated strategies. This can include differences in timing, scope, or priorities between national and regional authorities, as well as between sectors such as energy, transportation, and industry. As Bolhuis [7] notes, fragmented policy signals can hinder the behavioral changes necessary to support complex transitions.

Difference in policy approach between MS

The development of international hydrogen import chains relies on coherent and well-structured cooperation between the European Commission, EU Member States, third countries, and industry actors. One key challenge is the lack of a unified "Team Europe" approach. Although the Commission called in 2015 for a unified EU voice in external energy cooperation, this ambition has not materialized [28].

As one infrastructure actor stated:

> *There is no 'One Europe approach' to speak of. We are still competing more with each other than with actual global competitors like Japan or Korea". (Interview I01)*

In practice, Member States pursue divergent hydrogen strategies without clear EU coordination or guidance. This results in bilateral initiatives that risk fragmentation, competition, and duplication which can undermine Europe's strategic position in global hydrogen markets (Interview I01 & I03) [28, 2].

Coordination challenges also occur with neighboring countries such as Germany and Belgium. These countries are expected to rely partially on hydrogen imports that enter Europe via Dutch ports, which means that their infrastructure timelines, preferred transport modalities, and industrial strategies must be closely aligned with those of the Netherlands. However, existing policies and safety regulations, especially concerning ammonia transport, still vary between jurisdictions [50].

RFNBO Compliance with Third Countries

Another challenge in the development of hydrogen import value chains, related to insufficient coordination, is the uncertainty around the RFNBO compliance for imported green hydrogen carriers. This is particularly relevant for the UK, where diverging standards and certification frameworks raise questions about the future compatibility of imports with EU rules. However, it was not addressed by stakeholders from Dutch or European (semi)governmental organizations. This may suggest a lack of focus by the Dutch government on green hydrogen imports from the UK.

A key challenge lies in the lack of alignment between UK and EU definitions of renewable hydrogen. Under RED III, hydrogen must meet specific RFNBO criteria related to carbon intensity, temporal/geographic correlation, and additionality. The UK applies its own Low Carbon Hydrogen Standard (LCHS), which differs in scope and application. For example, while the EU will require hourly matching of renewable electricity from 2030, the UK allows monthly matching without such a future requirement.

> *If the rules are different, which do you apply to label something green in the EU? (Interview INL01)*

The Scottish Government has acknowledged this risk and is working with the UK government to prevent misalignment that could constrain exports [29].

A central issue lies in the divergent interpretations and implementations of three key compliance principles: temporal matching, geographical correlation, and additionality. These principles play a crucial role in defining what qualifies as "renewable" hydrogen in the EU; however, they are applied more flexibly in the UK system. Table 5.3 summarizes the key differences between the two renewable hydrogen standards. Until there is mutual recognition or alignment between the systems, producers targeting export to the EU from the UK may need to dual-certify their products or redesign their electricity sourcing strategies. This regulatory misalignment is a challenge for cross-border hydrogen and ammonia value chains.

Criterion	**EU RFNBO (RED II/III)**	**UK Low Carbon Hydrogen Standard (LCHS)**
Temporal matching	Until 2030, monthly matching is permitted; From 2030 onwards, every hourly matching is required.	Monthly matching permitted; no mandatory shift to hourly matching
Geographical correlation	Must be within same bidding zone or linked via PPA	Grid electricity allowed; validated by REGOs; no spatial restrictions
Additionality	Mandatory from 2028; electricity must come from new, unsubsidised sources	Not required; existing or subsidised renewable electricity permitted
Carbon threshold	Implied by 70% emission savings over fossil comparator ($\sim$3.4 kg CO_2/kg H_2)	Explicit 20 gCO_2e/MJ LHV threshold ($\sim$2.4 kg CO_2/kg H_2) cradle-to-gate

Table 5.3: Comparison of compliance criteria: EU RFNBO vs. UK Low Carbon Hydrogen Standard [58, 16]

This challenge is specific to the UK case study, as Norway has no different approach to qualifying green hydrogen compared to the EU. In addition, as an actor in the Norwegian industry noted in the interview, it is not a challenge for green hydrogen carriers imported from Norway to comply with EU criteria because due to the highly electrified grid from which the share of renewable electricity is greater than 90%, the renewable hydrogen produced in Norway is excluded from the additionality, temporarily and geographical correlation requirements due to this highly electrified grid. As stated by a Norwegian Industry Actor:

> *Norway is generally a good place for ammonia production because it has a more than 90% renewable share in its power system. That means that it is already RFNBO-compliant. If you do not have a grid that is that green, then you have a lot of other quite expensive criteria that you need to meet to be RFNBO-compliant. (Interview IN01)*

5.3.4. Lack of Shared Directional Vision

A shared directional vision is a crucial element in achieving systemic change. In the context of the hydrogen transition, this means that public and private actors align around a clearly articulated long-term perspective, which includes prioritizing technologies, promoting specific applications, and determining the policy and regulatory frameworks that will support this pathway over time. The absence of such direction creates uncertainty about regulation, investment priorities, and the future role of hydrogen across sectors, undermining coordination and slowing momentum [75, 7]. Unlike policy coordination failure, which reflects concrete misalignment between policies, directionality failure refers to the absence of a collectively endorsed strategic pathway.

Without clear guidance, actors may act in divergent or even conflicting ways. Governments may announce targets without specifying instruments or roadmaps. Businesses may delay investment due to unclear infrastructure planning or changing policy signals. As a result, the transformation process slows down, not because of a lack of ambition, but because the conditions for collective alignment are not sufficiently established.

Lack of a well-substantiated general green H_2 roadmap

Targets for hydrogen production and imports are often set without a realistic plan or supporting policy instruments to reach them. According to Weber, directionality is not just about setting ambitions, but about creating credible and shared 'corridors of development' that guide innovation and investment. Without such a structured direction, uncertainty persists and coordination between actors weakens [75].

At the EU level, the European Court of Auditors found that the renewable hydrogen targets were established without sufficient analysis and did not result in binding national targets. Where national goals were set, they were often misaligned or overly ambitious. As a result, the EU is unlikely to reach its 2030 hydrogen targets, especially since there are still no EU-wide targets for low-carbon hydrogen [28].

The insights of the interviews confirm this challenge. Stakeholders perceive a lack of concrete transition paths and a clear distinction between the use of green and blue hydrogen. An interviewee noted that goals such as 4 or 8 GW of electrolysis capacity were set based on political ambition rather than feasibility. In addition, setting unrealistic goals can be counterproductive. An interviewee noted:

> *It is better to aim a bit lower and succeed than to set astronomical goals and fail. (Interview INL01)*

Lack of a specific vision for hydrogen import

In addition to domestic hydrogen production, the Netherlands is expected to import between 40% and 70% of its hydrogen needs in the coming decades. This forecast is supported by the National Energy Program and the II3050 system study by Netbeheer Nederland [17, 52]. Despite this expected dependence on imports, several stakeholders interviewed in this study pointed to a perceived lack of a clear roadmap or strategic vision specifically focused on hydrogen imports. According to these stakeholders, current policy discussions seem to place relatively more emphasis on domestic production, which they consider disproportionate given the scale of expected imports. The lack of a more developed strategic approach to hydrogen import chains was identified as a challenge in the interviews, although this is not explicitly addressed in the policy documents examined. This suggests a potential discrepancy between the policy's direction and the practical implementation challenges identified by the sector's stakeholders.

CE Delft, NLHydrogen, VOTOB, and PBL indicate that hydrogen import remains underrepresented as a policy priority. A representative from NLHydrogen highlighted:

> *Import is actually seen as something that will simply happen. We just need to establish partnerships with other countries, and if we have those diplomatic relationships, it will all work out. That perception really needs to be adjusted. (Interview IA02)*

At the same time, stakeholders also recognize the rationale behind focusing on domestic production. As an AirLiquide interviewee stated:

> The policy on hydrogen imports remains relatively immature. There has been a lot of attention on domestic production, and I think rightly so, at least in part. It's something you can control yourself, and ideally, you want to do as much as possible on your own, from a strategic independence perspective. On the other hand, we already import most of our energy today, and this trend is expected to continue in the future. (Interview INL03)

Recent developments underscore the urgency of stronger policy direction. At the Hydrogen Summit 2025, a coalition of Dutch industry associations and ports issued the Hydrogen Import Manifesto, calling for a coherent and proactive hydrogen import strategy. The 24 signatories stressed that large-scale hydrogen imports are essential for an affordable and secure energy transition and without targeted policy, the Netherlands risks falling behind as a key hydrogen gateway to Europe. As stated by NLHydrogen director Alice Krekt on behalf of the group:

> *Clear choices and government support are needed to ensure that large-scale hydrogen imports are launched in a timely manner. [54]*

This initiative highlights that, despite ongoing investments and willingness within the sector, the current lack of a clear transition path for imports remains a challenge.

Geopolitical and national political instability undermines transition momentum

Political instability, both at the national and international levels, makes it challenging to maintain a shared and consistent long-term vision for the hydrogen transition. Changes in political priorities and geopolitical tensions can disrupt continuity and weaken confidence in future support measures.

A stakeholder noted that political priorities can quickly shift and that budgetary competition, for example, between defense spending and healthcare, makes it difficult to secure long-term commitments for hydrogen-related projects (Interview GVO3). Similarly, a Gasunie interviewee noted that ministries currently face financial constraints and prioritization issues, which hinder the consistent support needed to develop infrastructure such as import corridors.

The outcome of the Dutch parliamentary elections has added new uncertainties regarding the ambitions of the next cabinet on the hydrogen agenda. Due to these and other uncertainties, parties are reluctant to make investment decisions related to the production or import of green hydrogen [40]. Similar concerns were raised by a semi-governmental actor:

> *It all depends on what the next government decides. Will they still prioritize climate and strategic autonomy, or will hydrogen lose momentum? (Interview GV01)*

Stakeholders, therefore, emphasize the importance of integrating hydrogen policy into European frameworks to safeguard it against domestic political fluctuations. As an interviewee noted:

> *Once it is EU policy, a new cabinet cannot easily undo it. That's why European coordination is essential for long-term consistency. (Interview GV02)*

Recent political developments have intensified these concerns. The fall of the Dutch cabinet on June 3, 2025, exemplifies how political instability can undermine confidence in the continuity of hydrogen policy. Although the outgoing government advanced several initiatives under the leadership of Minister Hermans, its departure introduces uncertainty about the future direction of hydrogen investments. In a public statement responding to the cabinet's fall, NLHydrogen emphasized the following:

> *Our members are preparing billion-euro investments, and those can only happen with stable governance and consistent policy. We cannot afford stagnation. [54]*

This statement emphasizes the importance of policy continuity in unlocking large-scale private investment in hydrogen infrastructure and import chains.

Misalignment Policy and Market Vision on Hydrogen Carrier Choices

A misalignment between government policy and market perspectives on green ammonia was identified in stakeholder interviews, but not addressed in the reviewed policy documents. In the Dutch government's vision of hydrogen as a carrier, ammonia is recognized as a viable option for the short term but is treated with caution for the medium and long term due to safety concerns. The governmental vision report promotes the use of ammonia mainly in seaports and discourages its distribution beyond those areas (Interview GV02 & GV03) [39]. This position reflects a prioritization of safety considerations: in the government's multi-criteria analysis, safety was weighted at 30%, while affordability received less than 10%.

In contrast, market actors widely regard ammonia as the most cost-competitive and technically mature hydrogen carrier available today. Although they recognize the importance of safety, many stakeholders argue that affordability should also be a significant consideration, particularly given the scale of investment and infrastructure required for hydrogen imports (Interview I03).

The divergence in carrier preferences suggests that while the government has played a leading role by publishing one of the first national visions on hydrogen carriers, this vision may not yet be sufficiently aligned with current market dynamics. As an industry expert noted, the policy framework could lead to suboptimal societal outcomes if public authorities steer too strongly based on internally weighted criteria rather than fostering a balanced framework that allows industry to make location-specific and data-driven decisions.

5.3.5. Lack of Ecosystem-Wide Financing

Developing a hydrogen import economy requires large-scale, coordinated investments throughout the entire value chain, from production and transportation to infrastructure and end-use applications. However, organizing simultaneous financing across multiple interdependent actors is a challenge. Most existing financial instruments are tailored to individual projects rather than integrated investments at the system level [19, 7].

Limited Subsidy Budgets and Bridging the Green Hydrogen Cost Gap

Interviews reveal widespread concern about whether current and anticipated public funding will be sufficient to bridge the cost gap between conventional (fossil-based) hydrogen and green hydrogen during the early phase of market development. Scaling up import chains requires significant financial resources, either to build infrastructure or to cover the price gap between imported green hydrogen and market prices for conventional hydrogen [31].

Multiple interviewees questioned whether existing budgets could realistically cover the financial gap. This includes both infrastructure support (e.g., import terminals and ammonia crackers) and subsidies to make imported hydrogen prices competitive. As an interviewee noted:

> *With current budgets, we will never reach the ambitions, not even close. (Interview IA01)*

The size of the unprofitable cost gap presents a serious obstacle and cannot be overcome without targeted public intervention. As explained by another interviewee:

> *If companies cannot pass on the costs due to international competition, subsidies are needed, but those are becoming extremely expensive. (Interview RI01)*

Second, policymakers acknowledged that public funds are limited and must be divided between multiple national priorities. As an RVO representative explained:

> *We can only spend the money once. We need billions for the electricity grid, billions for hydrogen infrastructure, and billions for subsidies. That tension is simply inherent to the situation. (Interview GV03)*

This financial uncertainty affects both public and private actors involved in developing import corridors, creating hesitation and delaying investment (Interview I01).

Lack of Ammonia Cracker Funding as Barrier to Import Chain Development

The lack of targeted funding for ammonia cracking facilities was identified by multiple Dutch stakeholders as a key challenge in developing hydrogen import chains. This issue was raised exclusively in interviews and does not appear in policy documents. According to NLHydrogen, Air Liquide, VOTOB, and PBL, the absence of specific support limits the feasibility of deploying cracking infrastructure, which is necessary to convert imported ammonia into hydrogen for end-use applications. As stated in one interview, ammonia cracking is not yet a commercially mature technology and is currently excluded from major funding mechanisms, such as the SDE++ scheme (Interview IA02).

The interviewee of PBL notes that the SDE++ subsidy scheme is structured to prioritize cost efficiency by supporting the technologies that achieve the most significant reduction in CO_2 per euro spent. Although this makes the instrument effective in allocating public funds in a fiscally responsible way, it also means that more expensive or emerging technologies, such as ammonia cracking, may fall outside the scope of eligibility. As a result, promising innovations that are essential for building long-term hydrogen import infrastructure may struggle to secure support, not because they lack potential, but because they do not yet meet the scheme's strict cost-effectiveness thresholds (Interview RI02).

In particular, this challenge was not mentioned by stakeholders from countries such as the UK and Norway. This may reflect different expectations for the use of ammonia in the short term. In the short term, imported green ammonia is mainly intended for direct application (e.g., in fertilizers), rather than conversion to hydrogen. Moreover, the Hydrogen Backbone is not yet fully operational, limiting near-term opportunities for integrating cracked hydrogen into domestic networks.

5.3.6. Lack of Relevant Knowledge, Skills, and Resources

This transition challenge occurs when actors lack the necessary knowledge, skills, and productive resources to participate in new value chains [7, 75].

A key technical challenge is the immaturity of the conversion technology for ammonia cracking. Although ammonia is widely considered a promising hydrogen carrier for international transport, the infrastructure to convert it back to hydrogen at import hubs is not yet commercially available at scale. This limits the usability of ammonia as a carrier [31, 37].

5.3.7. Outdated or Incomplete Institutions and Rules

The development of a reliable hydrogen import value chain in the Netherlands is being hindered by outdated, incomplete or complex institutional structures and regulatory frameworks. This challenge arises when existing laws, norms, and procedures do not align with the demands of a transforming energy system.

Complex certification requirements for Green Hydrogen and its derivatives

A widely acknowledged challenge across all stakeholder groups is the complexity of certification requirements, which forms a key challenge that slows the development of hydrogen import chains. Stakeholders note that this complexity can introduce additional costs and delays and that the RFNBO criteria do not align with the current stage of market development.

EU regulations require hydrogen imports to comply with the RFNBO criteria, including rules on additionality, temporal and geographic correlation, and minimum life-cycle emission reductions [37]. Although these requirements are intended to ensure sustainability, their practical application are considered too stringent and hinder hydrogen developments [67, 28].

This was echoed by a representative from AirLiquide, who explained that despite the intention of the delegated acts to support the renewable hydrogen economy, their complexity can create practical challenges in the early stages of the project. For example, the additionality requirement, stipulating that an electrolyzer must start operating within three years of the renewable energy project it uses, adds significant project risk. Developers often face delays due to permits, subsidy approvals, or construction bottlenecks. As a result, they may lose access to certified renewable electricity, even when they had secured a contract with a new wind park. In such cases, the electricity used no longer qualifies as renewable under EU rules, and the hydrogen produced cannot be labeled as green. Therefore, this strict rule structure may delay rather than accelerate progress.

Permitting delays for critical infrastructure

Beyond certification, permit procedures are frequently cited as a challenge to the timely deployment of the infrastructure required for importing green ammonia. Multiple policy reports describe the current legal and procedural framework as slow, administratively burdensome, and not yet tailored to the specific characteristics of hydrogen and its derivatives [37, 19]. As a result, permitting delays can lead to postponed project delivery.

Infrastructure stakeholders interviewed for this study confirmed these observations. A representative from Port of Rotterdam stated the following:

> *We face significant delays due to all the permits you have to apply for. This is not just a Dutch issue; it is almost a European problem. (Interview I02)*

Other stakeholders pointed to broader uncertainties. EBN noted that fluctuating nitrogen policy and volatile energy prices contribute to investor hesitancy in industrial infrastructure, even in cases where port logistics are already in place (Interview GV01). Similarly, NLHydrogen highlighted that public concerns about ammonia toxicity complicate spatial planning decisions. Although ammonia has been safely used in the chemical industry for decades, its new role as a hydrogen carrier raises additional safety and perception issues that are not yet fully reflected in existing planning guidelines. These incomplete safety guidelines for ammonia hamper the development of required import facilities (Interview IA02).

Subsidy-Export Optics Dilemma

In the United Kingdom, a specific challenge has arisen regarding the export of green ammonia produced with the assistance of domestic public subsidies, which were initially intended to stimulate national hydrogen production. This uncertainty was explained exclusively by UK-based industry actors interviewed and has not been identified by other stakeholder groups or addressed in existing UK policy documents. Although the UK government is reportedly working on a solution, the issue has not yet been publicly acknowledged in the official literature or regulations. The absence of clear rules on whether and how subsidized green ammonia can be exported to Europe creates a regulatory gap, contributing to uncertainty for project developers. As such, it is a clear example of the broader challenge of incomplete institutions and rules. This challenge arises when existing legal frameworks and policy instruments fail to keep pace with the evolving needs of emerging markets and technologies. In this case, regulatory ambiguity around subsidy eligibility and export conditions delays investment decisions and hampers the timely development of cross-border hydrogen value chains between the UK and Europe.

To support the growth of a green hydrogen economy, the UK government created the Hydrogen Production Business Model (HPBM). This model is designed to help hydrogen producers cover their costs and reduce financial risk. The CfD approach helped reduce costs and expand the market by providing developers with a guaranteed price for the electricity they produce. The government saw the success of this method and decided to apply it to hydrogen production as well [60].

Under the HPBM, hydrogen producers receive financial support through a process called hydrogen allocation rounds (HAR). These are competitive rounds in which companies apply for funding. Projects that are successful in the HAR receive a subsidy to cover the difference between the reference price, which is the UK natural gas price, and the hydrogen sales price required for the project to be economically viable (the strike price). Hence, this subsidy enables hydrogen producers to sell hydrogen to off-takers at the natural gas price, while effectively receiving the strike price through the support mechanism.

The first round (HAR1) was completed in 2023. It awarded funding to three projects, guaranteeing them a price of £9.49 per kilogram of green hydrogen for the next 15 years. These projects were the first in the UK to benefit from this new hydrogen funding model.

The UK government has now started the second round (HAR2). After reviewing all applications, it published a shortlist in spring 2025. One of the projects shortlisted is Shetland Hydrogen Project 1, developed by Statkraft Hydrogen UK Holding in Scotland [20]. This means that Statkraft has passed the first stage of evaluation and may receive government support, depending on a further assessment of value for money and project readiness.

Being on the shortlist does not guarantee funding. The government will select the final projects based on their affordability and impact. Meanwhile, shortlisted companies are encouraged to continue developing their plans and lowering costs.

As confirmed in interviews with project developers in the UK, ammonia projects such as those led by Statkraft UK rely on this subsidy to become economically viable. An interviewee stated, ”Our ammonia projects in the UK are based on that commercial model. Without CfD, green ammonia would be very expensive” (Interview IUK01). Another added, ’This enables us to produce hydrogen at the cost of natural gas’ (Interview IUK02). In short, the subsidy reduces the cost of hydrogen, making it feasible to use it as a feedstock for green ammonia production.

The complication arises when these producers look to export ammonia to markets such as the Netherlands, where demand and willingness to pay are expected to be higher. Although the export of hydrogen in its pure form is legally restricted, ambiguity arises when publicly subsidized hydrogen is converted into ammonia and subsequently exported. As one respondent noted:

> *The government is skeptical of completely funding green ammonia and then exporting all of it to, say, Germany or the Netherlands, thus decarbonizing the economies of other countries. (Interview IUK01)*

This concern is particularly relevant given the limited domestic market for ammonia in the UK. According to an interviewee from Statkraft UK, there is only one fertilizer producer left in the country, as the second closed several years ago. The remaining company has indicated that it does not plan to use green ammonia but prefers to import blue ammonia from the United States. As a result, the domestic off-take market is very limited and there is little willingness to pay a premium for green ammonia. In contrast, there appears to be more willingness to pay in the European Union, including in the Netherlands. However, because the ammonia is produced with subsidized hydrogen, it remains unclear whether exporting green ammonia will be permitted or politically acceptable. The interviewee explained that while selling to Europe would be the logical commercial route, relying solely on export is risky. The level of willingness to pay on the continent is not yet high enough to support unsubsidized production, especially given the high power and infrastructure costs in the UK.

To address this dilemma, the UK government has launched a consultation within the HAR2 process to explore whether the export of subsidized hydrogen-derived products should be limited, allowed, or regulated differently. As a project developer involved in this consultation explained:

> *It is unlikely that there will be a complete ban, but the government is considering how to handle this and how much should be supplied domestically. (Interview Industry UK02)*

This uncertainty complicates planning for projects targeting export markets and raises the broader question of how subsidy leakage can be managed in a way that supports international value chains while respecting national funding boundaries.

In summary, while the UK’s subsidy system effectively supports green hydrogen production, it creates tension when that production feeds into export-oriented ammonia chains. Without clear rules on the acceptability of export or coordinated international agreements, the development of cross-border green ammonia value chains remains politically and commercially uncertain.

5.3.8. Political and Public Sensitivity to Energy Exports

Another identified challenge is the growing political and public sensitivity to the export of products derived from renewable energy, such as green hydrogen, in Norway. Although this issue has not been identified in the Norwegian government’s policy documents, it was repeatedly raised during interviews with stakeholders in the Norwegian industry. Specifically, they pointed out that concerns about domestic electricity availability and pricing may limit political and public support for exporting green hydrogen or green ammonia. This form of resistance may delay the development of imports from Norway to the Netherlands. These concerns were also informally confirmed in conversations with Norwegian hydrogen actors during the Hydrogen Summit 2025.

From 1991 until the early 2020s, Norway benefited from stable and low electricity prices, supported by ample hydropower resources and a relatively isolated market. However, market liberalization and the construction of new interconnectors with Europe have made Norwegian consumers more vulnerable to volatile international electricity prices, particularly during the energy crisis that followed the Russian invasion of Ukraine. This has triggered widespread public and political concern about energy security and affordability. In southern Norway, electricity prices have risen to levels comparable to continental Europe, causing regional inequality and fueling political debate [18].

> *There is a political debate, as the public does not want higher power prices. Exporting energy is politically sensitive at the moment. (Interview IN02)*

These political concerns are further exacerbated by the rising domestic demand for electricity. As multiple sectors, including data centers, battery factories, and hydrogen electrolysis, seek access to clean electricity, the pressure on the Norwegian power grid is increasing. Although the country currently has a renewable surplus of approximately 13 TWh per year, projections indicate that this could turn into a deficit by 2030 if demand outpaces renewable energy development [8]. Bottlenecks in the grid infrastructure further complicate the picture, as documented by Ekanem, Noble, and Poelzer [18], who highlight that current grid capacity is inadequate to meet the needs of a fully electrified economy.

According to a representative from Statkraft:

> *There is concern because there has been and is expected to be significant development of new industries using renewable energy. If you examine the grid reservations, there is a long queue to connect and utilize the power. [...] It does not mean that we will not have enough for ourselves, but with increasing demand, prices are also rising. (Interview IN02)*

Increased demand and limited access to the grid can delay the roll-out of electrolyzers, which, in turn, could restrict Norway's ability to export hydrogen to markets such as the Netherlands.

5.3.9. Limited Urgency for Export-Oriented Hydrogen Development

A challenge in developing a hydrogen import chain between Norway and the Netherlands is the limited sense of urgency within Norway to develop green hydrogen production projects and export green hydrogen. Although the Netherlands actively pursues hydrogen deployment to decarbonize hard-to-abate sectors and reduce dependence on fossil fuel imports, the domestic conditions in Norway differ significantly. These differences reduce the political and institutional momentum required for the rapid development of hydrogen infrastructure with an export focus.

This lack of urgency was raised in informal discussions with stakeholders from the Norwegian industry during the Hydrogen Summit 2025 in Rotterdam. The conversation emphasized that green hydrogen and ammonia exports to the EU are not perceived as a short-term necessity, but rather as long-term industrial opportunities.

This perception is also reflected in the Norway hydrogen policy. The government's 2020 hydrogen strategy was criticized for lacking concrete targets and measures and for largely presenting a description of existing activities rather than a strategic roadmap [66]. Although this criticism led to the publication of a hydrogen roadmap in 2021, accompanied by increased funding for hydrogen research and industrial projects, the roadmap has so far only been published in Norwegian. This may indicate a primarily domestic focus and limited engagement with the international policy community.

In addition, Norway's already high level of electrification, based almost entirely on renewable hydropower, reduces domestic pressure to develop green hydrogen solutions. As noted in Damman et al. [11], the country's electricity and heating sectors already have relatively low emissions. This reduces internal drivers for rapid hydrogen development and may slow the roll-out of infrastructure needed to enable exports.

5.3.10. Opposition from Stakeholders Adversely Affected by the Transition

A common challenge in sustainability transitions is resistance from so-called transition losers, actors who expect to lose income, security, or market position as a result of change. These actors may try to slow down or block the transition in order to protect the existing socio-technical system [7].

The exemption of ammonia producers from RED III obligations is an example of resistance that was discussed during the interviews. By protecting a major industrial sector from change, it reduces the pressure to adapt and makes the policy less effective.

In February 2025, the Dutch government further clarified its position on the RED III obligation for ammonia producers. Although RED III does not contain a formal exemption for ammonia, the European

Commission acknowledges in Recital 63 that existing production plants require significant investments to transition to renewable hydrogen. Based on this interpretation, the government proposed a partial exemption for 60% of the hydrogen used in ammonia production, citing technical feasibility and the potential role of alternative measures such as carbon capture. A full exemption was deemed neither fair nor effective, as it would increase pressure on other sectors. However, the government also indicated that the 60% threshold could be reassessed during the legislative process [45, 76].

Although the letter from the Minister of Climate and Green Growth, S.T.M. Hermans, has provided certainty for green ammonia producers, it also reduces part of the anticipated demand for green ammonia. An industry actor noted that these exemptions may reduce incentives for developing green ammonia production projects:

> *Most of the hydrogen in the Netherlands is currently used by the ammonia industry. If they are not included in the obligation, there is little incentive for them to switch, and there is no reliable demand for green ammonia. (Interview INL01)*

Without this demand, the scale required for import terminals or domestic green ammonia production may not materialize, as it would have without this exemption. The exemption of ammonia producers weakens the demand articulation for green hydrogen and ammonia. At the same time, the exemption helps prevent the relocation of ammonia production to countries with less stringent regulations, a risk that could undermine domestic industrial policy and sustainability goals.

5.4. Perceived Impact of Challenges on Import Development

Interviews with stakeholders reveal that the identified challenges and uncertainties are already having a concrete impact on the development of green ammonia import value chains to the Netherlands. The most frequently cited impact is the delay or cancellation of projects, which is causing doubts about the feasibility of the 2030 goals.

Multiple stakeholders emphasized that import projects are progressing more slowly than planned. According to the Port of Rotterdam:

> *We see a lot of delay, I hope there are no cancellations. Many projects aimed for 2030, but it is already 2025. To achieve that target, you need to start building now. (Interview I02)*

An infrastructure actor also noted that the timelines for hydrogen infrastructure are shifting and that achieving the 2030 targets is becoming increasingly unrealistic. Although many actors still refer to these targets, they are now being treated more flexibly, and delays are increasingly seen as inevitable in such large-scale developments (Interview I01).

A Norwegian industry actor noted:

> *There are no large-scale green ammonia projects that have taken final investment decisions. That means that the combined challenges are large enough to have prevented that from happening. (Interview IN01)*

Although Statkraft was still actively involved in the development of green hydrogen production at the time of the interviews, the company announced on 8 May 2025 that it would halt new hydrogen project developments due to growing market uncertainty. In their official press release, Statkraft stated that while it has built significant expertise and created value across multiple European markets, it will now prioritize other technologies and operations. The company explained:

> *After reducing the ambition level for green hydrogen development last year, we are experiencing even more uncertainty in the market. Therefore, Statkraft has decided to stop the new development of green hydrogen, and in the future, we will prioritize growth opportunities in other technologies and market operations. [69]*

Existing projects will be further matured with the intention of attracting external investors, and the company remains engaged in dialogue with public authorities to secure the continuation of selected initiatives. This move by a key player in the sector is illustrative of how perceived uncertainty can significantly affect strategic direction and investment flows [69].

The slowdown in project execution, along with Statkraft's recent strategic shift, underscores the seriousness of market uncertainties and transition challenges. Without clearer policy signals, financial support, and coordinated demand creation, the Netherlands risks falling behind in establishing a robust import infrastructure by 2030.

6

Policy Responses and Gaps

This chapter will examine how current policy instruments relate to the transition challenges identified in Chapter 6. It will assess to what extent these instruments address the identified challenges and where policy gaps or inconsistencies persist. The analysis will proceed in two steps. First, a co-occurrence analysis will be conducted within each method to link challenges to specific instruments, after which the results will be combined. Second, the Code-Document Group function in Atlas.ti will be used to compare how these instruments are represented in policy documents versus interviews. This will reveal which instruments are considered relevant by stakeholders in practice and which remain primarily within the policy domain. By combining both research methods, this chapter will provide an integrated understanding of how well current policy frameworks align with practical challenges and where divergences or implementation gaps emerge.

6.1. Broader Interpretation of Results

Based on the co-occurrence matrix generated in Atlas.ti, Table 6.1 has been created to provide an overview of the current challenges addressed by policy instruments and to highlight any existing gaps. These gaps may arise either because no suitable policy instruments are currently in place or because some challenges, particularly those involving uncertainty, are inherently complex and cannot be effectively addressed through a single, standalone policy measure.

In some instances, policy instruments are targeted explicitly at addressing particular challenges. In others, they play a more enabling role, supporting the broader conditions under which systemic change can occur. These instruments, along with how stakeholders perceive their effectiveness, will be discussed in more detail in the next chapter.

While the co-occurrence analysis technique enhances structure and transparency in qualitative analysis, it is essential to recognize that the coding and interpretation of co-occurrences remain subject to the researcher's judgment. The outcomes, therefore, reflect a combination of systematic coding and interpretive analysis. Nonetheless, the use of this method contributes to the internal consistency and traceability of the overall analytical process.

Challenge	Linked policy instrument(s)
Demand Articulation	
Gap between the green cost premium and WTP	EHB, Innovation Fund (CAPEX/OPEX), H2Global, HAR
Lack of reliable demand (stimulation)	FuelEU Maritime, ReFuelEU Aviation, RFNBO quotas (industry & mobility), EU ETS
Uncertainty about future demand and supply volumes and timelines	NECPs reporting, Tailored Agreements, RFNBO quotas (industry & mobility)
Uncertainty about future cost developments for green H_2	No linked policy instruments
Inadequate Physical & Knowledge Infrastructure	
Hydrogen infrastructure delays and uncertainties	IPCEI, TEN-E, MIEK
Lack of clarity on H_2 integration into existing systems	Hydrogen & Gas Decarbonization Package
Permitting delays for critical infrastructure	RED III permitting provisions, TEN-E, MIEK
Insufficient Policy Coordination	
Difference in policy approach between MS	Clean Hydrogen Partnership, Hydrogen Energy Network, IPCEI, Team Europe Initiative
Coordination challenge NL–export countries	Clean Hydrogen Partnership, CEM-H2I, IPHE, bilateral MoUs, International Hydrogen Trade Forum
Coordination challenge NL–neighboring countries	Bilateral MoUs
RFNBO compliance coordination with third countries	No linked policy instruments
Lack of Shared Directional Vision	
(Geo)political instability undermines transition momentum	No linked policy instruments
Lack of a well-substantiated general H_2 roadmap	No linked policy instruments
Lack of a specific vision for H_2 import	No linked policy instruments
Long-term industry transition vision	Tailored Agreements, NPVI
Misalignment between policymakers and market actors on H_2 carrier vision	Hydrogen carrier vision report (NL)
Lack of Ecosystem-wide Financing	
Limited subsidy budgets	European Hydrogen Bank, Horizon Europe Funding Programme, Innovation Fund, IPCEI, TEN-E, H2Global, national subsidies
Lack of NH_3 conversion support	No linked policy instruments
Lack of Relevant Knowledge, Skills & Resources	
Immature large-scale NH_3 cracker technology	R&D funding instruments (Horizon Europe, Innovation Fund)
Outdated or Incomplete Institutions & Rules	
Complex certification requirements for RFNBO	RED III Delegated Acts (RFNBO)
Subsidy-based export uncertainty for green NH_3	No linked policy instruments
Opposition from negatively impacted actors	Tailored Agreements
Political and public sensitivity to energy exports	No linked policy instruments
Limited urgency for green H2 exports	No linked policy instruments
NH_3 **societal acceptance concerns (safety)**	No linked policy instruments

Table 6.1: Overview of identified challenges grouped by category and their linked policy instruments

Table 6.2 illustrates the frequency with which policy instruments are cited in the reviewed policy-related documents and stakeholder interviews. This table provides valuable insights into the visibility and significance of specific instruments within both policy discourse and practical stakeholder engagement. Notably, some instruments, such as the RFNBO criteria, RED III sector obligations, EHB, and H2Global, are frequently mentioned in interviews, indicating that they are well-recognized and directly relevant to ongoing hydrogen import projects.

Conversely, other instruments, such as IPCEI, are extensively addressed in policy documents as critical funding mechanisms for large-scale hydrogen infrastructure, but were not mentioned by the interviewees. This omission may suggest that the stakeholders interviewed either were not involved in related initiatives or had not sought support through these schemes.

It is essential to note that these findings are contingent upon the selected documents and the composition of the interview sample. Therefore, the table should be interpreted as an indicative qualitative assessment, rather than a definitive measure of the instrument's importance or its familiarity among stakeholders. Nevertheless, the table offers valuable insights into which instruments currently stand out among the practitioners interviewed.

Policy Instrument	Policy Coverage (n=20)	Interview Coverage (n=18)
RFNBO Delegated Acts	15	15
RFNBO quotas	13	15
Imp/Dom (RED III)	4	0
Speed Permitting (RED III)	4	0
ReFuelEU Aviation	8	0
FuelEU Maritime	4	0
CBAM	6	4
ETS	9	9
Gas & Hydrogen Package	4	3
TEN-E	6	0
Team Europe Initiative	1	2
RFF Funding (RRF)	3	0
IPCEI	12	0
Innovation Fund	7	3
European Hydrogen Bank (EHB)	9	8
H2Global	12	13
Clean H2 Alliance	3	0
Clean H2 Partnerships	7	1
Horizon Europe	5	0
Hydrogen Energy Network	2	0
CEM Hydrogen Initiative	5	0
Hydrogen TCP	2	0
Hydrogen Trade Forum	3	0
IPHE	5	0
Hydrogen Carrier Vision Report	1	6
Domestic Subsidy	5	7
NPVI	2	0
Maatwerkafspraken	3	2
MIEK	5	2
MoU	7	4
SHIPNL	3	1

Table 6.2: Policy instruments mentioned in policy documents (n=16) and interviews (n=18). Values reflect the number of sources in which each instrument was mentioned.

A crucial consideration in analyzing policy responses and identifying gaps related to challenges is the disparity in policy contexts between the two case studies. Norway, as a member of the EEA, operates within a policy environment that is more closely aligned with that of the Netherlands. Being part of the EEA enables Norway to participate in certain EU regulations and funding programs. In contrast, the United Kingdom, which is neither a member of the EU nor the EEA, has established a more distinct policy framework. For instance, Norway is a participant in the EU ETS, while the UK is not. These differences impact how policy instruments are applied to imports from these countries, yielding varied implications for EU-related trade and regulation. Table 6.3 summarizes these distinctions.

Policy Category and Instruments	Netherlands	Norway	United Kingdom
Global: Financial Support			
H2Global	Financially involved and active participant	Eligible for participation (auctions)	Eligible for participation (auctions)
Fora			
CEM Hydrogen Initiative	Participant	Participant	Participant
IPHE	Participant	Not a participant	Participant
International Hydrogen Trade Forum	Participant	Not a participant	Participant
Hydrogen TCP	Participant	Participant	Participant
EU: Regulation			
RFNBO Delegated Acts	Applies	Uses same system; exports to EU must comply	Own system (LCHS); exports to EU must comply
ETS	Applies	Applies	own UK ETS
CBAM	Not applicable	Not applicable	Applies
Gas & Hydrogen Package	Applies	Not applicable	Not applicable
TEN-E Regulation	Applies	Not applicable	Not applicable
ReFuelEU Aviation	Applies	Not applicable; drives export demand	Not applicable; drives export demand
FuelEU Maritime	Applies	Not applicable; drives export demand	Not applicable; drives export demand
Directive			
RFNBO Quotas	Applies; flexible implementation	Not applicable; drives export demand	Not applicable; drives export demand
NECPs (RED III)	Applies	Not applicable	Not applicable
Permitting provisions (RED III)	Applies	Not applicable	Not applicable
Funding Support			
Horizon Europe	Eligible	Eligible	Eligible
RRF Funding	Eligible	Not eligible	Not eligible
IPCEI	Active participation	Eligible via national state aid	Eligible via national state aid
Innovation Fund	Participating	Participating	Not participating
European Hydrogen Bank	Participating	Participating	Not participating; potential via international pillar (under development)
Fora / Partnerships			
European Clean Hydrogen Alliance	Participating	Organizations eligible to join	Not eligible
Clean Hydrogen Partnership	Participating organizations	Participating organizations	Not participating
Team Europe Initiative	Participating	Eligible (EU-associated)	Not eligible
NL: Policy Landscape			
MoUs	-	MoU signed with NL (Nov 2024)	No MoU between Uk & NL
Tailored Agreements	In development	Drives import demand	Drives import demand
Domestic Subsidies	Support Dutch H_2 production	-	-
NPVI	Shapes national industrial policy	-	-
H_2 Carrier Vision Report	Influences import strategy	-	-

Table 6.3: Overview of policy instruments by category and applicability to the Netherlands, Norway, and the United Kingdom.

6.2. Evaluation of Policy Response

6.2.1. Response to Reliable Demand and Supply Timelines

Delegated Acts for RFNBO

The European Union's policy framework for the energy transition consists of a layered structure. The European Green Deal sets the overarching ambition of climate neutrality by 2050. The Fit for 55 package translates this into concrete targets for 2030, including a minimum 55% reduction in greenhouse gas emissions. As part of this package, the RED III, adopted in October 2023, establishes binding obligations for the use of renewable energy across various sectors.

The 2023 Delegated Acts adopted under RED III define the conditions under which hydrogen and its derivatives, including ammonia, can qualify as RFNBOs. This qualification determines whether they count towards EU renewable energy and emissions targets and are eligible for EU funding schemes [81, 19]. The rationale for the Delegated Acts, explained in detail in the previous chapter, is to ensure that the hydrogen sector contributes meaningfully to decarbonization, by avoiding the increase in the use of fossil-based electricity [19]. RFNBO qualification criteria set by the EU are a widely discussed topic in both the analyzed policy (related) documents and the semi-structured interviews.

Interviews with stakeholders indicate that, while the delegated acts finally provided the long-awaited legal clarity, they are perceived as being too rigid for the initial phase of market development and thus have a conflicting effect on import developments (Interviews INL01, IN02, IUK02, I01, INL03, INL04).

Developers have already postponed investment decisions due to the wait for the finalization of delegated acts, highlighting that incomplete institutional frameworks hinder development and emphasizing the importance of regulatory clarity in enabling project development [28] (Interview INL01).

The hourly temporal correlation rule, required from 2030, has been shown to increase production costs, due to the need for battery storage and over-sizing of renewable generation [3]. Industry voices also stress that market forces already encourage hydrogen production during periods of low electricity prices, which typically align with high renewable energy generation. Imposing additional matching rules may duplicate market incentives and unnecessarily raise costs (Interview INL01). When delegated acts lead to additional hydrogen production costs, it weakens the business case for hydrogen or ammonia. Therefore, it can slow the development of import chains of green ammonia to the Netherlands.

RED III RFNBO obligations for Industry and Transport Sector

One of the most widely discussed policy responses to the challenge of creating reliable demand for green hydrogen and ammonia is the obligation set in RED III for the use of RFNBOs in the transport and industry sector. The RED III directive introduces binding EU-level targets for RFNBOs across industry and transport sectors. These mandates include a minimum share of 42% RFNBOs in industrial hydrogen use by 2030 (up to 60% by 2035), and a 5.5% quota in transport fuels by 2030, of which at least 1% must be from RFNBOs [58]. The central policy rationale is to create a stable and predictable future demand base, thus reducing market risk and supporting large-scale investment in hydrogen production and import infrastructure. Therefore, these policy instruments help overcome the previously indicated challenges, including the lack of reliable demand, and reduce uncertainty in future demand and supply volumes and timelines.

Both the interviewed stakeholders from the UK and Norway see these obligations as an essential element, as reliable demand creation is necessary to justify the development of hydrogen export chains to the Netherlands or transit through the Netherlands to Dutch neighboring EU Member States.

Stakeholders confirm that if RED III were fully implemented in all Member States, it could alone generate the off-take certainty needed to finance hydrogen and ammonia import routes. However, this potential is currently undermined by slow, inconsistent, and fragmented national implementation.

In the Netherlands, the industrial RFNBO obligation is still under political negotiation. According to an RVO policy advisor, the final design and level of the commitment are still awaiting parliamentary debate. This lack of national clarity undermines the certainty necessary for investments. As an infrastructure actor stressed, companies cannot commit to long-term hydrogen investments without knowing the policy trajectory:

> It remains unclear how we will implement RED III. That makes it very hard for companies to make 15-year decisions. (Interview I01)

Furthermore, RED III is a directive, not a regulation, which means that differing national interpretations are likely and are already occurring. As observed by Corbeau and Nassif [10], this regulatory fragmentation weakens the coherence of RED III as a unified demand signal across borders. For hydrogen import infrastructure, which typically involves multi-country coordination, such fragmentation poses challenges. Divergent timelines and enforcement levels between countries reduce the viability of cross-border value chains and delay infrastructure investment.

These implementation gaps contribute directly to the broader challenge of weak demand articulation. The absence of firm national obligations erodes the credibility of projected hydrogen demand. It prevents the emergence of long-term off-take contracts, which are critical to the bankability of import projects. An industry actor emphasized that without enforceable demand, import projects remain high-risk:

> *If RED III were implemented strictly, that alone could generate the demand we need. But until that happens, everyone remains on standby. (Interview IN01)*

In conclusion, RED III is designed to send a strong market signal in support of renewable hydrogen. However, its delayed and uneven implementation results in three key challenges for hydrogen import development:

- The instrument addresses the issue of weak demand articulation only to a limited extent, as it currently lacks the policy certainty and practical implementation required to support long-term contracts and de-risk investment decisions, despite its potential to contribute more substantially in the future.
- It reveals a regulatory mismatch between the EU's ambition and national implementation, limiting the effectiveness of the directive as a demand-driven tool.
- It highlights the risk of fragmented execution, which complicates cross-border coordination and undermines confidence in the formation of international value chains.

Tailored Agreements Industry

Tailored agreements ("maatwerkafspraken") are an essential policy instrument in the Netherlands to support industrial decarbonization, including the development of hydrogen value chains. Although this instrument was not widely discussed in the interviews, it was primarily mentioned by Dutch industry actors, reflecting their direct involvement and interest in implementing these agreements.

These agreements aim to provide large industrial emitters with customized pathways toward emission reduction. Hydrogen is a key decarbonization pathway that should be formalized within these agreements [50]. According to Nationaal Waterstof Programma [50], this includes accelerating infrastructure development, providing financial support, and streamlining permitting processes.

An important implication of the agreements is that they help create a predictable demand for green hydrogen. The NVDE emphasizes the need for clear obligations or incentives for hydrogen users to stimulate market demand, which is currently lacking. Until 2030 and beyond, tailored agreements are considered crucial to providing investment certainty on the supply side [57]. This point was also echoed during the H2A Symposium 2025, where tailored agreements were described as essential for stimulating demand in hydrogen import chains.

Leguijt et al. [40] also stresses the importance of tailored agreements in implementing the RED III obligations in the Netherlands. For example, with the ammonia producers Yara and OCI, clear agreements on their decarbonization paths could provide clarity not only for the companies themselves, but also for other stakeholders in the hydrogen supply chain [40]. This clarity helps to reduce risk investments and supports the development of upstream infrastructure, particularly in an early-stage market characterized by high costs and uncertainty [57].

Currently, implementation is progressing more slowly than expected. Only one binding agreement has been signed so far (with Nobian), while others, such as Shell, Tata Steel, and Yara, are still in early stages. This slow progress reduces the ability of agreements to provide a strong and consistent market signal and can delay the development of related infrastructure and supply chains [57, 49].

From the perspective of an industry actor, the concept of tailored agreements is seen as promising, especially when it allows for custom solutions such as ammonia import. However, they also note that, in practice, the process is too slow and cautious, thereby limiting its effectiveness (Interview INL04).

ReFuelEU Aviation and FuelEU Maritime

ReFuelEU Aviation and FuelEU Maritime are part of the EU's Fit-for-55 package and support the climate objectives of the European Green Deal. They translate RED III's general goals into sector-specific obligations for aviation and shipping [62]. These regulations help to create a growing and predictable demand for renewable hydrogen and its derivatives, thus supporting the development of international import value chains [3, 62]. However, they were not mentioned in the interviews. One possible reason for this is that both regulations offer technological flexibility: they mandate emission reductions but do not prescribe the use of specific fuels, such as green ammonia. As a result, they are less effective in explicitly stimulating demand for green ammonia, in contrast to RED III, which includes specific targets for the use of RFNBOs, including green hydrogen and its derivatives.

EU ETS

The EU ETS is frequently cited in policy documents and interviews as a potential driver for the uptake of green hydrogen and green ammonia, including for imported volumes. In theory, the ETS should increase the cost of carbon-intensive alternatives, making renewable hydrogen more competitive. However, current CO_2 prices remain too low to stimulate demand in the short term.

As an industry actor stated:

> *CO_2 prices are still too low to change the business case for imports. (Interview IUK01)*

Another stakeholder confirmed this:

> *ETS creates a theoretical advantage for clean hydrogen, but in reality, the market sees no shift. (Interview INL01)*

The ETS influences the economics of hydrogen imports by creating a price signal for low-carbon alternatives. A sustained increase in CO_2 prices in the coming years could enhance the cost competitiveness of imported green ammonia.

The Carbon Border Adjustment Mechanism (CBAM) is an EU regulation instrument that applies a carbon price to selected imports, ensuring they are subject to the exact emissions costs as goods produced under the EU ETS. Green ammonia imports from Norway and the United Kingdom are subject to different considerations under the EU's CBAM. Norway, a participant in the EU ETS, is exempt from CBAM, meaning green ammonia imports from Norway are not subject to additional carbon-related charges. Until recently, the United Kingdom, operating its own UK ETS, fell under the scope of CBAM. However, as of 19 May 2025, the European Commission and the UK Government have announced their intention to link their respective ETSs through a formal agreement [35]. Once implemented, this linkage would exempt UK-based exports, including green ammonia, from coverage under the CBAM. In the interim, RFNBO-compliant green ammonia from the UK, characterized by low or zero embedded emissions, would likely face minimal CBAM costs when RFNBO certification is in place.

6.2.2. Policy Instruments to Close the Green Cost Gap

An instrument available to reduce the cost gap between green hydrogen and fossil-based alternatives is the EU Innovation Fund. This fund supports the commercial deployment of innovative low-carbon technologies. It is financed through EU ETS revenues and has a projected budget of approximately €40 billion until 2030 [24, 81].

The eligibility for the Innovation Fund differs between the case studies (see Table 6.3). Norway is eligible to apply for funding, while the UK, as a non-EU and non-EEA country, is not eligible, which limits its access to this financial instrument for de-risking investments in green hydrogen and ammonia.

The Innovation Fund contributes to closing the green premium in two different ways. Firstly, it provides capital and operational subsidies for low-carbon projects, covering up to 60% of costs, depending on the projected greenhouse gas reductions. These grants are designed for projects that are beyond the R&D stage but not yet fully commercial [24, 81]. By reducing upfront investment risks and operational expenses, the fund helps lower cost levels, thereby reducing the difference between fossil-based and renewable hydrogen. Although this contribution is valuable, it was not frequently mentioned in interviews. One Norwegian project developer commented:

> *The Innovation Fund seems quite low and marginal in terms of how much support they can give to a large-scale ammonia plant. For a large-scale ammonia plant, you could potentially cover 10–15% of your CapEx, which helps, but it is not necessarily a game changer. (Interview IN01)*

This suggests that, although helpful, the instrument alone is insufficient to bridge the cost gap fully.

Secondly, the Innovation Fund also plays a strategic role by financing the EU Hydrogen Bank, an instrument designed to further close the cost gap through price support mechanisms. Although the Innovation Fund itself was less prominently discussed in interviews, the EU Hydrogen Bank was frequently mentioned and is regarded as a crucial instrument for scaling up hydrogen import chains, both in policy analyses and by stakeholders (see Table 6.2).

The EHB was launched in 2022 by the European Commission to stimulate renewable hydrogen markets and improve investment security in Europe [21, 74]. It consists of two pillars: a domestic pillar for renewable hydrogen production within the EEA, and an international pillar aimed at supporting imports from non-EEA countries (see 6.1).

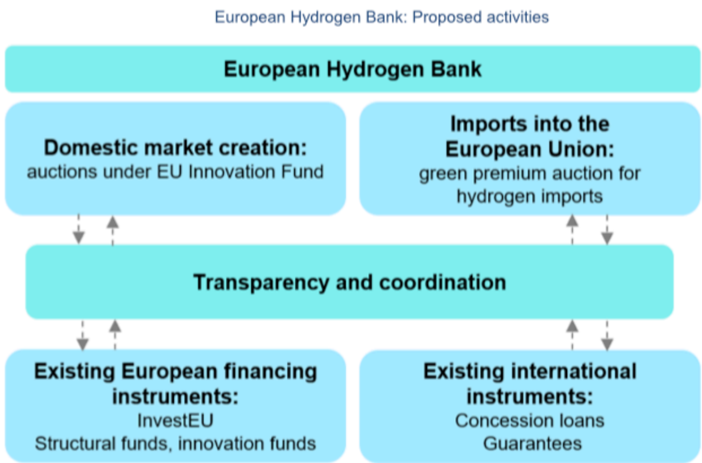

Figure 6.1: Overview of EHB domestic and international pillar [37]

The domestic pillar provides fixed-premium subsidies for certified renewable hydrogen production within the EEA. This support is awarded through competitive auctions under the Innovation Fund, to which the Hydrogen Bank is closely linked [81]. For example, the second domestic auction closed in February 2025, awarding €992 million to 15 projects in five EEA countries. Producers receive a fixed premium per kilogram of renewable hydrogen produced for up to ten years. These premiums help close the gap between production costs and market prices, directly addressing the cost barrier for renewable hydrogen [41]. Although useful, these auctions have not been considered transformative.

> *A lot of the first-round auction prices were pretty low. It does not completely make these projects profitable. (Interview IN01)*

Norway, as part of the EEA, is eligible to participate in the domestic pillar and has access to these subsidy schemes. In contrast, the United Kingdom, as a non-EU and non-EEA country, cannot participate in this pillar, which limits its access to direct financial support for renewable hydrogen production within the current framework.

However, the international pillar of the EHB is still under development. It aims to facilitate the import of renewable hydrogen into the EU by organizing supply-side auctions and off-take agreements with third countries. This pillar of EHB is likely to be linked to the H2Global model to align demand and financing efforts throughout the EU [44, 47, 25]. The idea of linking the Hydrogen Bank to H2Global was introduced by Commissioner Kadri Simson and Minister Robert Habeck, but concrete mechanisms are still being discussed with the Member States [47]. Although it has been officially announced, details about its structure and operation are still limited.

Several stakeholders see this potential link as a crucial opportunity for the rapid development of the import market. Using H2Global as the foundation for the international pillar would avoid creating fragmented or overlapping tools, as stated by Wijk, Westphal, and Braun [79]:

> *It creates a 'ready-available' opportunity for rapid and effective market expansion. Building new structures would cost time the EU cannot afford [79].*

A respondent confirmed this outlook and noted that while the domestic pillar is helpful, greater impact is expected from the international instrument, particularly in supporting import value chains (Interview IN01).

In conclusion, the European Hydrogen Bank plays a valuable role in supporting the renewable hydrogen market and reducing the green premium. The domestic pillar is operational and provides moderate but relevant support for actors based in the European Economic Area, like Norway. However, the international pillar remains a critical missing piece, particularly for non-EEA countries such as the UK. Its development is essential to unlock the full potential of hydrogen import chains and to avoid fragmented support structures across Europe.

The H2Global mechanism is the most widely acknowledged policy instrument among stakeholders and is considered one of the most concrete and operational tools currently available to support the import of renewable hydrogen into Europe (see Table 6.2). In the interviews, the mechanism was consistently mentioned as a positive intervention that helps to address market gaps during the early stages of hydrogen market formation.

H2Global is a German support scheme aimed at stimulating hydrogen imports from non-EU countries. It operates through a double auction system: one auction for purchasing hydrogen or its derivatives from producers and another for selling them to European buyers. The difference between the purchase and sale price is covered by a public intermediary company, Hint.co. This setup offers long-term contracts (up to ten years), which reduces investment risks for producers and supports the growth of international hydrogen supply chains. The Netherlands, Canada, and Australia have joined the H2Global mechanism and collectively allocated €5.86 billion to tenders administered by Hintco [81, 32].

The design of H2Global, which operates on a double auction model, is often praised for its ability to match long-term supply contracts (10 years) with short-term demand contracts (1 year) through CfDs. This structure enables participating governments to bridge the price gap between renewable hydrogen supply and current market demand, effectively de-risking investments in both production and off-take.

As explained in several interviews (Interviews IN01, IA02, GOV03), the mechanism is perceived as valuable for improving transparency, establishing price signals, and supporting the market's basic functioning. It is seen to address both the price gap and the mismatch in contract durations, where sellers require long-term commitments for financing, while buyers often seek more flexible arrangements. As an interviewee observed:

> *You are basically solving two problems with the scheme like H2Global: you are addressing the difference in timescales between the buyers and sellers, and you are also addressing the price difference. (Interview IN01)*

The Dutch co-financing of €300 million was repeatedly referenced as a significant move to stimulate hydrogen imports (Interviews RI02, GOV02, I01). The mechanism provides clear incentives for both suppliers and off-takers, helping to catalyze early-stage projects that might otherwise stall due to financial uncertainty.

The instrument is also seen to contribute to price discovery and market benchmarking. As noted in the interviews, it gives insight into price developments and buyer willingness to pay (Interview GOV02, IN02).

Despite its broad support, several stakeholders stressed that H2Global is not sufficient on its own. First, infrastructure alignment remains a challenge. As highlighted in interviews with EBN and AirLiquide, even with long-term contracts in place, importers face challenges in securing storage and distribution infrastructure.

> The instrument helps, but you also need to make sure that the hydrogen actually arrives where it is needed. Without matching infrastructure, it remains incomplete. (Interview INL03)

Second, risk allocation and design complexity were raised as concerns. Interviews with EBN indicated that some early tenders required suppliers to deliver directly to the off-takers without government facilitation of logistics, thereby placing infrastructure risks on producers. This was seen as a potential deterrent for project participation, particularly for smaller or early-stage developers.

In general, H2Global is considered a valuable part of the policy toolbox, particularly as a model for the international pillar of the European Hydrogen Bank. Multiple interviewees stated that it was currently the most well-developed and promising instrument for organizing hydrogen trade at scale (Interview SK UK (1); Interview NLHydrogen). One stakeholder concluded:

> *H2Global is probably the best one I have seen so far because it really links producers and off-takers in a smart way. (Interview IUK01)*

However, stakeholders stressed that its impact will depend on further scaling. Interviewees from both the public and the private sectors acknowledged that while H2Global fills key gaps, it cannot solve the full set of challenges facing hydrogen imports on its own.

6.2.3. Cost Uncertainty and the Need for Derisking in Green Hydrogen Markets

Uncertainty about future cost trajectories for green hydrogen is a challenge to investment in hydrogen infrastructure and import chains. The uncertainty around cost is not an isolated issue; it is compounded by a larger set of unknowns, including unclear future demand and supply timelines, evolving regulatory requirements, and uncertainty about sufficient financial support, as well as geopolitical and national political tensions. This combination of uncertainties creates a situation in which market actors hesitate to take FIDs because the cumulative risk is too high [40]. In such an immature market, producers are likely to include risk premiums in their price calculations, which drives up costs further and makes projects even less attractive.

This creates a negative feedback loop: uncertainty leads to inaction, which delays the development of infrastructure and market demand, thereby reinforcing the uncertainty. This is particularly problematic for hydrogen import projects, which require long-term coordination across international supply chains and large investments.

Leguijt et al. [40] highlights the role of government in breaking the investment deadlock by actively derisking green hydrogen projects. The importance of government involvement in addressing market risks and overcoming the identified challenges was also consistently confirmed by interviewees in semi-structured interviews.

Derisking cannot be achieved through a single policy instrument, but requires a coherent mix of measures, including clear long-term policy frameworks and financial tools such as price guarantees or long-term off-take contracts, similar to those used in the offshore wind sector. The absence of a dedicated instrument to address cost uncertainty underscores the need for such a combined approach. Without it, uncertainty around future cost trajectories will continue to hinder demand articulation, even in the presence of climate mandates or fuel quotas.

6.2.4. Policy Responses to Infrastructure Challenges for Hydrogen Imports

The development of hydrogen import infrastructure faces structural challenges, including long lead times, high capital requirements, and fragmented and delayed planning, as outlined in the previous chapter. Stakeholder interviews and policy analyses confirm that infrastructure uncertainty, such as delays in the Dutch Hydrogen Backbone or cross-border pipelines, can hinder investment decisions and project development. Several policy instruments have been introduced to address these challenges, each with specific contributions, limitations, and varying levels of visibility between stakeholders.

A key challenge is the permitting process, which stakeholders have widely identified as a cause of delays. Despite efforts by the European Commission to accelerate permitting through legislative initiatives presented in the RED III, TEN-E regulation, and the Hydrogen and Gas Decarbonization Package, the complexity and fragmentation of these frameworks remain a concern. Permitting durations differ across instruments, and implementation depends heavily on national authorities. For example, the Netherlands missed the deadline for transposing the RED III permitting rules, resulting in a formal notification from the Commission [22]. This ongoing uncertainty particularly affects the infrastructure required for hydrogen import and demand value chains.

IPCEI: Important Projects of Common European Interest

The IPCEI instrument supports large-scale cross-border projects of strategic importance to the EU. In hydrogen, four IPCEIs have been launched, including Hy2Infra, which focuses on infrastructure such as pipelines, storage, and port facilities [3]. Approved in 2024, Hy2Infra mobilizes € 6.9 billion in public funding and an additional €5.4 billion in private investment. Although frequently referenced in policy documents, IPCEI was not mentioned in interviews, possibly due to the limited direct involvement of the actors interviewed. However, it plays a vital role in supporting the critical infrastructure for hydrogen imports. Both Norway and the UK can participate in IPCEI projects if national co-financing is secured, although no UK projects have been included to date.

Hydrogen and Gas Decarbonization Package

Adopted in 2024, this package introduces a harmonized framework for EU hydrogen infrastructure. It mandates network development plans, establishes access and cost-sharing rules, and allows for intertemporal cost allocation to reduce initial user burdens [23].

Although these measures aim to provide long-term regulatory certainty, interviewees expressed concern about a mismatch between regulation and market reality. One stakeholder described the framework as ”written from a fiction,” highlighting the assumption of an already fully functioning hydrogen market (Interview Airliquide). Furthermore, the practical implementation of these rules remains uncertain. For instance, ACM’s guidance (Q&A) clarified certain regulatory interpretations, but also revealed new uncertainties regarding terminal operations and ammonia handling.

Stakeholders also highlighted the regulatory ambiguity surrounding infrastructure built with private capital. Rules on third-party access, designed for publicly funded networks, are applied to private investments, raising concerns about investor confidence and commercial viability (Interview I03). Some investors hesitate to commit capital to infrastructure projects that may later be subject to price regulation and access requirements.

TEN-E Regulation: Cross-Border Infrastructure Support

The revised TEN-E Regulation supports Projects of Common and Mutual Interest, including hydrogen infrastructure, through funding and streamlined permitting capped at 42 months [28, 19]. Although not mentioned in interviews, TEN-E is cited in policy documents as essential to enable terminals, pipelines, and conversion facilities linked to hydrogen import corridors. Although the UK and Norway fall outside its scope, TEN-E indirectly influences the development of EU-based infrastructure that may serve future imports from these countries.

MIEK: Dutch National Coordination Mechanism

The MIEK (Meerjarenprogramma Infrastructuur Energie en Klimaat) program aims to streamline and govern the Dutch energy infrastructure, including regional hydrogen networks [46]. Although not widely discussed in interviews, this may reflect the limited current role of regional hydrogen networks in international green ammonia import value chains, which is expected to be delivered directly to industrial users by ship or inland waterways.

However, MIEK remains relevant for future hydrogen infrastructure development, particularly as regional networks evolve to connect international supply chains with domestic demand. However, a semi-governmental actor remarked that MIEK has potential but ”does not yet work optimally” (Interview GOV01).

6.2.5. Policy Responses to Enhance Required Policy Coordination

The successful development of international hydrogen import chains depends not only on technical readiness and market maturity but also on the effectiveness of policy coordination, both between EU member states and with non-EU partner countries. The previous chapters identified several coordination-related challenges, ranging from fragmented regulatory approaches to misaligned certification frameworks.

Lack of a Unified European Approach: Progress and Persistent Fragmentation

A key issue raised by stakeholders is the lack of a clearly unified European approach to the development of hydrogen imports. Although the European Commission has introduced the Team Europe Initiatives (TEIs) to promote more coordinated external action, the application of this framework to hydrogen remains relatively nascent. TEIs focus on aligning priorities and pooling resources to implement projects in third countries. In practice, this approach transforms EU strategic goals into coordinated actions [26]. In 2023, only several TEIs had been launched with a focus on renewable hydrogen, and participation has so far been limited to a subset of Member States, including Germany, the Netherlands, Belgium, France, and Spain [28].

Feedback from an infrastructure actor indicates cautious optimism about the TEI model. The interviewer noted that the TEI could provide a promising foundation for aligning national strategies and combining resources in third countries. However, it was observed that implementation remains fragmented and often lacks operational depth. For instance, Gasunie emphasized the need for deeper cooperation between Member States and EU institutions to effectively position the Northwest European market in third countries. They pointed out that the principle of 'Team Europe' has not yet been fully institutionalized (Interview with I01). Similarly, VOTOB mentioned that the lack of a shared European narrative can result in parallel, and sometimes competing, bilateral engagements, which reduces overall strategic coherence (Interview I03).

Regulatory coordination, particularly on certification, remains a key challenge in EU-third-country relations. This is especially evident in the case of the United Kingdom, where there is currently no formal mechanism for mutual recognition of renewable hydrogen certification (e.g., RFNBO criteria). Although international standardization efforts are underway through forums such as IPHE and IHTF [38, 37], these initiatives are still under development, and their integration with existing EU regulatory frameworks remains complex [63]. Without such alignment, market actors face uncertainties regarding eligibility, compliance, and project viability.

Bilateral MoUs: Valuable Diplomatic Tools with Conditional Impact

MoUs have become a widely used tool for facilitating international cooperation on hydrogen. During the 2025 H2A Symposium, the hydrogen sector was informally referred to as 'The MoU Sector', reflecting the high number of non-binding agreements being signed across jurisdictions. MoUs formalize shared intent and facilitate dialogue between governments, ports, and industry stakeholders. The Netherlands has been highly active in establishing bilateral MoUs with future hydrogen-exporting countries. In total, the Dutch government has signed 19 bilateral MoUs with countries such as Canada, Chile, Oman, Namibia, the United Arab Emirates, and Spain [53, 44]. The most recent MoU was signed between the Netherlands and Norway on 14 November 2024. Currently, no MoU has been signed between the Netherlands and the United Kingdom.

Interviewees from both the public and private sectors noted that MoUs play a useful role in relationship building and early-stage cooperation (Interviews GOV2, GOV3). MoUs contribute to the broader energy diplomacy strategy of the Netherlands, including its ambition to serve as a European hydrogen hub, with ports such as Rotterdam and Amsterdam using them to align logistic planning with potential exporters [31, 40].

However, stakeholders at the Hydrogen Import Breakthrough Symposium noted that the practical impact of MoUs will depend on further measures, such as regulatory harmonization. Without concrete follow-up instruments, MoUs may remain limited to symbolic intent. As such, they are best understood as facilitating frameworks that require additional policy tools to unlock investment decisions or accelerate infrastructure delivery.

Multilateral Platforms and Networks

The Netherlands actively participates in a wide range of multilateral platforms and coordination networks that support hydrogen diplomacy, international standard-setting, and knowledge exchange. Key initiatives include the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), the Clean Energy Ministerial Hydrogen Initiative (CEM H2I), the International Hydrogen Trade Forum (IHTF), the Clean Hydrogen Partnership, and the European Clean Hydrogen Alliance.

Through its participation in these forums, the Netherlands contributes to the development of international hydrogen standards and supports the ongoing policy dialogue [37, 31].

Despite these efforts, almost none of these initiatives were cited by stakeholders as major enablers for hydrogen import developments. Only policy documents referred to these multilateral platforms. This likely reflects the longer-term and more strategic focus of such platforms, many of which are designed to facilitate dialogue rather than deliver concrete outcomes.

Unlike many international initiatives, SHIP-NL was mentioned by stakeholders as a helpful platform that supports the development of hydrogen imports in the Netherlands. It brings together representatives from government, industry, and research in monthly meetings to discuss the progress of hydrogen import chains and identify what the system needs. Although SHIP-NL does not have executive power and mainly plays an advisory role, some stakeholders see it as a helpful contribution to national coordination efforts (Interviews IA02, RI01) [51, 50, 44].

Although many coordination instruments are valuable for long-term planning and alignment, their current contribution to accelerating short-term investment decisions remains limited. A more unified European strategy, complemented by more precise bilateral mechanisms and mutual recognition agreements, could enhance trust and reduce regulatory risk for investors and developers. However, the progress made to date, especially at the national level in the Netherlands, demonstrates a firm foundation upon which more effective coordination and cooperation can be built.

6.2.6. Strategic Direction in Advancing Hydrogen Imports

Stakeholders have identified the absence of a clearly defined and actionable strategy for hydrogen imports as a gap within the broader Dutch hydrogen policy landscape. Although the Netherlands has committed to national hydrogen targets, including specific volumes for domestic production and infrastructure development, the pathway toward achieving these targets, particularly concerning imports, remains insufficiently elaborated. This was notably highlighted in the stakeholder manifesto presented at the 2024 Hydrogen Summit, which explicitly called for more targeted import policies. Although the government has issued several policy documents on hydrogen, including a chapter on imports in the 2022 National Hydrogen Strategy and a recent parliamentary letter, interviewees generally perceived these efforts as limited in terms of operational clarity and strategic guidance (Hydrogen Summit 2025; Interviews INL01, IA02).

In the absence of a more detailed vision and aligned framework, uncertainty can arise about future infrastructure plans, investment conditions, and the expected role of imports within the broader energy system. This may slow progress, not due to a lack of ambition, but because the conditions for coordinated action remain underdeveloped.

The stakeholder groups pointed to several specific areas where the current vision for hydrogen imports could be strengthened. These include the need for (Interview IA02) [54]

- Dedicated financial support for key infrastructure elements, such as ammonia cracking facilities;
- A plan for ensuring sufficient spatial and grid capacity to accommodate import chains;
- A framework for the safe and responsible handling and certification of hydrogen carriers;
- Clarity on how the import infrastructure will be phased in and aligned with domestic demand projections.

Although these gaps remain, there are also signs of increased attention to the issue. The National Hydrogen Program has announced a public session to discuss the status of the Dutch hydrogen import policy (the session will take place on 9 July 2025). Although it is too early to assess the impact of such initiatives, this response signals a growing recognition of the importance of a more structured approach to imports.

International comparisons highlight the varying levels of strategic direction adopted by different countries. In Norway, government policy documents concerning the export of green hydrogen remain very limited. In stark contrast, Scotland unveiled a comprehensive hydrogen export strategy in November 2024 [29]. Additionally, the UK government commissioned a study in December 2024 to examine the potential for exporting hydrogen from the UK to continental Europe, complementing the ”Hydrogen Strategy Update to the Market” that was also published in December 2024 [16, 73]. These documents reflect a clear strategic intention to become a leading exporter of hydrogen. While each country operates within its own unique context, an updated hydrogen import strategy for the Netherlands could help establish a more cohesive vision among domestic stakeholders. This, in turn, could improve coordination and support the continued development of import chains.

6.2.7. Lack of Ecosystem-wide financing

Although public funding plays a vital role in the early development of hydrogen markets, limited subsidy budgets remain a challenge, particularly given the substantial cost gap between green and conventional hydrogen. As long as this gap persists and production costs remain high, the feasibility of fully bridging it through direct subsidies is increasingly questioned. Multiple stakeholders pointed out that a long-term reliance on subsidies is unlikely to be fiscally sustainable (Interviews RI01, GOV02).

At the same time, several sources indicate a narrowing price gap between green and conventional hydrogen at the end of the value chain, referred to as ”green end-products.” When the cost of green hydrogen is embedded in end products, such as green ammonia-based fertilizers or sustainable fuels, the relative price difference can potentially be more manageable for consumers than for upstream producers [57] (Interviews RI01, GOV02, INL02).

This insight underpins growing interest in demand-side policy instruments aimed at creating market value for green end products. By stimulating demand further downstream, it is expected that market pull can be increased, which in turn would incentivize investments across the supply chain. Interviewees noted that obligations or incentives at the end of the chain, such as through product standards and green procurement criteria, could reduce reliance on subsidies and help make the chain more self-sustaining (Interviews RI01, GOV02).

However, stakeholders warn that implementing such policies is a complex and time-consuming process, indicating that this will be a long-term endeavor. Setting legally binding standards for green content in a wide range of end products requires careful design and coordination, particularly in sectors with numerous small producers or those involved in internationally traded goods (Interviews RI01, GOV02).

6.2.8. Policy Gap in Ammonia Cracking Financial Support

The stakeholder highlighted the lack of financial support for ammonia cracking plants. These installations are crucial for converting imported green ammonia into hydrogen, particularly for users who cannot utilize ammonia directly. Without such infrastructure, green ammonia can only be delivered to a limited group of end-users, restricting its market potential [54].

Moreover, local transport and storage of ammonia often face public opposition due to safety concerns, which can delay project development. By placing cracking units at port locations, ammonia can be converted into hydrogen close to the import point, and, if pipeline infrastructure is available, transported further inland through pipelines, which is considered the safest mode of transport for ammonia (Interviews GOV02, GOV03, I02).

6.2.9. Public Acceptance and the Role of Safety Frameworks

Public concerns regarding the safety and handling of ammonia present a notable challenge for the development of hydrogen import chains. While ammonia is widely used in existing industrial applications, its association with toxicity and potential risks in the event of an accident leads to public opposition, particularly when storage or transport facilities are planned near residential areas. These concerns can lead to delays in project development on both the import and export sides of the supply chain.

In Norway, public resistance to green ammonia exports has been observed, in part due to broader debates on the export of renewable energy. Additionally, on the export side, the public is skeptical about the safety concerns associated with green ammonia.

In several cases, infrastructure development has been delayed or adjusted in response to local concerns (Interview IN01). On the Dutch side, interviews highlighted that ammonia is often perceived as less safe than alternative hydrogen carriers such as liquid hydrogen or LOHCs (Interview IA02). Although ammonia has been handled safely in the Dutch industry for decades, this familiarity does not always translate to public acceptance (Interviews IA02, I03).

Stakeholders have expressed concerns regarding the absence of dedicated safety frameworks for large-scale ammonia transport. While there are general safety regulations for hazardous substances, specific guidance for using ammonia within large-scale hydrogen import chains is currently lacking. The absence of tailored safety regulation for ammonia in the context of hydrogen imports presents a regulatory gap that may hinder project development and public acceptance (Interview IA02). Additionally, the UK government recognizes the need to establish further safety requirements for ammonia bunkering in ports [73].

Several initiatives have been undertaken to address these concerns. The Institute for Sustainable Process Technology is currently leading research on safety frameworks for green ammonia and public acceptance related to its use in the Dutch context (Interview GOV02).

Additionally, the SHIP-NL plays a coordinating role by facilitating knowledge exchange among stakeholders. The platform aims to identify areas where further research or innovation is needed, including public engagement and safety-related issues, and supports early hydrogen projects by fostering transparency and shared understanding [50].

7 Discussion

7.1. System Perspective on the Results

This study explores the challenges of developing green ammonia import value chains to the Netherlands from a systemic perspective. While the systemic complexity and interdependence of international energy value chains are widely acknowledged in existing literature, this study has particularly highlighted the depth and practical implications of this complexity in the context of green ammonia import chains. Rather than isolated issues, the study reveals a web of interconnected challenges spanning technical, regulatory, infrastructural, public, and demand-related domains, on both the export and import sides. These interdependencies mean that disruptions or delays in one segment of the import value chain can trigger cascading effects throughout the entire value chain.

Interviews conducted with various stakeholders highlighted the complex interdependencies inherent within the value chain. I had expected to encounter a wide range of actor-specific concerns, but instead I found a high degree of shared understanding across stakeholders. Most challenges were recognized as interconnected and not solvable in isolation. This level of mutual awareness was greater than I had anticipated.

One respondent from NLHydrogen articulated this perspective particularly well:

> *The puzzle isn't complete until every piece is in place. Ideally, you'd hope that having 80% of the elements in order would be enough to move forward with a project or reach an investment decision. But in practice, we've learned that nearly all of these elements are interdependent and must be addressed in parallel (Interview IA02).*

Another key element that particularly surprised me was the combination of continuously shifting policy frameworks and, at the same time, overly ambitious targets. These targets for hydrogen production and import were often set without clear implementation pathways or the necessary instruments to ensure delivery. In multiple interviews, stakeholders expressed that ambitions seemed politically driven rather than grounded in feasibility. Personally, I found it problematic that new ambitions were being announced while previous targets had not yet been met or even operationalized. This dynamic creates confusion and undermines credibility.

The interconnected challenges create significant uncertainty, which leads to development delays or withdrawal from project development. For example, Statkraft announced during this study that it would not pursue new hydrogen development initiatives and would instead focus on advancing existing projects to attract investors. Graczyk, Brusiło, and Graczyk [30] support these empirical insights by emphasizing the multi-dimensional nature of the challenges associated with the development of international hydrogen trade. Instead of being isolated issues, the challenges in green ammonia systems span multiple areas, political, technical, market, and social, each of which is closely interconnected. For instance, stable policy measures such as long-term subsidies, carbon pricing, or sector obligations can help mitigate techno-economic risks and encourage private sector participation. At the same time, clear and consistent regulatory standards can minimize implementation hurdles and build public trust, which in turn can shape social acceptance. This social acceptance can influence demand trends and the feasibility of investments.

Related to this, I was suprised by how the dominant narrative around “scaling up” often does not align with the practical realities of market development. While scaling is frequently portrayed as the primary objective, stakeholders also emphasized the need for smaller-scale, manageable projects that build trust, reduce risk, and create learning effects. In fact, a counter-movement towards “down-scaling” or more controlled development was visible in several conversations, something I had not anticipated but found both interesting and logical given the current stage of market maturity (Interview INL01, INL02). This observation also aligns with literature describing early-stage hydrogen markets as progressing through localized “hydrogen islands,” in which production, transport, and consumption occur in close proximity as outlined in Chapter 3 [70, 77].

Building on this systemic view, a comparative analysis between the United Kingdom and Norway revealed national variations in the characterization of these challenges. In the UK case study, the challenges are more operational, which can be partly attributed to the case study project being in a more advanced phase compared to the Norwegian project. Conversely, in Norway, the challenges are primarily associated with public perceptions of green energy exports and safety concerns related to ammonia. These concerns primarily highlight underlying societal and political considerations that must be addressed to facilitate further progress. While part of this divergence can be attributed to differences in project maturity, it also reflects varying degrees of political attention and institutional commitment. Recent developments in the UK and Scotland, such as the publication of hydrogen export strategies and updated regulatory frameworks [73, 29, 16], contrast with Norway’s hydrogen strategy, which was last revised in 2021 [56]. The Norwegian approach continues to emphasize blue hydrogen and provides limited guidance on green hydrogen carrier exports. This discrepancy suggests differing levels of urgency and strategic prioritization regarding hydrogen export readiness between the two countries.

Finally, I was surprised by the limited policy attention toward the UK as a potential export partner for the Netherlands. Given the UK’s clear export ambitions and active strategy development, it is notable that no bilateral MoUs with the Netherlands exist, despite the Netherlands being generous in signing such agreements with other countries. During the symposium on achieving breakthroughs in the hydrogen import sector, panel speakers even described the hydrogen sector as the “MoU sector,” highlighting the frequency with which these agreements are announced. From my perspective, mutual ambition and coordination are essential for building international hydrogen supply chains, and the absence of formal engagement between the Netherlands and the UK stands out as a missed opportunity. The UK’s position outside the EU and EEA introduces additional complexity in harmonizing certification systems with those used in the EU. These differences underscore the need for tailored strategies that account for the distinct political and institutional contexts in each exporting country when seeking to accelerate import developments. Developing a bilateral agreement could enhance policy coordination and improve the feasibility of cross-border trade in green ammonia.

7.1.1. Linking Outcomes to the Theoretical Framework

Not all challenges identified in this study fit neatly within the existing typologies of transition failures Weber and Rohracher [75] and Bolhuis [7]. One notable gap concerns the issue of public acceptance, which emerged as a challenge not only in the Norwegian export side but also more broadly in relation to green hydrogen and ammonia.

While public resistance could arguably be linked to the category of “opposition from transition losers”, this classification is only partially adequate. That category assumes resistance primarily stems from actors who anticipate economic disadvantages from the transition, such as job losses or loss of market power. In contrast, the resistance observed in this study is rooted in broader societal concerns, including safety and affordability. It reflects not self-interest, but collective hesitation about system-scale changes, particularly where local communities perceive disproportionate risks or uncertainties.

These findings point to a potential blind spot in current transition failure theories: the absence of an explicit category for societal legitimacy as a structural challenge to systemic change. I think that the current transition failure theories understate the role of public trust and acceptance in shaping the feasibility of transition pathways. Particularly in the case of green hydrogen and ammonia, where infrastructure, safety, and spatial planning are highly visible and politically sensitive, public acceptance emerges as a key precondition for progress.

In addition to transition theory, the Product Life Cycle framework by Levitt [42] provided valuable insight into the market conditions in which hydrogen import chains are currently operating. The hydrogen import market is still in an early development stage, characterized by high uncertainty, limited demand, and investment hesitancy. In this phase, strong government involvement is essential to create the necessary preconditions for market emergence, including infrastructure, regulatory clarity, and risk mitigation. However, the constantly changing policy environment, such as evolving RFNBO rules, posed challenges for both stakeholders and this research. During the final stages of writing, RFNBO rules were adjusted again, making them less strict. While this development was relevant, it could not be fully reflected in the report. This illustrates the difficulty of doing research in a highly dynamic policy landscape. Despite this, I believe documenting the challenges identified throughout the process remains valuable, as it helps inform better decision-making in the future and avoids repeating past mistakes.

This highlights a key challenge for policymakers: the need to align policy design with the specific needs of the market phase. On the one hand, early-stage markets benefit from flexible, adaptive, and pragmatic policy approaches that accommodate innovation and market learning. On the other hand, excessive policy volatility and frequent rule changes create uncertainty, which undermines investor confidence and slows development.

7.2. Policy Implications

Considering the findings presented in Chapter 5 and Chapter 6, various strategic actions, both short-term and long-term, should be taken to support the development of hydrogen import value chains in the Netherlands.

Short-Term Actions

In the short term, policymakers should focus on measures that can directly address coordination failures, mitigate investment uncertainty, and facilitate the development of critical infrastructure. A key action is to clarify the demand articulation policy. This can be achieved by officially translating RED III RFNBO obligations into clear national implementation targets, accompanied by enforceable, tailored agreements with industry that specify the timeline and scope of hydrogen use in industrial applications. Accelerating these agreements would give market actors greater visibility into the future policy landscape and help stimulate early investments.

Additionally, expanding the H2Global, in connection with the European Hydrogen Bank, would enable third countries, including the UK, to access financial support for export-oriented projects. This is particularly relevant given that the UK is currently excluded from the domestic funding pillar of the EHB. Facilitating UK participation in the international pillar could help scale up supply while supporting alignment with EU hydrogen import objectives.

In the short term, attention should be focused on infrastructure development. By removing permitting bottlenecks and streamlining licensing procedures, delays can be reduced, and risks associated with early-stage projects can be mitigated. Additionally, the Netherlands should develop an updated and clearly articulated national hydrogen import strategy. This document would align with recent strategies published in the UK and Scotland, providing essential clarity on how imports will integrate with domestic supply, safety regulations, and infrastructure. Stakeholders have highlighted the lack of such a strategy as a challenge to coordination and long-term planning.

From a regulatory standpoint, making short-term adjustments to the compliance criteria for RFNBO could ease project realization for early adopters and enhance project viability. The existing framework often imposes strict requirements that can be challenging to meet during the early stages of market development.

While the actions mentioned above would generally accelerate developments in hydrogen carrier imports, a specific issue within the ammonia import value chain is the lack of financial support for ammonia cracking infrastructure. Without sufficient cracking capacity at or near port locations, imported ammonia can only be utilized by actors equipped to handle the molecule in its original form, which substantially limits the potential off-take base. In addition, clear and specific safety regulations are essential to gain public confidence and prevent further delays to the project, particularly given concerns about the transport and storage of ammonia in residential areas. Existing research must be translated into concrete regulatory frameworks tailored to the role of ammonia in hydrogen import chains.

Country-specific measures are also required. For the United Kingdom, it is crucial to establish bilateral cooperation with the Netherlands in the area of certification systems (e.g., by ensuring mutual recognition between RFNBO and LCHS) to minimize regulatory compliance friction. In addition, the British authorities must provide clarity on the competence to export green ammonia, produced based on subsidized hydrogen, to the EU, as uncertainty on this issue is leading to delays in development. In Norway, where export ambitions are less articulated and public acceptance poses a more significant challenge, a renewed national strategy could signal a more substantial commitment and help mobilize institutional support for export-oriented hydrogen infrastructure.

Long-Term Considerations

Looking further ahead, policy efforts should gradually transition from direct subsidies toward structural market creation tools that embed decarbonization goals in end-product markets. One promising approach involves introducing mandates for green end-products that create stable downstream demand for hydrogen-derived inputs. By creating a ”pull” at the end of the chain, such instruments could reduce dependence on subsidies and distribute transition costs more evenly across the value chain.

This long-term shift would also support the development of self-sustaining markets, as it allows cost differentials between green and conventional products to be absorbed where they are smallest: at the end-consumer level. However, such mandates would require careful design and sector-specific tailoring to avoid unintended competitive disadvantages, particularly in internationally exposed sectors.

In conclusion, short-term interventions should focus on de-risking and enabling early investment, while long-term policies should aim to institutionalize market demand and ensure international compatibility. This requires striking a balance between targeted support and structural market reforms.

7.3. Scientific Contribution

This research contributes to the existing literature on energy transition policy by providing a comprehensive, system-level perspective on the development of hydrogen import chains. By combining a documentary policy analysis with stakeholder interviews, the study identifies the practical implications of policy responses to challenges faced throughout the entire supply chain.

A review of the existing literature reveals that chain-specific challenges between the United Kingdom and the Netherlands, as well as between Norway and the Netherlands, have not been explicitly addressed. This research contributes new insights into case-specific challenges and highlights differences between these two bilateral contexts. While prior studies have analyzed the hydrogen landscape in the Netherlands, they have predominantly focused on domestic production challenges [19, 33]. For instance, Hasankhani et al. [33] systematically categorizes challenges into five key areas: technical, infrastructural (focusing on supply chain complexities), socioeconomic, environmental, and institutional. However, their analysis is limited to national-scale hydrogen production.

This study focuses specifically on international hydrogen supply chains to the Netherlands, with the United Kingdom and Norway as key case studies. This perspective generated context-specific and practical challenges that have not been addressed in the literature, such as the UK’s export-subsidy dilemma, where the absence of a clear regulatory framework for green ammonia exports creates uncertainty and hinders market development.

Methodologically, the study shows the added value of qualitative mapping approaches in understanding complex transition processes. Instead of assessing individual policies in isolation, it captures the highly interdependent systemic character of challenges across the supply chain. This approach generated empirical insights that can inform more targeted, hypothesis-driven, or quantitative follow-up research.

A key theoretical contribution lies in the identification of public acceptance as a transition challenge that is currently underrepresented in dominant typologies of transition failures (e.g., [75, 7]). This study shows that public resistance to energy transition initiatives is not always rooted in narrow economic self-interest, as is often implied by the notion of "transition losers", but can also emerge from broader societal concerns. These include perceptions of safety risks, fears over declining affordability, or unease about changes to the local environment. While the energy transition ultimately aims to create a more secure and sustainable energy system that benefits society as a whole, its intermediate steps can generate public opposition when burdens are perceived as unevenly distributed or poorly justified. In such cases, insufficient societal support can become a structural challenge to progress in transition. The case of green ammonia illustrates this clearly: public acceptance emerges as a significant challenge, not only in importing countries like the Netherlands, but also in exporting countries such as Norway.

7.4. Limitations of Research

This study combined policy document analysis with stakeholder interviews. While this methodological integration enhances the robustness of the findings, several limitations should be acknowledged.

First, the composition of the code groups revealed an imbalance between interview and document-based data, which may limit the depth of integrated insights. For example, no interviews were conducted with governmental representatives from the UK and Norway. As a result, the analysis relied on policy documents to represent the current governmental perspective. However, it is possible that more recent or nuanced developments would have emerged through direct conversations with government actors.

Second, the interview sample was weighted towards industry stakeholders, particularly those associated with Statkraft. This focus influenced the nature of the challenges identified, which were closely tied to Statkraft's project context. Engaging a broader set of industry actors in both Norway and the UK could have yielded additional insights, validated existing findings, or revealed divergent perspectives. Similarly, representatives from research institutions were underrepresented in the formal data. Although informal meetings were held with several research institutes, these stakeholders chose not to be officially included in the study. While their input was helpful for my contextual understanding, it was not incorporated into the formal analysis. A greater inclusion of independent research actors could have enriched the systemic perspective of this study.

Third, the selected case studies differ in terms of project maturity. Generally, the UK-based projects are at a more advanced stage compared to those in Norway. This difference likely influenced the types of challenges identified. In the UK case, more operational challenges were noted, while the Norwegian case focused on structural challenges, such as public acceptance. Future research could improve upon this by selecting case studies at similar development stages and ensuring a more balanced representation of stakeholder groups.

Finally, while this study focuses on the Netherlands as an import destination, the generalization of its findings to other EU member states is limited. Although many challenges are common across the sector and across international borders, national policy frameworks, institutional arrangements, and public debate can have a significant impact on how these challenges are understood and prioritized.

7.5. Future Research

The hydrogen system is a dynamic and continuously evolving landscape, and its regulatory framework is developing in tandem with it. Given this rapid evolution, maintaining an up-to-date understanding of policy alignment remains essential. In addition, each market phase, as described in Chapter 3, introduces new challenges and may require distinct policy responses. Longitudinal research that tracks both the evolution of these challenges and the effectiveness of policy instruments over time would therefore be highly valuable.

Moreover, this research has highlighted the diversity of challenges across different chain segments and countries, from certification bottlenecks and infrastructure delays to diverging government visions on hydrogen carriers. While the system perspective has proven essential for mapping these interdependencies, further research could benefit from a deeper focus on specific challenges. For instance, future studies could investigate the economic viability of green end-product mandates or assess public acceptance dynamics around ammonia imports through sociological or behavioral frameworks.

8
Conclusion

This study has explored the extent to which the current Dutch policy framework addresses the key challenges in developing hydrogen import value chains, with a focus on green ammonia. Through an integrated approach that encompasses the analysis of policy documents and stakeholder interviews, this research has yielded a comprehensive understanding of the systemic challenges, policy responses, and the perceived efficiency of implemented interventions by market actors within a practical context. The findings are summarized below by addressing each of the sub-research questions before turning to the central research question.

8.1. Sub-Questions

The first sub-question posed:

What challenges hinder the development of hydrogen import chains in the Netherlands?

The results show that a series of interrelated challenges hinder the development of hydrogen import chains. These challenges are not independent; problems in one part of the chain often affect other parts. This interdependency means that delays or uncertainties in one segment can slow down the overall chain. The combined impact of these challenges has already contributed to project delays and the withdrawal of actors from new hydrogen developments. For instance, during this research, Statkraft announced that it would not pursue additional hydrogen projects at this stage.

Identified challenges include limited financial viability due to the price gap between green and conventional hydrogen, unclear or insufficient demand, complex RFNBO certification procedures, and lengthy permitting procedures that impede infrastructure developments. In addition, specific to ammonia, challenges include the lack of financial support for conversion facilities and limited public acceptance.

Some challenges are also linked to the national context of exporting countries. In the UK, being outside the EU and EEA, the lack of alignment with EU certification schemes and uncertainty around export subsidies are key challenges. In Norway, which is part of the EEA, the regulatory context is more aligned, but public concerns about green energy exports and ammonia safety are more prominent.

The second sub-question stated:

What are the current Dutch and EU policy instruments governing hydrogen imports?

The analysis identified a range of policy instruments relevant to the development of hydrogen import chains. These include regulatory frameworks, such as the RFNBO criteria under RED III, as well as financial support mechanisms, including H2Global, the Innovation Fund, and the IPCEIs.

H2Global and the EHB were frequently mentioned by interviewees as key mechanisms for facilitating import development. RFNBO sector mandates were also discussed as essential instruments, particularly in terms of creating predictable demand conditions needed to support investment in supply chains.

The Netherlands actively engaged in international hydrogen cooperation through various multilateral initiatives and has signed multiple MoUs with prospective exporting countries. While MoUs were mentioned by some (semi) governmental stakeholders, multilateral partnerships, although frequently referenced in policy documents, were not discussed during interviews. This suggests that, although such partnerships may contribute to international coordination in the longer term, their perceived relevance to short-term import project development remains limited.

The third sub-question asked:

> *How do stakeholders perceive the effectiveness of current policy interventions in addressing hydrogen import development challenges?*

Stakeholder interviews provided a mixed assessment of the existing policy instruments. Several interviewees considered instruments like H2Global and the proposed demand targets for RFNBOs to be relevant and conceptually suitable for promoting hydrogen imports. However, they expressed concerns about the limited financial scale of these instruments and delays in implementation.

Other instruments were considered less suitable for the current stage of market development. Stakeholders emphasized the complexity of complying with the rules for RFNBO, noting in particular that the strict criteria, including temporal and geographical correlation, pose challenges for early-stage projects.

In addition, gaps were identified in instruments addressing cross-border coordination, safety regulation, and inland transport logistics. For example, the absence of a clear regulatory framework for ammonia transport within the Netherlands was mentioned as a source of uncertainty, which may hinder planning and permitting of import-related infrastructure. As such, the perceived effectiveness of current interventions varied depending on their applicability to specific chain segments and the maturity level of projects under development.

The fourth sub-question posed:

> *What additional interventions are needed to effectively support the development of hydrogen imports in the Dutch context?*

The findings suggest that several targeted interventions are needed to address current gaps in the policy landscape. Stakeholders emphasized the importance of providing greater clarity on demand articulation policy, particularly through the national implementation of RFNBO obligations. In addition, instruments such as H2Global and the EHB were considered relevant but limited in scope. Finalizing the development of the international pillar of the EHB to allow participation from third countries, including the United Kingdom, could improve the economic viability of supply chains.

An updated national hydrogen import strategy could help provide direction and improve coordination between public and private actors. Specific issues related to ammonia imports were also highlighted. The lack of financial support for cracking infrastructure restricts the usability of imported ammonia, and clear safety regulatory frameworks are necessary to reduce safety risks for the public.

Finally, developments in key exporting countries underline the need for bilateral cooperation. In the UK, unresolved questions about export eligibility for subsidized hydrogen and the lack of alignment between certification systems create uncertainty. In Norway, public opposition and limited political prioritization of hydrogen exports suggest the need for a more evident strategic commitment. Addressing these country-specific challenges through dialogue and regulatory coordination could improve the reliability and scalability of future import chains.

8.2. Main Research Question

The central research question asked:

> *To what extent does Dutch policy effectively respond to the key challenges in developing hydrogen import value chains?*

The research shows that although a wide range of policy instruments is currently in place, their alignment with the specific needs of early-stage hydrogen and ammonia import chains remains mixed. Some instruments show a clear connection to the challenges identified by stakeholders, whereas others appear less adapted to the practical realities of project development.

Several instruments are perceived as directly enabling by stakeholders. H2Global, for example, addresses price volatility and contractual mismatches by offering a double auction mechanism that supports long-term off-take agreements. It is frequently mentioned in both policy and interview sources as a relevant solution to the cost gap between green and conventional hydrogen. Similarly, the RED III industry and transport obligations are designed to stimulate demand; however, their effectiveness is undermined by uncertainties surrounding national implementation, particularly in the Dutch context. This limits their capacity to provide reliable investment signals.

At the same time, the analysis identifies important policy misalignments. Ammonia cracking facilities remain unsupported. In addition, there are currently no specific safety frameworks tailored to the role of ammonia in hydrogen import chains. Concerns about public safety and acceptance have already delayed projects, both in the Netherlands and abroad. The lack of dedicated safety regulation reinforces uncertainty and can weaken societal support.

Furthermore, the absence of an updated national hydrogen import strategy was cited by multiple stakeholders as a challenge to effective coordination. While the Netherlands participates in international cooperation and has developed strategies for domestic hydrogen production, it has yet to provide a more elaborate, updated, and integrated vision on how imports will be integrated into the broader energy system. In contrast, countries such as Scotland and the UK have published detailed export strategies that offer guidance to project developers.

In summary, Dutch policy demonstrates growing engagement with the hydrogen import agenda and encompasses instruments that address key transition challenges. However, important gaps remain in the areas of infrastructure development, safety regulation, strategic direction, and cross-border coordination. Addressing these challenges through targeted policy adjustments and clearer long-term signals would substantially strengthen the enabling environment for hydrogen import developments.

References

[1] International Energy Agency. *Northwest European Hydrogen Monitor*. Accessed: YYYY-MM-DD. 2022. URL: https://www.iea.org/.

[2] Abdurahman Alsulaiman. *Renewable Hydrogen Import Routes into the EU*. OIES Paper ET 24. OIES-Aramco Fellow. Oxford Institute for Energy Studies, May 2023. URL: https://www.oxfordenergy.org.

[3] Abdurahman Alsulaiman and Kong Chyong. *The Economics of Decarbonising Europe's Ammonia Industry: Policy, Pathways, and Trade-offs in a Hard-to-Abate Sector*. OIES Paper ET 43. OIES Visiting and Senior Research Fellows. Oxford Institute for Energy Studies, Mar. 2025. URL: https://www.oxfordenergy.org.

[4] Max Baumgart and Saskia Lavrijssen. "Exploring regulatory strategies for accelerating the development of sustainable hydrogen markets in the European Union". In: *Journal of Energy & Natural Resources Law* 42.2 (2024), pp. 137–166.

[5] Pamela Baxter, Susan Jack, et al. "Qualitative case study methodology: Study design and implementation for novice researchers". In: *The qualitative report* 13.4 (2008), pp. 544–559.

[6] Karen M Benzies et al. "State-of-the-evidence reviews: advantages and challenges of including grey literature". In: *Worldviews on Evidence-Based Nursing* 3.2 (2006), pp. 55–61.

[7] WD Bolhuis. "Beleidseconomen moeten weten wat transitiefalen is". In: *Economisch Statistische Berichten* 109.4831 (2024), pp. 136–139.

[8] C Cheng, Koen van Greevenbroek, and Isabelle Viole. "The competitive edge of Norway's hydrogen by 2030: Socio-environmental considerations". In: *International Journal of Hydrogen Energy* 85 (2024), pp. 962–975.

[9] CIEP. *Van onzichtbare naar meer zichtbare hand*. Clingendael International Energy Programme (CIEP), 2019.

[10] Anne-Sophie Corbeau and Lilian Nassif. *Challenges and Opportunities Posed by the EU's 42 Percent Renewable Hydrogen Target by 2030*. OIES Paper ET 42. Global Research Scholar and Research Assistant at the Center on Global Energy Policy. Oxford Institute for Energy Studies, Mar. 2025. URL: https://www.oxfordenergy.org.

[11] Sigrid Damman et al. "A hybrid perspective on energy transition pathways: Is hydrogen the key for Norway?" In: *Energy Research & Social Science* 78 (2021), p. 102116.

[12] Marie Dejonghe. "Risky Business? Evaluating Hydrogen Partnerships Established by Germany, The Netherlands, and Belgium". In: *Sustainability* 15.24 (2023), p. 16876.

[13] Marie Dejonghe, Thijs Van de Graaf, and Ronnie Belmans. "From natural gas to hydrogen: Navigating import risks and dependencies in Northwest Europe". In: *Energy Research & Social Science* 106 (2023), p. 103301.

[14] J. Delbeke et al. "The Paris Agreement". In: *Towards a Climate-Neutral Europe*. Routledge, 2019, pp. 24–45.

[15] Energy & Industrial Strategy Department for Business. *UK Hydrogen Strategy*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf. Accessed: 2025-06-06. 2021.

[16] Department for Energy Security & Net Zero. *UK Low Carbon Hydrogen Standard: Greenhouse Gas Emissions Methodology and Conditions of Standard Compliance*. Version Version 3. Crown copyright, published under the Open Government Licence v3.0. Dec. 2023. URL: https://www.gov.uk/government/publications/low-carbon-hydrogen-standard-version-3.

[17] Ministerie van Economische Zaken en Klimaat. *Nationaal Plan Energiesysteem*. Dutch. https://www.rijksoverheid.nl/documenten/rapporten/2023/12/06/nationaal-plan-energiesysteem. Hoofddocument gepubliceerd door de Rijksoverheid. Dec. 2023.

[18] Minika Ekanem, Bram Noble, and Greg Poelzer. "The effects of institutional layering on electricity sector reform: Lessons from Norway's electricity sector". In: *Energy Research & Social Science* 119 (2025), p. 103864.

[19] Hans Elzenga, Emma Eggink, and Jeroen de Joode. *Groene Waterstof: De praktische uitdagingen tussen droom en werkelijkheid*. Een verkenning naar de knelpunten en mogelijke oplossingsrichtingen in de ontwikkeling van een groenewaterstofmarkt. Den Haag, Nederland: Planbureau voor de Leefomgeving, Mar. 2025.

[20] Department for Energy Security and Net Zero. *Hydrogen Allocation Round 2 (HAR2): shortlisted projects*. Apr. 2025. URL: https://www.gov.uk/government/publications/hydrogen-allocation-round-2-har2-projects/hydrogen-allocation-round-2-har2-shortlisted-projects.

[21] European Commission. *European Hydrogen Bank*. Accessed: 2025-05-16. 2024. URL: https://energy.ec.europa.eu/topics/eus-energy-system/hydrogen/european-hydrogen-bank_en.

[22] European Commission. *February infringement package – key decisions on energy*. Directorate-General for Energy. Accessed 13 June 2025. Feb. 2025. URL: https://energy.ec.europa.eu/news/february-infringement-package-key-decisions-energy-2025-02-12_en.

[23] European Commission. *Hydrogen and Decarbonised Gas Market*. https://energy.ec.europa.eu/topics/markets-and-consumers/hydrogen-and-decarbonised-gas-market_en. Accessed: 2025-06-16. 2025. URL: https://energy.ec.europa.eu/topics/markets-and-consumers/hydrogen-and-decarbonised-gas-market_en.

[24] European Commission. *Innovation Fund*. https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds/innovation-fund_en. Accessed: 16 May 2025. 2024.

[25] European Commission. *Joint Statement by Commissioner Simson and German Minister Habeck on Energy Issues*. News announcement, 5 min read. Directorate-General for Energy. May 31, 2023. URL: https://energy.ec.europa.eu/news/joint-statement-commissioner-simson-and-german-minister-habeck-energy-issues-2023-05-31_en.

[26] European Commission. *Team Europe Initiatives*. 2025. URL: https://international-partnerships.ec.europa.eu/policies/team-europe-initiatives_en.

[27] European Commission. *The European Green Deal*. https://ec.europa.eu/. 2019.

[28] European Court of Auditors. *The EU's Industrial Policy on Renewable Hydrogen: Legal Framework Largely Adopted – Time for a Reality Check*. Tech. rep. Special Report 11/2024. Special report assessing the EU's renewable hydrogen industrial policy. Luxembourg: European Court of Auditors, 2024. URL: https://www.eca.europa.eu/en/publications?ref=SR-2024-11.

[29] Scottish Government. *A Trading Nation: Realising Scotland's Hydrogen Potential – A Plan for Exports*. Co-produced with stakeholders in the hydrogen sector; aligns with Hydrogen Action Plan and Green Industrial Strategy. Nov. 2024. URL: https://www.gov.scot/publications/trading-nation-realising-scotlands-hydrogen-potential-plan-for-exports/.

[30] Andrzej Graczyk, Paweł Brusiło, and Alicja Małgorzata Graczyk. "Hydrogen as a Renewable Fuel of Non-Biological Origins in the European Union—The Emerging Market and Regulatory Framework". In: (2025).

[31] Guidehouse Netherlands. *Onderzoek noodzaak rol overheid bij opschaling importketens voor waterstof*. Technical Report. Ministerie van Economische Zaken en Klimaat, 2023.

[32] H2Global Foundation. *H2Global Stiftung Fact Sheet*. Overview of the H2Global mechanism, international engagement, and pilot auction results. Jan. 2025. URL: https://www.h2global-stiftung.com.

[33] Mahshid Hasankhani et al. “Unveiling complexity of hydrogen integration: A multi-faceted exploration of challenges in the Dutch context”. In: *Journal of Cleaner Production* 434 (2024), p. 139927.

[34] D. Hjeij et al. “Hydrogen export competitiveness index for a sustainable hydrogen economy”. In: *Energy Reports* 9 (2023), pp. 5843–5855. DOI: 10.1016/j.egyr.2023.05.041.

[35] International Carbon Action Partnership. *EU and UK commit to linking emissions trading systems in landmark cooperation agreement*. 2025. URL: https://icapcarbonaction.com/en/news/eu-and-uk-commit-linking-emissions-trading-systems-landmark-cooperation-agreement.

[36] International Energy Agency. *Northwest European Hydrogen Monitor*. Accessed: 2025-02-04. 2022. URL: https://www.iea.org/reports/northwest-european-hydrogen-monitor.

[37] International Energy Agency. *Northwest European Hydrogen Monitor 2024*. CC BY 4.0 licence. International Energy Agency (IEA), Apr. 2024. URL: https://iea.org/reports/northwest-european-hydrogen-monitor-2024.

[38] International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE). *What We Do*. https://www.iphe.net/what-we-do. Accessed: 2025-06-16. 2025. URL: https://www.iphe.net/what-we-do.

[39] Ministerie van Klimaat en Groene Groei. *Verdiepingsdocument beoordeling waterstofdragers*. Rapport. Bijlage bij de Kamerbrief over kabinetsvisie waterstofdragers. Nov. 2024. URL: https://www.rijksoverheid.nl/documenten/rapporten/2024/11/22/verdiepingsdocument-beoordeling-waterstofdragers.

[40] Cor Leguijt et al. *Toetsing beleidsontwikkelingen waterstof*. 24.230415.024. In opdracht van het Ministerie van Economische Zaken en Klimaat. Delft: CE Delft, Feb. 2024. URL: https://www.ce.nl.

[41] Maija Lehtonen. “Unveiling obstacles and assessing the EU policy and funding instruments for low-carbon hydrogen investments”. In: (2024).

[42] Theodore Levitt. “Exploit the Product Life Cycle”. In: *Harvard Business Review* 43.6 (1965), pp. 81–94.

[43] Ministerie van Economische Zaken en Klimaat. *Government strategy on hydrogen*. Publication | Government.nl. https://www.government.nl/documents/publications/2020/04/06/government-strategy-on-hydrogen. Apr. 2020.

[44] Ministerie van Economische Zaken en Klimaat. *Kamerbrief: Energiediplomatie en import van waterstof*. https://www.rijksoverheid.nl/documenten/kamerstukken/2023/06/02/kamerbrief-energiediplomatie-en-import-van-waterstof. Policy letter to the House of Representatives (Tweede Kamer), reference DGKE-DE / 26898257. Signed by ministers R.A.A. Jetten, M.A.M. Adriaansens, E.N.A.J. Schreinemacher, and W.B. Hoekstra. The Hague, The Netherlands, June 2023.

[45] Ministerie van Klimaat en Groene Groei. *Brief van de Minister van Klimaat en Groene Groei aan de Tweede Kamer, nr. 417*. Tweede Kamer, vergaderjaar 2024–2025, 31 239, nr. 417. Feb. 2025. URL: https://zoek.officielebekendmakingen.nl/kst-31239-417.html.

[46] Ministerie van Klimaat en Groene Groei. *MIEK-handleiding 2025*. https://www.rijksoverheid.nl. 2025.

[47] Marie Münch et al. “Status of Hydrogen and Potential for Cooperation”. In: (2024).

[48] Kelvin Mwita. “Factors influencing data saturation in qualitative studies”. In: *Available at SSRN 4889752* (2022).

[49] Nationaal Programma Verduurzaming Industrie. *Maatwerkafspraken*. https://verduurzamingindustrie.nl/hulp-bij-verduurzaming/maatwerkafspraken/default.aspx. Accessed: 2025-06-16. 2025. URL: https://verduurzamingindustrie.nl/hulp-bij-verduurzaming/maatwerkafspraken/default.aspx.

[50] Nationaal Waterstof Programma. *Routekaart Waterstof*. https://www.nationaalwaterstofprogramma.nl. Commissioned by the Dutch Ministry of Economic Affairs and Climate Policy. The National Hydrogen Programme (NWP) is a public-private partnership supporting the coordinated implementation of national hydrogen ambitions. The Netherlands, Nov. 2022.

[51] Nationaal Waterstof Programma. *SHIPNL: Sustainable Hydrogen Import Program Netherlands*. https://nationaalwaterstofprogramma.nl/themas/thema+import/sustainable+hydrogen+import+program+netherlands/default.aspx. Accessed: 2025-06-16. 2025. URL: https://nationaalwaterstofprogramma.nl/themas/thema+import/sustainable+hydrogen+import+program+netherlands/default.aspx.

[52] Netbeheer Nederland. *Het energiesysteem van de toekomst: de II3050-scenario's. Integrale energiesysteemverkenning 2030-2050*. Geraadpleegd op 30 juni 2023. June 2023. URL: https://www.netbeheernederland.nl/_upload/Files/II3050_2023_Het_energiesysteem_van_de_toekomst_5d3472f5d1.pdf.

[53] Netherlands Enterprise Agency (RVO), Energy Innovation NL, and FME. *Excelling in Hydrogen Solutions for a Sustainable World*. 2025. URL: https://www.rvo.nl/topics/hydrogen.

[54] NLHydrogen. *NLHydrogen na val kabinet: blijf bouwen aan de waterstofeconomie*. Geraadpleegd op 4 juni 2025. June 3, 2025. URL: https://nlhydrogen.nl/nlhydrogen-na-val-kabinet-blijf-bouwen-aan-de-waterstofeconomie/.

[55] Hans van't Noordende et al. "Clean Ammonia Roadmap". In: (2024).

[56] Norwegian Ministry of Petroleum and Energy and Norwegian Ministry of Climate and Environment. *The Norwegian Government's Hydrogen Strategy: Strategy Towards a Low Emission Society*. National hydrogen strategy published by the Norwegian government. June 2020. URL: https://www.regjeringen.no/en/dokumenter/the-norwegian-governments-hydrogen-strategy/id2716740/.

[57] NVDE. *Commissiedebat Waterstof, groen gas en andere energiedragers*. Position paper / debate summary. 2024.

[58] European Parliament and Council. *RED III – Richtlijn (EU) 2023/2413*. EU directive. 2023.

[59] Bartjan Pennink and Duën Holterman. "Scenario's for the hydrogen market and strategic options for MNEs". In: *The Central European Review of Economics and Management* 8.1 (2024), pp. 7–37.

[60] Rahmatallah Poudineh. *Can UK green hydrogen contract for difference (CfD) match the cost-saving success of renewable electricity?* 39. OIES Paper: ET, 2024.

[61] Rainer Quitzow, Almudena Nunez, and Adela Marian. "Positioning Germany in an international hydrogen economy: A policy review". In: *Energy Strategy Reviews* 53 (2024), p. 101361.

[62] Rainer Quitzow et al. *Mobilizing Europe's Full Hydrogen Potential: Entry-Points for Action by the EU and its Member States*. HYPAT Discussion Paper 05/2023. Fraunhofer ISI, RIFS Potsdam, and dena (German Energy Agency), May 2023. URL: https://www.hypat.de.

[63] Ellie Raphael et al. *Emissions from Scottish Hydrogen – International Standards and Export Competitiveness*. ERM, Oct. 2024. DOI: 10.7488/era/5354. URL: http://dx.doi.org/10.7488/era/5354.

[64] Rijksoverheid. *Memorandum of Understanding tussen Noorwegen en Nederland over samenwerking op het gebied van waterstof en koolstof afvang en opslag (CCS)*. Diplomatieke verklaring, Ministerie van Klimaat en Groene Groei. Nov. 2024. URL: https://www.rijksoverheid.nl/documenten/diplomatieke-verklaringen/2024/11/13/memorandum-of-understanding-tussen-noorwegen-en-nederland-over-samenwerking-op-het-gebied-van-waterstof-en-koolstof-afvang-en-opslag-ccs.

[65] Dolores de Rooij et al. *Green Hydrogen Import through the Port of Amsterdam*. Commissioned by Port of Amsterdam. Amsterdam: Invest-NL and ABBEL, Dec. 2024.

[66] Jon Birger Skjærseth et al. "Norway's Hydrogen Strategy: Unveiling Green Opportunities and Blue Export Ambitions". In: *The Geopolitics of Hydrogen: Volume 1: European Strategies in Global Perspective*. Springer Nature Switzerland Cham, 2024, pp. 213–232.

[67] Roelof Stam, Coby van der Linde, and Pier Stapersma. "Hydrogen Policy in the Netherlands: Laying the Foundations for a Scalable Hydrogen Value Chain". In: *The Geopolitics of Hydrogen* (2024), p. 165.

[68] Martha A Starr. “Qualitative and mixed-methods research in economics: surprising growth, promising future”. In: *Journal of Economic Surveys* 28.2 (2014), pp. 238–264.

[69] Statkraft. *Statkraft stops new development of green hydrogen projects*. Accessed: 2025-06-23. May 8, 2025. URL: `https://www.statkraft.com/newsroom/news-and-stories/2025/statkraft-stops-new-development-of-green-hydrogen-projects/`.

[70] Sarah A. Steinbach and Nikolas Bunk. “The future European hydrogen market: Market design and policy recommendations to support market development and commodity trading”. In: *International Journal of Hydrogen Energy* 70 (2024), pp. 29–38.

[71] Kim Talus, Jaqueline Pinto, and Francisca Gallegos. “Realism at the end of the rainbow? An argument towards diversifying hydrogen in EU regulation”. In: *The Journal of World Energy Law & Business* (2024), jwae007.

[72] UK Department for Energy Security and Net Zero. *Hydrogen Production Delivery Roadmap 2023*. Accessed: 2025-06-06. 2023. URL: `https://www.gov.uk/government/publications/hydrogen-production-delivery-roadmap-2023`.

[73] UK Department for Energy Security and Net Zero and ARUP. *The potential for exporting hydrogen from the UK to continental Europe. Hydrogen Technical Advisor WP45*. Version V1. Commissioned by the UK Department for Energy Security and Net Zero. May 2024.

[74] Rubén Vezzoni. “A “return of the state” in energy transitions? The making of a hydrogen economy in the European Union”. In: *ZFW–Advances in Economic Geography* 68.3-4 (2024), pp. 195–212.

[75] K Matthias Weber and Harald Rohracher. “Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive ‘failures’ framework”. In: *Research policy* 41.6 (2012), pp. 1037–1047.

[76] Joep Westerveld. *Kamer wil ammoniakproductie vrijstellen van waterstofplicht*. maart 2025. URL: `https://energeia.nl/kamer-wil-ammoniakproductie-vrijstellen-van-waterstofplicht/`.

[77] Kirsten Westphal et al. *Hydrogen and Market” Ramp Up”-Phases and Target Models*. H2Global Stiftung, 2023.

[78] Martin Wietschel et al. “What do we know about importing green hydrogen and its derivatives and what can be derived from this for Germany’s import strategy”. In: *HYPAT Position paper* 2 (2024), p. 2024.

[79] Ad van Wijk, Kirsten Westphal, and Jan Frederik Braun. *How to Deliver on the EU Hydrogen Accelerator*. Endorsed by African Hydrogen Partnership (AHP), Dii Desert Energy, EU-GCC Clean Energy Technology Network, H2Global Foundation, MENA Hydrogen Alliance. Brussels, May 2022. URL: `https://www.h2-global.de/`.

[80] Robert K Yin. *Case study research: Design and methods*. Vol. 5. sage, 2009.

[81] Yana Zabanova. “The EU in the Global Hydrogen Race: Bringing Together Climate Action, Energy Security, and Industrial Policy”. In: *The Geopolitics of Hydrogen: Volume 1: European Strategies in Global Perspective*. Springer Nature Switzerland Cham, 2024, pp. 15–47.

A
Literature Synthesis

A.1. The Role of Grey Literature

In academic research, traditional peer-reviewed literature is often regarded as the standard of credibility and accuracy. However, in emerging areas such as hydrogen import development, in which commercial application is still at an early stage, gray literature plays a crucial role in complementing academic sources. Grey literature refers to publicly available information that is not published through traditional channels like books, academic journals, or commercial publishers. Instead, it is often shared through special sources such as government reports, policy papers, conference proceedings, position papers, and industry white papers [6]. Given the rapid evolution of hydrogen policy, gray literature helps capture real-time policy developments and how they are perceived by the private sector, making it essential to understand current challenges.

However, the inclusion of gray literature also presents certain challenges. Unlike peer-reviewed journals, gray literature is not always subject to rigorous intellectual oversight, raising concerns about credibility and bias [6]. For example, government reports may reflect national priorities and political agendas, while industry papers may promote specific commercial interests. When using grey literature it is important to critically evaluate the authorship, methodology, and transparency of grey literature sources to ensure their reliability. It is important to assess whether a document provides objective data or whether it serves as a strategic communication tool for stakeholders.

A.2. Selection Process

Google Scholar and Scopus were used as the primary search engines for this research. The search terms and Boolean operators were selected and revised to extract the most relevant literature. The search strings are listed below.

- (Hydrogen OR hydrogen derivatives) AND (Germany OR Netherlands) AND (trade OR import)
- (Hydrogen OR hydrogen derivatives) AND (European market OR EU trade) AND (policy OR government role) AND (market development)
- (Hydrogen OR hydrogen derivatives) AND (Netherlands OR Dutch market) AND policy AND (import OR trade)
- (Hydrogen OR hydrogen derivatives) AND trade AND (Europe OR Netherlands)
- (Hydrogen OR hydrogen derivatives) AND (market development) AND policy
- (Hydrogen OR hydrogen derivatives) AND (development OR transition) AND (government OR policy) AND (Europe OR Germany OR Netherlands)

The following exclusion criteria were applied to refine the initial literature selection:

- **Timespan:** Only literature published from 2020 onward was included to ensure the use of the most recent findings. This criterion accounts for the rapid advancements in the research field and minimizes the risk of outdated information.
- **Relevance:** Search terms were required to appear in the title, abstract, or author-defined keywords to ensure specificity. Additionally, the reliability of each article was evaluated based on factors such as peer review status and citation count.
- **Language:** The study includes only documents published in English and Dutch.

Records excluded from the manual full scan for relevance, as well as those obtained through backward snowballing, were assessed based on their geographical scope (EU countries, the EU as a whole, or the Netherlands) and their focus on hydrogen import policy. Articles that did not meet these criteria were excluded. Following an in-depth analysis using these exclusion criteria, a final selection of 12 articles/reports was made from the initial 34 articles reviewed. The PRISMA Flow Diagram in Figure 1 illustrates this process.

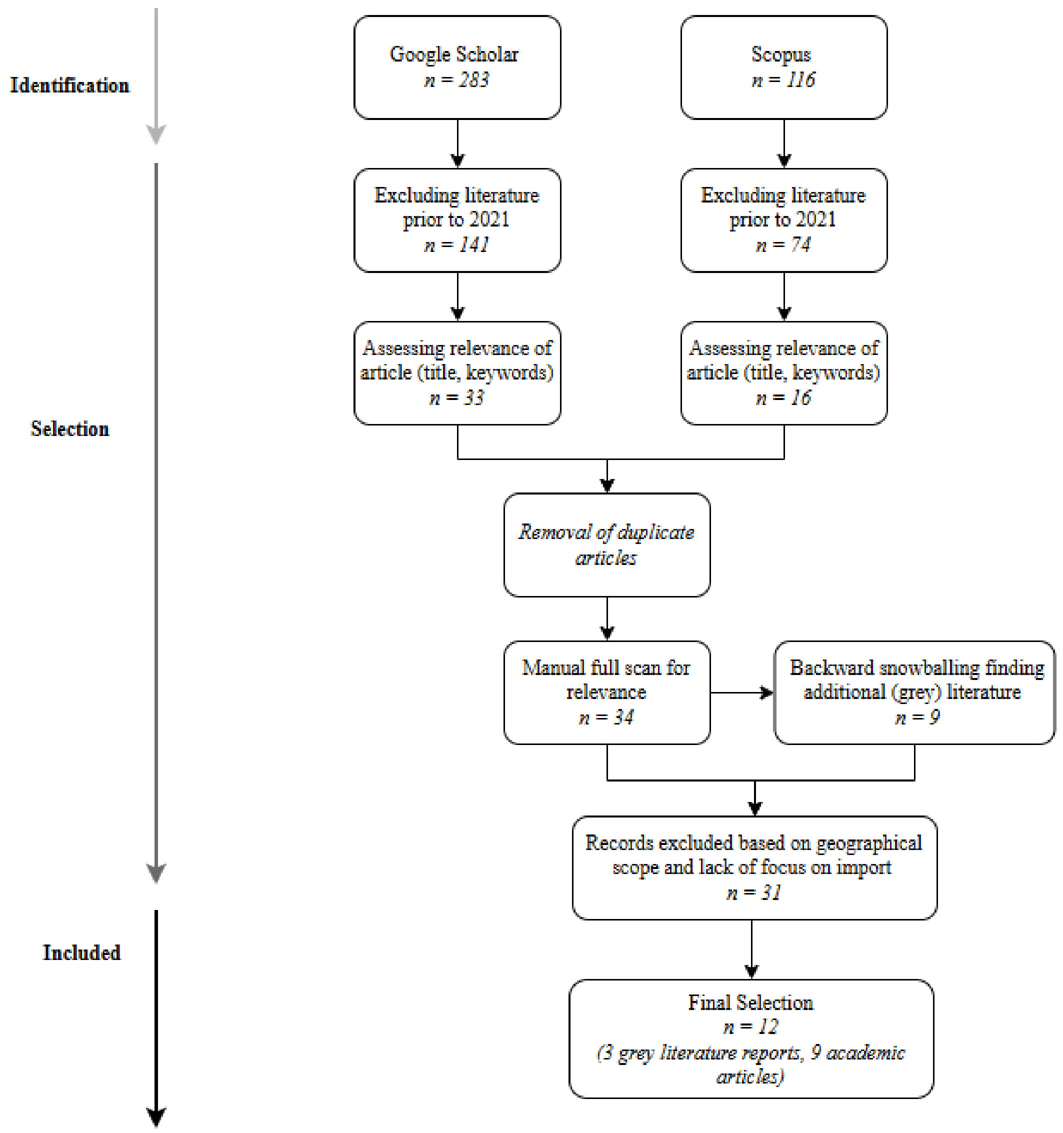

Figure A.1: PRISMA Flow Diagram illustrating the selection process.

A.3. Selected Documents for Literature Synthesis

Reference	Topic	CH?	Policy?	Role GOV	Scope
Quitzow et al. (2024)	Germany's hydrogen strategy: global partnerships, green hydrogen focus.	Yes	Yes	Yes	DE
Steinbach & Bunk (2024)	Future hydrogen market design, lessons from natural gas markets.	Yes	Yes	Yes	EU, DE
Stam et al. (2024)	Dutch hydrogen strategy, infrastructure, international approach.	Yes	No	Yes	NL
Wietschel et al. (2024)	Overview of barriers to green hydrogen imports based on techno-economic studies.	Yes	No	No	DE
Dejonghe (2023)	Feasibility and risks of hydrogen partnerships (MoUs).	Yes	No	Yes	DE, NL, BE
IEA (2022)	Northwest European hydrogen import strategies and policies.	Yes	Yes	Yes	NW EU
Elzenga et al. (2025)	Practical challenges in developing the hydrogen economy in the Netherlands.	Yes	Yes	Yes	NL
Hasankhani et al. (2024)	Key stakeholders in Dutch hydrogen sector and related challenges.	No	No	Yes	NL
de Rooij et al. (2024)	Importing green hydrogen via Amsterdam.	Yes	Yes	Yes	NL
Pennink & Holterman (2024)	Future hydrogen market scenarios and strategic options for MNEs.	Yes	No	No	EU
Talus et al. (2024)	EU should broaden hydrogen strategy beyond RFNBOs for market growth.	Yes	Yes	Yes	EU
Baumgart & Lavrijssen (2024)	Regulatory strategies for developing sustainable hydrogen markets in the EU.	Yes	No	Yes	EU, DE

Table A.1: Overview of H=hydrogen import policy literature and discussed key features (CH = Challenges, GOV = Government)

B

Interview Protocol

B.1. Interview Guide

Introduction

In this interview, I would like to gather your experiences and insights regarding the development of hydrogen import value chains to the Netherlands. I am specifically interested in:

- The challenges you encounter in this process;
- Your opinion on the effectiveness of current (Dutch/EU) policy;
- What you believe is needed to enable further development of these import chains.

Role in the Value Chain

Could you briefly describe the role of your organization within the hydrogen import value chain?

Challenges in the Import Chain

- What concrete challenges are you or your organization currently facing in establishing a hydrogen import chain to the Netherlands?
- In your view, what is the impact of these challenges on the realization of the value chain?
- What is the role of the government in addressing these challenges?

Effectiveness of Current Policy Measures

- How do you perceive current Dutch and/or European policies regarding hydrogen imports?
- Are there policy measures you consider effective? If so, which ones?
- Are there any measures that, in your opinion, are insufficient or not aligned with what is needed in practice?
- Do you have suggestions for improving existing instruments or regulations?

Policy Adjustments and Future Support

- What kinds of additional support or policy measures do you think would help further develop the hydrogen import value chain?
- Are there any countries or examples you find inspiring in terms of effective hydrogen import policy?

Closing

Is there anything else you would like to share on this topic that we have not yet discussed?

B.2. Interview Consent Form

Study Title: *Optimizing Policy Interventions for Scaling Hydrogen Imports in the Netherlands*

You are invited to participate in a research study as part of a Master's thesis at TU Delft, in collaboration with Statkraft. The purpose of this research study is to identify the challenges in the development of hydrogen imports to the Netherlands and assess the effectiveness of current policy interventions.

Participation Details: Participation involves a semi-structured interview of approximately 45 minutes. The topics discussed during the interview relate to hydrogen import policies, regulatory barriers, stakeholder perspectives on policy effectiveness, and potential policy improvements.

Confidentiality and Data Management: Personal data (name, job title, email) will be collected for administrative purposes only. Interviews will be recorded, transcribed, anonymized, and stored securely on TU Delft Storage, which is accessible only to the project research team. The anonymized findings will be included in the Master's thesis and published in the TU Delft repository. Personally identifiable data will be deleted upon project completion. All personal data will be handled in accordance with the European GDPR.

Risk Mitigation: You will have the opportunity to review your transcribed interview to validate content and ensure no confidential or commercially sensitive information is included. Findings will be presented in a anonymized manner, ensuring no statements are directly attributed to individuals. Company names will be anonymized by using general descriptions when explicitly requested by the company. Despite our best efforts, there remains a possibility that members of your company may still be able to reidentify you.

Your Rights: Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. If you decide to withdraw after completing the interview, you may request to have your data removed. In addition, you have the right to rectify your data by contacting the researcher.

For questions or concerns, please contact the project research team:
Doris Brasser (Lead Researcher) – `e-mail`
Dr. Aad Correljé (Responsible Researcher) – `e-mail`

Consent Statement

I confirm that:

- I have read and understood the study details.
- I voluntarily agree to participate.
- I understand how my data will be collected, stored, and used.
- I know I can withdraw at any time.

Participant Name:

Participant Signature:

Date:

C

Coding Book

Table C.1: Codebook: Challenges for Hydrogen Import and Use (derived through iterative inductive first-order coding phase)

Code	Definition	Coding Rules
Gap between the green cost premium and WTP	Refers to the price gap between green hydrogen (or derivatives) and fossil-based alternatives, and the lack of willingness or ability of market actors to absorb this premium without public support.	Code when: the price difference is described as a barrier for demand, especially in internationally exposed sectors (e.g., fertilizers, chemicals), or when this gap is linked to risk premiums or financing concerns. Clarification: The green premium is central to the economic viability of green hydrogen imports. In sectors with tight profit margins and global competition, actors cannot pass on additional costs, making government support essential.
Lack of reliable demand (stimulation)	Refers to the absence of policies, incentives, or mechanisms that create reliable long-term demand for green hydrogen and its derivatives.	Code when: the lack of implementation of EU obligations (e.g., RED III) or general absence of demand-pull mechanisms is discussed. Do not code when: demand is only described as low, without reference to missing instruments or regulation that could stimulate it.
Uncertainty About Future Cost Developments for Green H_2	Refers to unpredictability about future price trends for green hydrogen, including the cost of production, technology (e.g., electrolysers), and financing.	Code when: interviewees or documents mention that expectations for price declines have not materialized, or when they raise concerns about investment risk due to uncertain future costs.
Uncertainty About Future Demand and Supply Volumes and Timelines	Refers to the lack of clarity about how much hydrogen will be needed or produced in the future, and when these volumes will materialize.	Code when: uncertainty is mentioned as a barrier to investment or coordination, including unclear demand trajectories, import targets, or production capacities. Do not code when: volume projections are discussed as facts, without reference to uncertainty, hesitation, or coordination challenges.
Hydrogen Infrastructure Delays and Uncertainties	Refers to delays or lack of clarity in the rollout of key hydrogen infrastructure, such as pipelines (e.g., Dutch Hydrogen Backbone), import corridors, or transnational connections.	Code when: delays in infrastructure planning, unequal access to the network (e.g., Chemelot), or misalignment with EU targets (e.g., 2030 benchmarks) are discussed. Do not code when: infrastructure is mentioned without reference to timing, access issues, or project delays. Clarification: This challenge is often described as a “chicken-and-egg” dilemma where private investment is delayed due to uncertainty about infrastructure, which in turn delays infrastructure due to lack of private commitments.
Lack of clarity on H2 integration into existing systems	Refers to challenges related to integrating hydrogen into existing gas infrastructure and regulatory frameworks under the EU Hydrogen and Decarbonised Gas Market Package.	Code when: the role of hydrogen within existing gas networks, market access, infrastructure repurposing, or related regulatory implementation is discussed. Do not code when: hydrogen infrastructure is mentioned without connection to regulatory or system integration issues.

(Continued on next page)

Code	Definition	Coding Rules
Permitting Delays for Critical Infrastructure	Refers to slow or complex permitting procedures for infrastructure projects related to green hydrogen or its carriers.	Code when: permit bottlenecks, administrative burden, or procedural uncertainty are mentioned as reasons for project delay.
Difference in policy approach between MS	Refers to the lack of alignment or coordination between EU Member States on hydrogen strategies, infrastructure timelines, and external partnerships.	Code when: national strategies conflict or diverge (e.g. NL vs. DE), or when lack of unified EU approach is mentioned as a challenge. Clarification: This challenge limits the formation of coherent cross-border value chains and undermines the EU's collective bargaining and strategic positioning.
Policy alignment NL - neighboring and exporting countries	Refers to insufficient coordination between the Netherlands and key partner countries (e.g. Germany, Belgium, Norway, UK) regarding infrastructure, timelines, standards, or trade routes.	Code when: bilateral coordination failures or misalignments in regulation, logistics, or safety standards are discussed. Do not code when: coordination issues are framed only at the broader EU level.
RFNBO compliance coordination with third countries	Refers to challenges in aligning certification rules with third countries' standards, particularly in export contexts.	Code when: inconsistencies in definitions (e.g. additionality, temporal/geographic correlation), dual certification concerns, or compatibility issues with non-EU countries (e.g. UK) are mentioned. Do not code when: RFNBO is discussed only for intra-EU applications.
(Geo)political instability undermines transition momentum	Refers to how political uncertainty (domestic or international) slows progress on hydrogen strategy, investment, or implementation.	Code when: political turnover, budget shifts, elections, or geopolitical tensions are mentioned as causes of hesitation or delay.
Lack of a well-substantiated general H_2 roadmap	Refers to the absence of a concrete, credible and actionable long-term hydrogen roadmap at national or EU level.	Code when: targets are seen as unrealistic, politically motivated, or unsupported by policy instruments or implementation plans. Do not code when: ambitions or goals are mentioned without critique of feasibility or credibility.
Lack of a specific vision for H_2 import	Refers to the underdeveloped strategic focus on hydrogen imports in Dutch energy policy, despite expected import dependence.	Code when: lack of clear plans or dedicated targets for hydrogen imports is mentioned. Do not code when: domestic production is discussed without contrast to import needs.
Misalignment between policymakers and market actors on H2 carrier vision	Uncertainty about which hydrogen carrier will be preferred or dominant in future policy, infrastructure, and market development.	Code when: doubts are expressed about long-term carrier choices or when this uncertainty affects investment, planning, or coordination.

(Continued on next page)

Code	Definition	Coding Rules
Limited subsidy budgets	Refers to concerns about whether current or planned public funding is sufficient to support infrastructure and import facilities investments and to cover the green premium.	Code when: public funding is described as too limited to meet hydrogen policy ambitions or bridge the cost gap. Do not code when: financing is discussed without concern for scale, sufficiency, or impact.
Lack of financial support NH_3 cracking facilities	Refers to the absence of targeted funding for ammonia cracking infrastructure, essential for converting imported ammonia to hydrogen.	Code when: cracking infrastructure is described as underfunded or ineligible for subsidies. Do not code when: ammonia cracking is discussed without mention of funding challenges.
Immature large-scale NH_3 cracker technology	Refers to the early development stage and limited commercial readiness of large-scale ammonia cracking systems.	Code when: cracking is described as technically immature, unproven at scale, or a source of uncertainty for project developers.
Complex certification requirements for RFNBO	Refers to the complexity or rigidity of EU rules for certifying hydrogen as renewable under RFNBO criteria (e.g., additionality, temporal/geographic correlation).	Code when: rules are described as unclear, overly strict, or unfit for the early market phase. Do not code when: RFNBO is mentioned only as a necessary standard without critique or concern.
Subsidy-based export uncertainty for green NH_3	Uncertainty about whether green ammonia produced with domestic subsidies (e.g. UK's HPBM) can be exported, especially to EU markets like the Netherlands.	Code when: Unclear rules or political hesitation about exporting subsidized green ammonia are mentioned.
Opposition from negatively impacted actors	Refers to resistance by incumbent actors or sectors (e.g. fossil industry, large ammonia users) who may lose out from the hydrogen transition.	Code when: interviews or documents mention lobbying, exemptions, or protection of vulnerable stakeholders, slowing change. Do not code when: general political or market inertia is mentioned without attributing it to affected actors.
Political and public sensitivity to energy exports	Refers to political or societal resistance to electricity-derived products, due to concerns over domestic energy prices, availability, or grid capacity.	Code when: Export of hydrogen or electricity is framed as politically sensitive or publicly contested / Concerns are raised about energy security, price impacts, or fairness for domestic users. / Public or political hesitation is mentioned as a challenge to export-oriented hydrogen projects.
Limited urgency for green H_2 exports	Refers to the lack of institutional or political momentum in exporting countries to accelerate hydrogen production aimed at export markets.	Code when: exporting countries are described as slow-moving, hesitant, or lacking strategic urgency for export-oriented hydrogen. Do not code when: delays are due to technical, financial, or demand-side constraints only.

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Code	Definition	Coding Rules
NH_3 societal acceptance concerns (safety)	Refers to concerns about public acceptance of ammonia as a hydrogen carrier, primarily due to safety, toxicity, or environmental risks during transport, storage, or use.	Coded when: Ammonia is described as risky, dangerous, or controversial from a public or societal perspective. Concerns are raised about handling, accidents, toxicity, or safety regulations influencing acceptance or project development. Do not code when: Safety is mentioned only in the context of design or engineering standards, not public perception.

Table C.2: Codebook: 2nd order deductive code categories based on Weber and Rohracher [75] and Bolhuis [7]

Code	Definition	Coding Rules
Lack of (shared) directional vision	Collective action is hindered by the absence of a joint vision or clear long-term goal and roadmap towards that joint goal.	Assign code when text fragments refer to a lack of collective future vision, direction between actors in the value chain. Do not code when only general uncertainty is mentioned without connection to collective direction.
Inadequate physical infrastructure	Structural underinvestment in physical or knowledge infrastructure due to low (short-term) returns, despite its strategic importance.	Assign code when references are made to the absence of essential infrastructure (knowledge, physical, technological) required for the transition.
Insufficient policy coordination	Public authorities issue inconsistent or conflicting policies across governance levels, hindering behavioral change.	Assign code when there are references to policy conflicts, incoherence, or confusion caused by contradictory government communication or measures.
Demand articulation	Limited or unclear demand hinders investments and innovation. The government plays a key role in steering demand.	Assign code when there is hesitation among actors due to low or uncertain demand, and demand coordination or government steering is explicitly or implicitly missing.
Opposition by transition losers	Actors defend existing systems due to fear of losing certainty, profit, or income.	Assign code when resistance, delay or lobbying is described from groups negatively affected by the transition.
Outdated or incomplete institutions	Existing laws and regulations hinder the behavioral changes required for the transition.	Assign code when legal or institutional challenges are mentioned, including outdated rules or lack of updated legislation that hinder developments.
Lack of knowledge, skills and resources	Shortages in competencies, knowledge or resources (e.g., labor, technology, materials) essential to transition progress.	Assign code when missing skills, expertise, or resources necessary for change are described. Do not code when general complaints about labor shortages are made without connection to transition goals.
Lack of ecosystem-wide financing	Emerging value chains fail to attract capital or financing instruments, hampering collective behavioral change.	Assign code when multiple parties require simultaneous financing but available instruments or mechanisms are lacking.
Limited reflexivity and learning capacity	Actors fail to monitor, learn, and anticipate effectively, leading to delayed or ineffective responses to transition developments.	Assign code when failed feedback loops, poor monitoring, limited adjustment, or learning capacity are mentioned. Do not code in cases of general uncertainty or risk without reference to learning or adaptive behavior.

Table C.3: Codebook: Policy Instruments Related to Hydrogen Import Chains

Code	Definition	Coding Rules
Delegated Acts for RFNBO	Defines EU-level criteria for hydrogen and derivatives to be classified as Renewable Fuels of Non-Biological Origin (RFNBOs) under RED III.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
RFNBO Quotas (RED III)	Sets mandatory RFNBO share targets in industry and transport sectors across EU Member States.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
RED III Permitting Rules	Streamlines permitting for renewable energy infrastructure, including hydrogen production and transport assets.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
ReFuelEU Aviation	Sets minimum shares for sustainable fuels in aviation, allowing RFNBOs to be part of the mix.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
FuelEU Maritime	Mandates GHG intensity reduction in shipping fuels, stimulating the use of renewable ammonia or hydrogen.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
CBAM	Applies carbon pricing on selected imports to align with EU ETS, including consideration for hydrogen-based products.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.

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Code	Definition	Coding Rules
EU ETS	Market-based cap-and-trade system creating a CO_2 price signal.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
Hydrogen and Gas Decarbonization Package	Defines market rules and infrastructure planning for hydrogen networks within the EU.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
Trans-European Energy Networks Regulation (TEN-E)	Supports strategic cross-border hydrogen infrastructure with streamlined permitting and funding access.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
Team Europe Initiative (TEI)	EU external action framework promoting coordinated hydrogen project development with third countries.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
Recovery and Resilience Facility (RRF)	EU post-COVID fund supporting energy and climate investments, including hydrogen infrastructure.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
IPCEI	Supports large-scale, cross-border hydrogen projects with EU and national co-funding.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.

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Code	Definition	Coding Rules
Innovation Fund	Funds low-carbon technologies, including hydrogen production and related infrastructure.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
European Hydrogen Bank	EU instrument offering financial support for renewable hydrogen via fixed premiums and auctions.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
H2Global Mechanism	Germany-led double auction system supporting long-term hydrogen import contracts to the EU.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
European Clean Hydrogen Alliance	EU research partnership funding innovation in hydrogen and fuel cell technologies.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
Horizon Europe	EU research and innovation programme that includes hydrogen import and infrastructure projects.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
Clean Energy Ministerial Hydrogen Initiative	Multilateral forum for advancing global hydrogen policy alignment and best practices.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.

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Code	Definition	Coding Rules
Hydrogen Technology Collaboration Programme (IEA)	IEA-led international R&D cooperation platform on hydrogen technologies.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
Hydrogen Trade Forum	Multilateral initiative supporting alignment on hydrogen trade rules and standards.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
International Partnership for Hydrogen and Fuel Cells in the Economy	Global initiative supporting international hydrogen certification and policy dialogue.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
Dutch Hydrogen Carrier Vision	Dutch governmental vision report outlining preferred hydrogen carriers (e.g., ammonia) and related import infrastructure.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
Dutch Tailored Agreements (Maatwerkafspraken)	Custom decarbonization agreements with large Dutch industrial emitters.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
Dutch Energy Infrastructure Planning (MIEK)	National infrastructure coordination programme including hydrogen transport infrastructure.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.

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Code	Definition	Coding Rules
Memoranda of Understanding (MoUs)	Non-binding bilateral agreements facilitating international hydrogen cooperation and alignment.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.
SHIP-NL Platform	Multi-actor Dutch coordination forum on hydrogen import chain development.	Coded when the text fragment includes explicitly the instrument and only if the text fragment links it directly or indirectly to the development of hydrogen import chains. Do not code when the instrument is mentioned in general terms, or in relation to other energy sectors, without any explicit or implicit relevance to hydrogen import development.