Reviewing Hydrogen Regulations

Exploring Regulatory Frameworks and Reforms Needed for Regional Hydrogen Distribution in the Netherlands

Master Thesis, CoSEM

Hidde Meijer

Delft University of Technology

TU Delft

Reviewing Hydrogen Regulations

Exploring Regulatory Frameworks and Reforms Needed for Regional Hydrogen Distribution in the Netherlands

by

Hidde Meijer

Student Name	Student Number
Hidde Meijer	4662814

Supervisors:	Amineh Ghorbani & Zofia Lukszo
Assistant Supervisor:	Renske van 't Veer
Company Supervisors:	Arjen Jongepier & Edward Droste
Project Duration:	12\02\2024 - 08\07\2024
Faculty:	Faculty of Technology, Policy and Management, Delft
To be defended on:	05-07-2024
Cover Image Source:	ChatGPT.com

TU Delft

Preface

This thesis represents the culmination of my Master's program Complex Systems Engineering and Management at Delft University of Technology. The journey towards completing this research has been challenging yet rewarding, and I am very grateful to all those who have supported me along the way.

I would like to thank my assistant supervisor, Renske van 't Veer, for her insightful comments and continuous support. Your contributions have been vital to the development of this thesis. Our meetings and your critical feedback helped shape the thesis and gave me useful insights and directions.

I would also like to express my gratitude to my supervisors, Amineh Ghorbani and Zofia Lukszo, for their constructive feedback, and support throughout this project. Your expertise has been extremely useful in shaping this thesis, and I am immensely thankful for your guidance.

Special thanks to my company supervisors, Arjen Jongepier and Edward Droste, whose practical insights and industry know-how enriched the study and provided a crucial link between academic research and real-world application. They showed me what it is like to be actively involved in the dealings of a company such as Stedin. This was an interesting and exciting experience I will carry with me into the future.

To my family and friends, I am grateful for your encouragement and understanding. Your support has been a source of motivation and inspiration. To my mother, thank you for your unwavering support and for teaching me the values of hard work and discipline. To my late father, I thank you for giving me the best upbringing anyone could ever wish for and believing in me until the very end.

The completion of this thesis has been a significant milestone in my academic and professional career, and I appreciate all the support, motivation and knowledge I have received.

Hidde Meijer
Delft, June 2024

Executive Summary

Hydrogen is seen as a crucial element in the transition to a sustainable energy system. The Netherlands aims to use it in transportation, heating and energy-intensive processes. Due to its existing gas infrastructure and location, the Netherlands is well-positioned to become a leader in hydrogen technology, distribution and trade. Despite numerous announcements, plans and ideas, the development of hydrogen distribution networks has not quite taken off yet. On the European level initiatives such as the European Hydrogen Backbone try to promote cross-border cooperation and hydrogen market formation. In the Netherlands, HyNetwork Services (HNS) has been appointed to develop a national hydrogen network connecting several large industrial hubs. On the regional level, however, no responsible parties have been appointed yet and regulations are lacking. To develop efficient and effective regional hydrogen distribution networks, a clear regulatory framework is needed to provide stakeholders in the system with security, clarity and direction. The case that was used to analyse the regulatory framework and provide advice is the Dutch cluster 6. This cluster includes regional industries such as ceramics and glass located throughout the Dutch landscape.

The objective of this research was to analyze the current and upcoming regulations influencing hydrogen distribution networks and formulate possible reforms that can accelerate the development of these hydrogen distribution networks. The study aimed to answer the following main research question: *"How can regulatory frameworks influence the development of the Dutch regional hydrogen distribution networks?"*

The research method involved a comprehensive literature review, stakeholder identification, and institutional analysis. The Institutional Analysis and Development (IAD) framework was used to examine the action situation describing the regulatory context in which the development of hydrogen networks takes place. To analyse the documents and simplify the articles into institutional statements, Institutional Grammar (IG) was used. Institutional Network Analysis (INA) provided a detailed map of the institutional statements and their interactions. Data collection included document analysis and semi-structured interviews with key stakeholders from regulatory bodies, industry stakeholders and overarching organisations. The interviews provided crucial insights into the perspectives of actors in the Dutch hydrogen sector on the current regulations, what they see as barriers and drivers for the development of hydrogen distribution networks and what changes or additions they would prefer.

Key Findings

In the current regulatory landscape, The Environment and Planning Act, the Gas Act, and the Electricity Act are the primary regulatory documents governing hydrogen projects. These regulations lack the specificity needed to support the development of hydrogen networks. The Energy Act and EU-Decarbonisation Package introduce new requirements that are expected to significantly impact hydrogen infrastructure development. These regulations emphasize the integration of renewable energy sources, specify roles in the future system and aim to create a foundation for a hydrogen market. The interviews revealed that stakeholders perceive the regulatory environment as fragmented and insufficient. There is a need for clearer guidelines and more supportive policies to reduce uncertainties and foster investment in hydrogen projects.

Key barriers that were found, include the complexity of the permitting process, grid congestion, insufficient subsidy schemes and the lack of norms and standards tailored to hydrogen. On the other hand, drivers include the strategic importance of hydrogen in the energy transition, national and EU-level incentives, and the potential for hydrogen to alleviate grid congestion in the long term and enhance energy security.

Recommendations

Several recommendations were made based on the document analysis and stakeholder interviews. These recommendations include the simplification of the permitting process by increasing flexibility in

provincial ordinances. This is needed so that the local authorities can prioritize projects that address grid congestion and demonstrate the viability of hydrogen as a key energy carrier. Secondly, a clear and robust subsidy scheme is needed to support the development of regional distribution networks. To increase clarity for the development of hydrogen projects, the Dutch government needs to implement specific guidelines for hydrogen as soon as possible. Lastly, stakeholder collaboration will need to increase to create a shared vision and coordinated approach to regional hydrogen network development.

Specific advice to different actors was also given in this thesis. For regulatory bodies, it is advised to establish a dedicated national entity together with DSOs to oversee hydrogen projects and streamline regulatory processes. This will support the development of regional, independent hydrogen networks. To increase certainty it is needed to develop a long-term strategy for hydrogen that includes clear targets, timelines, and milestones. For the Distribution System Operators (DSOs) it is advised to develop convincing development and investment plans, actively engage in the planning and development of independent hydrogen networks, and ensure regulatory alignment with the overall goals of the energy transition through engagement with the regulatory bodies.

A special part of the recommendations was a look into potential future strategies. These potential development routes for regional hydrogen networks were discussed, specifying the role of DSOs. The first route involves the formation of independent hydrogen networks, such as the DOW-YARA pipeline in Zeeland. These are privately owned and operated and they must balance hydrogen supply and demand, potentially requiring storage solutions. The role of a DSO in these networks is limited unless the private owners fail in operation, in which case the DSO takes over and establishes an operating tariff. The DSO can also play an advisory role in the technical specification during the formation of these networks. The second route is an extension of route 1 where independent networks expand and connect to the larger hydrogen system. The main problem here is the lack of standardization in operational and technical characteristics, which can lead to high integration costs. To avoid this the DSO will need to advise and monitor these independent networks to ensure compatibility with the larger system. They will also operate these integrated networks. The last route involves regional clusters near the hydrogen backbone that are connected directly to the hydrogen backbone by the DSO. Currently, it is unclear how these connections will be funded and how the initial hydrogen supply will be ensured.

Conclusion

The temporary regulatory frameworks that have been developed in the Netherlands lack overall long-term vision. Because of this, the government does not provide the security that companies need to invest in hydrogen technologies and infrastructure. Upcoming regulations try to create a clearer arena for hydrogen development by outlining roles for stakeholders and laying the foundation of a hydrogen market. This is, however, still not enough to accelerate the development of regional hydrogen distribution networks according to stakeholders. A more robust subsidy framework is needed that provides the certainty that investors crave. Changes to the provincial ordinance regulatory structure and the Energy Act (ENA) can help increase allocation flexibility which can drive hydrogen projects and infrastructure development in the region. Providing certainty across the value chain is needed to create an efficient hydrogen system. By addressing regulatory barriers and enhancing support mechanisms, the Netherlands can lead the way in hydrogen technology and infrastructure development, contributing to national and global sustainability goals.

Keywords: Hydrogen regulations, Institutional Analysis, Energy transition, Regulatory framework, the Netherlands.

Contents

Preface i

Executive Summary ii

List of Figures vi

List of Tables vii

Nomenclature viii

1 Introduction 1
- 1.1 Background 1
  - 1.1.1 European Background 1
  - 1.1.2 National Background 1
  - 1.1.3 Regional Background 2
- 1.2 Literature Review on Hydrogen Regulations 3
  - 1.2.1 Influence of Regulations 3
  - 1.2.2 Regulation of Hydrogen 5
  - 1.2.3 Wrap-up Review 6
- 1.3 Knowledge Gap 6
- 1.4 Main Research Question and Sub-questions 7
- 1.5 Research Objective 8
- 1.6 Link to Study Program 8
- 1.7 Thesis Outline 8

2 Methodology 11
- 2.1 Research Approach & Scope 11
  - 2.1.1 The Cluster 6 System 11
- 2.2 Analysis Methods 12
  - 2.2.1 Institutional Grammar 12
  - 2.2.2 The IAD Framework 13
  - 2.2.3 Institutional Network Analysis 14
  - 2.2.4 Hypotheses and Interviews 15

3 Case Background 18
- 3.1 The State of Hydrogen 18
  - 3.1.1 Role of Hydrogen in the Netherlands 18
  - 3.1.2 Hydrogen Value Chain 19
  - 3.1.3 Hydrogen Regulations 21
- 3.2 Stakeholder Identification 21
  - 3.2.1 Regulatory Bodies 22
  - 3.2.2 Policy Subjects 22
  - 3.2.3 Power/Interest Grid 24

4 Institutional Analysis 27
- 4.1 Action Situation 27
- 4.2 Current Regulations 27
  - 4.2.1 Environment and Planning Act 28
  - 4.2.2 Gas Act 30
  - 4.2.3 Electricity Act 31
  - 4.2.4 Guidelines Hydrogen 32
  - 4.2.5 Temporary Framework Hydrogen Pilots 34

4.2.6 Letter to Parliament on HNS . . . 35
4.2.7 Institutional Coding & Visualisation . . . 36
4.2.8 Action Situation Network Diagram . . . 37
4.3 Upcoming Regulations . . . 39
4.3.1 Energy Act . . . 39
4.3.2 EU Hydrogen and Decarbonisation Package 2023 . . . 40
4.3.3 New Action Situation Network Diagram . . . 43

5 Hypotheses & Interview Formulation **47**
5.1 Hypotheses . . . 47
5.1.1 Hypotheses from Current Regulations . . . 47
5.1.2 Hypotheses from Upcoming Regulations . . . 48
5.2 Interview Example Questions . . . 49

6 Stakeholder Perceptions **50**
6.1 Interview Results . . . 50
6.1.1 Barriers and Drivers . . . 50
6.1.2 Suggested Regulatory Reforms . . . 52
6.2 Hypotheses Discussion . . . 54
6.2.1 Current Regulations Hypotheses Review . . . 54
6.2.2 Upcoming Regulations Hypotheses Review . . . 55
6.3 Possible Additions to the Network Diagram . . . 55

7 Conclusion **58**
7.1 SQ1 Conclusion . . . 58
7.2 SQ2 Conclusion . . . 58
7.3 SQ3 Conclusion . . . 59
7.4 SQ4 Conclusion . . . 59
7.5 Main RQ Conclusion . . . 60

8 Discussion **61**
8.1 Action Recommendations . . . 61
8.1.1 Regulatory Body Advice . . . 61
8.1.2 DSO Advice . . . 62
8.1.3 Development Routes . . . 63
8.2 Contribution to Scientific Landscape . . . 64
8.3 Limitations and Recommendations . . . 65

References **66**

A Holistic view on Stakeholders **74**

B Coded Institutional Statements **78**

C Visualisation of Individual Institutional Statements **85**
C.1 Statements First Network Diagram . . . 85
C.2 Statements Second Diagram . . . 87
C.2.1 Proposed Additions . . . 87

D Interview Template **92**

E Interview Summaries **94**
E.1 Interview Summary ZonXp . . . 94
E.2 Interview Summary Groenleven . . . 95
E.3 Interview Summary Stedin . . . 97
E.4 Interview Summary Top Sector Energie . . . 100
E.5 Interview Summary Alliander . . . 102
E.6 Interview Summary Kapelle . . . 105

List of Figures

1.1 National Hydrogen Transportation Network, (Gasunie, 2023) 2
1.2 Cluster 6 Distribution, (Ministerie van EZK, 2020c) 3
1.3 Planned Research Flow with Chapters 10

2.1 Cluster 6 System & Research Scope 12
2.2 Steps for INA, (Adapted from Mesdaghi et al., 2022) 12
2.3 Components of IAD framework, (McGinnis, 2011) 14
2.4 Representation of Institutional Statement, (Mesdaghi et al., 2022) 14
2.5 Regulatory connection coded using INA, (Mesdaghi et al., 2022) 15
2.6 Regulatory conflict coded using INA, (Mesdaghi et al., 2022) 15

3.1 Hydrogen production processes, (Nikolaidis & Poullikkas, 2017) 19
3.2 Hydrogen Applications, (Adapted from Mansilla et al., 2018) 20
3.3 Active area DSOs, (NetbeheerNL, 2024) 24
3.4 Example Power-interest grid, (Ahsan & Pedersen, 2018) 25
3.5 Power-Interest Grid Regional Hydrogen Transportation & Distribution 25

4.1 Visualisation of Statement EPA8 37
4.2 Action Situation of Current Regulations 38
4.3 Action Situation of Upcoming Regulations 46

6.1 Possible Additions to Network Diagram 56

C.1 Statement EPA8 85
C.2 Statement GA3 85
C.3 Statement GA10 85
C.4 Statement EA10 86
C.5 Statement TFHP2 86
C.6 Statement ENA2 & EUGD7 87
C.7 Statement EUGR1 87
C.8 Statement EUGR2 87
C.9 Statement EUGR3 88
C.10 Statement EUGR4&6 88
C.11 Statement EUGR5 88
C.12 Statement EUGR8 88
C.13 Statement EUGR10 88
C.14 Statement EUGD2 89
C.15 Statement EUGD3&14 89
C.16 Statement EUGD5 89
C.17 Statement EUGD6 89
C.18 Statement EUGD8 89
C.19 Statement EUGD9&10 90
C.20 Statement EUGD11&12 90
C.21 Addition 1 90
C.22 Addition 2 90
C.23 Addition 3 90
C.24 Addition 4 91
C.25 Addition 5 91

List of Tables

2.1 Interviewed Actors 16

3.1 List of Relevant Policy Documents 21
3.2 List of Regulatory Bodies in the Netherlands, (adapted from CMS, 2022) 22

4.1 List of Analysed Current Policy Documents 28
4.2 Relevant Environment and Planning Act Articles 29
4.3 Relevant Gas Act Articles 31
4.4 Relevant Electricity Act Articles 32
4.5 Relevant Guidelines for Hydrogen Articles 33
4.6 Relevant TFHP Articles 34
4.7 Relevant HNS articles 36
4.8 List of Analysed Upcoming Policy Documents 39
4.9 Relevant Energy Act Articles 40
4.10 Relevant EU Gas Regulation Articles 41
4.11 Relevant Gas Directive Articles 42

5.1 Interview Topics & Example Questions 49

A.1 A holistic view of the stakeholders, presenting their categories and roles. 74

B.1 All coded institutional statements 78

D.1 Interview Topics and Possible Questions 92

Nomenclature

Abbreviations

Abbreviation	Definition
ACM	Autoriteit Consument en Markt
CCS	Carbon Capture and Storage
DSO	Distribution System Operator
EA	Electricity Act
EHB	European Hydrogen Bank
ENA	Energy Act
ENNOH	EU Entity for Hydrogen Network Operators
EPA	Environment and Planning Act
GA	Gas Act
GH	Guidelines for Hydrogen
GTS	Gasunie Transport Services
GW	Gigawatt
HNS	HyNetwork Services
IAD	Institutional Analysis and Decision
IG	Institutional Grammar
INA	Institutional Network Analysis
IND	Institutional Network Diagram
IPP	Independent Power Producers
PEM	Proton Exchange Membrane
RES	Renewable Energy Source
RFNBOs	Renewable Fuels of Non-Biological Origin
RQ	Research Question
SodM	State supervision for the Mines
SQ	Sub-question
TFHP	Temporary Framework for Hydrogen Pilots
TSO	Transmission System Operator

Chat.GPT was used for spelling, clarity and text flow corrections during this thesis.

1
Introduction

In this first chapter, the basis of this master thesis research project is discussed. Section 1.1 contains the background of the system and the problem analysed in this project. The current state-of-the-art literature on regulatory influence and hydrogen regulations is discussed in Section 1.2. In Section 1.3 the knowledge gap is described and in Section 1.4 the research questions that follow out of this knowledge gap are discussed. Section 1.5 is used to describe the objective of this research. The link to the study program CoSEM is reported in Section 1.6. Lastly, Section 1.7 outlines the structure of the entire thesis.

1.1. Background

The Netherlands has set high standards for sustainable energy use in response to worries about climate change and problems with energy security. The goal is that by 2030, 27% of energy consumed will come from sustainable sources; by 2050, this percentage will need to reach nearly 100% (Ministerie van Algemene Zaken, 2017). Hydrogen is viewed as one potential solution to lower CO2 emissions for energy-intensive processes, such as those in the industry sector (Ministerie van EZK, 2020b). There have been plans, announcements, and promises to support hydrogen development, but the transition to hydrogen has taken some time to get off the ground. In the following sections, the plans, strategies and initiatives that are being developed will be discussed on different levels.

1.1.1. European Background

In the European arena, the largest initiative on hydrogen infrastructure development is the European Hydrogen Backbone with thirty-three infrastructure operators (EHB, 2024). The mission of this initiative is to promote cross-border cooperation between European nations and their neighbours, market competition, and supply and demand security. On the policy front, the EU has already outlined a hydrogen strategy in July 2020 (EC, 2020), that suggests actions in five different areas. These areas include investment support, production and demand support, the creation of a hydrogen market and infrastructure, research and international cooperation. Current hydrogen regulations frequently make distinctions between the ”colours of hydrogen” (Machado et al., 2022). grey meaning: hydrogen produced using fossil fuels, blue is also produced with fossil fuels but with the addition of carbon capture and storage (CCS), and lastly green meaning hydrogen produced using renewable energy sources. Green is seen by the EU as the best solution for decarbonizing large industries in the long run. However, in the short term, all colours of hydrogen will be produced and used and thus considered in this study. For the hydrogen markets, the EU aims to implement a strict command and control structure that allows for strict guidance in the hydrogen sector. However national governments, such as in Germany, are in favour of a more flexible approach (Baumgart & Lavrijssen, 2023).

1.1.2. National Background

In the Netherlands, Gasunie is a state-owned company responsible for the transport of natural gas throughout the country. Gasunie’s subsidiary: HyNetwork Services (HNS) is the primary accountable party designated by the Dutch government for the hydrogen infrastructure development and management (Ministerie van EZK, 2022b). Gasunie's subsidiary Gasunie Transport Services (GTS) is the national network operator in charge of managing and utilising the Netherlands' gas network. With the goal of creating a "hydrogen backbone" for the major industrial clusters in the Netherlands, HNS has been gradually developing the network, incorporating small sections into the overall system starting in 2025 (Gasunie, 2023).

The Netherlands is one of the first European countries to develop a nationwide hydrogen infrastructure (CMS, 2022). The national hydrogen strategy of the Dutch government aims to coordinate and plan the development of this network. Using four pillars, this plan provides a clear outline of the policy agenda (Ministerie van EZK, 2020a). Increasing the production of green hydrogen, promoting sustainable consumption, and enacting laws and regulations are some of the key components of these pillars. As was previously said, the integration of the five sizable industrial clusters with a pipeline-based hydrogen network represents the first steps towards development. Since these clusters are already very well connected by gas pipelines, a hydrogen retrofit is an affordable, secure, and environmentally friendly option (Gasunie, 2024). The position of the clusters and the hydrogen backbone can be found in Figure 1.1.

Figure 1.1: National Hydrogen Transportation Network, (Gasunie, 2023)

1.1.3. Regional Background

For the regional situation, different actors, institutions and issues apply. As discussed in Chapter 1.1.2. the national situation focuses on a transport network for the 5 large industry clusters. There is however much more industry in the Netherlands than those 5 clusters. All these industries combined are called cluster 6 and they can be found throughout the Netherlands, often more close to urban areas than the other clusters (Oldenhof, 2020). The industries that make up this cluster are the food industry, the paper industry, the chemical industry outside of clusters 1 to 5, the glass industry, the ceramic industry, the waste and recycling sector, the ICT companies, the metallurgical industry, and the oil and gas exploration companies. The distribution of these industries throughout the Netherlands can be seen in Figure 1.2. Cluster 6 is responsible for 30% of industrial CO2 emissions and should therefore not be forgotten in the energy transition (Ministerie van EZK, 2020c).

Smaller projects are being tested in anticipation of a future when hydrogen may find widespread usage. Network operators have conducted tests to demonstrate the potential of hydrogen concepts and technologies. To show how hydrogen may be used in an urban setting, Stedin, the network operator in charge of a portion of the Dutch gas distribution network, has been testing hydrogen boilers in Rozenburg (Stedin, 2018). For regional transportation, Stedin has used a small disused gas distribution network in Uithoorn to test the feasibility of retrofitting regional networks for hydrogen use (Stedin, 2020). However, retrofitting is not yet possible because regional gas networks are still required for gas distribution. Furthermore, because of the distributed nature of cluster 6, a significant amount of additional infrastructure will be required (de Flart, 2024). It is vital to conduct experiments and gather knowledge for the future, even though Stedin does not yet see hydrogen playing a significant role before 2030. The experiments will be crucial in defining the guidelines and conditions for the development of regional networks because they can raise concerns about the use of hydrogen as a viable choice in urban areas (Stedin, 2020). The Dutch government has laid out the development strategy for hydrogen in the national hydrogen program. Although the importance of incorporating the sixth cluster in the creation of the national network is mentioned in this roadmap, no legislative or regulatory measures are mentioned to accomplish this (NWP, 2022a). To develop efficient and effective regional hydrogen distribution networks, a clear regulatory framework is needed to provide stakeholders in the system with security, clarity and direction.

Figure 1.2: Cluster 6 Distribution, (Ministerie van EZK, 2020c)

1.2. Literature Review on Hydrogen Regulations

This section describes the state-of-the-art literature on regulations, their influence and their connection to hydrogen distribution infrastructure development. It will be used to describe what research has already been done on the impact of regulations on the adoption and development of new energy technologies, such as hydrogen, and stakeholders in this sector. Section 1.2.1 will be used to discuss this. Next, Section 1.2.2 is used to describe the current governance of hydrogen, its problems and opportunities. Lastly, Section 1.2.3 will wrap up the review.

1.2.1. Influence of Regulations

In current society, businesses and sectors with high carbon footprints are facing stricter environmental and climate change-related laws. This can lead to industries and businesses having to confront difficult challenges when it comes to staying competitive and complying with the set rules (Martin & Rice, 2014). However, in the early stages of market and commercial development, innovations such as hydrogen, require a support program tailored to the particular technology (Bleischwitz & Bader, 2010). It is therefore necessary to understand the impact that regulatory frameworks can exert on emerging technologies and the stakeholders that operate within such a sector. This method of socio-technical systems thinking recognizes the complex nature of the hydrogen sector (Gordon et al., 2023). The following subsections discusses these two parts of a socio-technical system and their connection to regulations.

Technology

Using the example of environmental policies, they have influenced the amount of greenhouse gas emissions globally, but the effect on innovative technologies from these policies is often overlooked (Bergek & Berggren, 2014). A means to measure the effect of energy regulations on these technological developments is an evaluation approach to the socio-technical system. By using outcome indicators, one can continuously monitor the impact of regulatory instruments on new energy technologies (Neij & Åstrand, 2006). This can prove useful for the development of hydrogen networks if it is discovered that the progress is not where it should be, changes can be made to the regulations. This might, however, require a flexible form of governance. This is a form of governance that allows for innovation to take place by having a more relaxed and reactive approach to developments (Sergeeva, 2019).

Different types of regulatory instruments that influence the innovation of energy technologies have been identified in the past. The three distinct types are technology-push, demand-pull, and systemic instruments (Pitelis et al., 2020). For each type of technology, one instrument fits better than another, but demand-pull instruments are the most effective overall. Demand-pull is where demand-related factors promote the market for and enhance the motivation of businesses to innovate (Pitelis, 2018). This can include rebates for customers or tax credits, this way increasing demand for a certain technology. These kinds of regulatory interventions should be kept in mind when designing supporting regulations for hydrogen as regulations will guide investors and businesses into adopting certain technologies and a lack of clear structure can act as a barrier in the transition to clean energy technologies (Rosenow & Kern, 2017).

Stakeholders

Understanding how stakeholders interact within existing regulatory frameworks is crucial for determining their actions due to regulatory changes and identifying new regulations that can foster the development of hydrogen networks. In recent times, stakeholders have become increasingly included in the policy-making process (Baldwin, 2019). Including sector-specific stakeholders can create bureaucratic accountability for the policymakers, as well as the legitimacy and effectiveness of regulations (Fung, 2006) (West, 2009). Stakeholder interaction can however be limited due to the lack of knowledge about the specific issue or their lack of resources to sustain long-term participation (Rountree & Baldwin, 2018). Determining whether stakeholders' viewpoints present a risk to the implementation of energy regulations requires taking stakeholder values and interests into consideration (Díaz et al., 2017). All these aspects: sector-specific stakeholders, limited knowledge, and different stakeholder values and goals, should be kept in mind when analysing and designing regulations, as they can influence the outcome of hydrogen network development.

Impact of Regulatory Uncertainty

The section above describes the different interactions that regulations have with technology and stakeholders in a socio-technical system. This description did however assume that there was certainty surrounding the regulatory frameworks in which the technology and stakeholders operate. Outlining the impact of regulatory uncertainty is key to understanding why there is a need for clear regulatory structures in the Dutch hydrogen sector.

When looking at the adoption of sustainable energy technology adoption, such as Carbon Capture and Storage (CCS), regulatory uncertainty is often pointed out as a key source of risk (Fais et al., 2016). If the regulatory environment is unstable or unclear, businesses can change their responses to the current regulatory framework, making the regulations less effective (Fabrizio, 2013). This regulatory instability can reduce the amount of new investments made in the energy sector and therefore undermine the environmental goals set by the Dutch government. Even though some regulatory changes can open new investment opportunities, too frequent changes will inhibit these investments (Liu et al., 2020). Regulatory uncertainty affects investment timing and selection when different investment alternatives exist. If regulations on emissions are uncertain, an investor is more likely to choose the cheaper, more polluting alternative than the cleaner one (Detemple & Kitapbayev, 2020).

It seems that regulatory uncertainty mostly affects the economic actions in the energy systems as it lowers stakeholder trust and therefore the amount of investments made. More specifically, the shift to renewable hydrogen is significantly impacted by the unpredictability of regulations. Various policies may suggest a carbon fee, to support green technologies, but this has not been adapted on a national scale which hampers the effectiveness of this fee (Fazeli et al., 2022). On the other hand, due to the huge investment costs and low maturity of hydrogen, investors in hydrogen technologies have to deal with enormous uncertainty (Alonso-Travesset et al., 2023). To give suppliers a bit of security when investing in hydrogen production technology, regulations on blending hydrogen into the natural gas system can be advantageous (Erdener et al., 2023). From this section can be gathered that regulatory uncertainty affects technologies, stakeholders and the adoption of new technologies in different ways. A framework outlining support mechanisms or assurances as well as the responsibilities of actors in the system can help to create an environment where all parties feel secure in investing in new energy technologies such as hydrogen. In the Next section, research into current hydrogen regulations will be discussed to show both the existing barriers and what possible support mechanisms can help accelerate the development of a hydrogen system.

1.2.2. Regulation of Hydrogen

As hydrogen is still a maturing technology in the energy sector, so is the governance surrounding it (Dixon et al., 2016). If hydrogen is to be a substantial part of the energy mix, this governance and its supporting policy frameworks need to be clear and well-developed (Hassan et al., 2024). In this section, the current barriers and possible support mechanisms or drivers will be discussed to show what the developments are in the hydrogen regulatory arena.

Barriers in Hydrogen Regulations

Some investigations have been done into the barriers and drivers of hydrogen institutions. However, a comprehensive understanding of the shift to a sustainable energy system is lacking (Hisschemöller et al., 2006). Local and provincial governments in the Netherlands are well-positioned to take the lead in developing hydrogen technology initiatives. However, they are limited by gaps in regulations for hydrogen investment and infrastructure, as well as a lack of experience in developing strategies for hydrogen development (Hasankhani et al., 2024). Understanding the barriers and drivers for the development of hydrogen infrastructures and their market can help these governments create a clear and constructive hydrogen regulatory framework.

Lowering the costs of hydrogen to be price competitive with other fuel sources is crucial for its acceptance. One of the biggest components of these costs is the transportation of hydrogen. The hydrogen system's infrastructure design will be a crucial component and its development must be supported in some way to make the business case viable (Tseng et al., 2005). When developing production facilities, special permits are required in many European countries. The specific requirements change per country, but this does add a lot of time and costs to the development of these facilities (Dolci et al., 2019). Other regulatory procedures, such as land use planning and related zoning restrictions typically do not differentiate between different techniques of producing hydrogen, which limits the incentives for local production facilities. Moreover, tariffs are still applied to the electricity used for hydrogen production. This increases the price of hydrogen making it relatively expensive. Lastly, the lack of a clear hydrogen payment framework between regions limits the overall business case for hydrogen systems (Gordon et al., 2023). This payment framework should cover things such as connection fees, use charges and re-numeration for hydrogen supplied to the system. This can be established through bilateral or multi-lateral agreements for example the UK and the EU.

All these different barriers limit the incorporation of hydrogen into the energy mix. Introducing supporting mechanisms in the Dutch regulatory framework for hydrogen can help to overcome these barriers and accelerate the transition.

Possible Support Mechanisms

Some research has been done on support mechanisms that could drive the development of hydrogen markets and networks. Current policy frameworks do not yet constitute a large push factor for hydrogen development, even though some support mechanisms have been discussed in the political arena (Bleischwitz & Bader, 2010). Because the cost of production and hydrogen pricing are directly related and cannot be completely resolved by current technologies, regulatory reform and institutional support are crucial to the hydrogen economy (Lee et al., 2024). Such support can include but is not limited to, renewable energy expansion support, carbon pricing, infrastructure development funding and sector integration (Hassan et al., 2024). It seems that carbon pricing will help to create a more competitive price for hydrogen, while infrastructure development funding will remove some of the uncertainties for investors as were discussed before.

To create a market for hydrogen, it is necessary for countries to encourage the use of hydrogen in different sectors such as industry and transport (Falcone et al., 2021). Similar to the electric car subsidy, such a subsidy can create a greater demand for hydrogen vehicles, which in turn creates demand for hydrogen. Other dated regulations should not impede hydrogen initiatives unnecessarily, such as planning and zoning (Farrell, 2023). Creating a more flexible approach to zoning could allow for these new initiatives to have a substantial impact on the transition to hydrogen.

1.2.3. Wrap-up Review

In the Sections above, many different aspects of regulations have been discussed. They can influence many different parts of a socio-technical system, such as technological development and stakeholders' actions. When regulatory uncertainty exists, the development and acceptance of new technologies is hampered. Investors are often likely to choose a cheaper alternative due to the effect of uncertainty on economic conditions, slowing down the development of hydrogen facilities and infrastructure. Current barriers in hydrogen regulations are a lack of clear payment, development and planning frameworks. The development of hydrogen can be supported by creating mechanisms such as carbon pricing, infrastructure funding and renewable energy expansion support. These mechanisms have not yet been incorporated into a single framework, which leads to uncertainty. This uncertainty highlights the necessity of analysing the current regulatory framework in the Netherlands to show what has been done in the area of hydrogen and discover what can be added to this framework to accelerate the development of hydrogen distribution networks.

1.3. Knowledge Gap

The Paris Agreement's urgency and geopolitical concerns like the Russo-Ukrainian War are the key forces driving the current speed in hydrogen research (Machado et al., 2022). The extent to which hydrogen is used will depend on how well-received it is by society, industry, and politics (Garcia-Navarro et al., 2023).

The primary objectives of hydrogen development can be divided into two parts: to provide sustainable energy carriers for hard-to-abate sectors such as transportation and industry, and to enhance the renewable energy sector by facilitating power storage (Alverà, 2021). Determining the priority between these two goals is essential, as it could significantly influence the willingness of investors and governments to offer funding or support (Machado et al., 2022). This consideration is essential for the development of hydrogen distribution in cluster 6, as it could affect financial and other forms of support. However, the Netherlands lacks a comprehensive regulatory framework that defines requirements, obligations, and roles for the hydrogen sector (OECD, 2023). This gap can create uncertainty among stakeholders and delay the investment and construction necessary for the hydrogen infrastructure.

Supply and demand determine whether it is feasible to successfully introduce hydrogen regulations and technologies into a system or industry. The introduction of hydrogen technologies and regulations is therefore a matter of timing and coordination. This phenomenon is called the chicken and egg problem (van Zoelen & Jepma, 2022). This problem is stated quite simply as follows: due to a lack of infrastructure and stable supply, there is no demand, and because of that lack of demand, there are no investments in supply and infrastructure. Regional industries may also face difficulties as a result of this. After all, what business would invest large amounts of capital in hydrogen technology if the supply of hydrogen is uncertain? The Dutch Ministry of Economic and Climate Affairs tries to address this in a letter to parliament (Ministerie van EZK, 2022b). In this letter, the minister outlines the interest of different sectors to define some form of supply and demand. It is however also stated that these interests are just a snapshot of the current situation.

Another issue in early market development is known as the "valley of death stage" (van Zoelen & Jepma, 2022). This is the stage where due to the high investment costs and low production scale, market perspectives of hydrogen are very poor. This issue will require all parties involved, including legislators and investors, to take the full value chain into account when assessing the potential of the hydrogen industry. Only then will it be possible to obtain a thorough understanding of what regulations are needed to successfully include hydrogen into the energy mix.

The government, network operators, and customers are some of the most obvious stakeholders in the Netherlands. Further in this research, all key stakeholders must be identified for the Dutch regional distribution of hydrogen to define the proper action arena. These players are bound by the regulations of the market in which they operate. This covers both the formal rules established by agreements and the unofficial rules developed by bottom-up dynamics (Rèfle et al., 2022). For the scope of this research, only the formal rules will be investigated.

As mentioned, the regulations for developing hydrogen and its regional infrastructure are still lacking. The barriers and lack of a regulatory framework can create uncertainty in the system as discussed in Section 1.2. The impact of regulatory uncertainty when developing CCS has already been researched (Fais et al., 2016), but the effects on hydrogen adaptation remain unclear. In countries such as Mexico and the US, studies have already been done on the legal structures surrounding hydrogen (Ávalos Rodríguez et al., 2022) (Bade et al., 2024). The Dutch hydrogen sector has been studied to find the current stakeholders and challenges (Hasankhani et al., 2024). However, there has not been a study into the existing regulatory framework and possible additions it might require to support the development of regional hydrogen infrastructures. Because of this local governments and many other stakeholders remain in the dark about what actions to take. This could mean that certain regulations are insufficient in guiding the development, while others might be helpful but not clear enough.

Following all the points discussed above, the knowledge gap that exists in this system is the lack of a clear regulatory framework for regional hydrogen distribution networks and how this regulatory framework influences the development of hydrogen distribution networks. Investigating this framework and its influence on the development of regional hydrogen distribution networks are the goals of this research. The questions for this research will be discussed in the following section.

1.4. Main Research Question and Sub-questions

With the main knowledge gap defined as the lack of a clear regulatory framework for regional hydrogen distribution networks and the unclear influence that this framework has on the development of these networks, the research will be focused on this, using regional industries as the basis. This choice is motivated by the fact that the Netherlands is one of the first countries with a national hydrogen infrastructure (CMS, 2022), but it still lacks infrastructure for regional industries. Additionally, cluster 6 industries experience a lot of uncertainty regarding prices, connections and capacity of hydrogen (Huneman, 2022). These issues need to be addressed by providing a clear regulatory framework. The result of this is the following main research question:

How can regulatory frameworks influence the development of the Dutch regional hydrogen distribution networks?

To be able to answer this main RQ, different parts of the system have to be analyzed. These parts will address several aspects of the problem that are vital for the understanding of the problem in its entirety. First, a good understanding of the current regulatory framework in the Netherlands surrounding regional hydrogen distribution has to be defined and subsequently analysed.

After determining the framework in place, looking into who is responsible for everything inside the system is necessary. A thorough examination of each stakeholder offers a transparent picture of the relationships and playing field. In Chapter 1.3, it has become evident that there is much doubt over the identity of the dominant authority within this system with regard to the establishment of regional hydrogen networks. Who is who in the Dutch regional hydrogen distribution system must be made clear to answer the main RQ.

It will be important to look into the stakeholders' perspectives on the regulations to comprehend the system's current challenges. The opinions of the identified stakeholders can include issues they've recognized, opportunities they may have, or a desire for particular adjustments. Before obtaining the perspectives it will be necessary to hypothesize what these perspectives could be, the method of this will be discussed in Chapter 2.

Last but not least, while creating potential pathways for regulatory improvements, it is necessary to figure out how the choices revealed by those interviewed will affect the regulatory structure and the development of hydrogen networks. Regulation changes could have a positive or negative effect on the system and are therefore crucial to understand before actual implementation.

Following this reasoning, the research is broken down into the following sub-questions (SQs):

1. What specific regulations currently govern the development of regional distribution networks of hydrogen?
2. Who are the key actors in the Dutch regional hydrogen distribution system for cluster 6?
3. To what extent do the actors perceive the current regulations surrounding regional hydrogen distribution networks as barriers or enablers?
4. What are possible additions to the regulatory framework for regional hydrogen distribution networks that will support the development of these networks?

1.5. Research Objective

This study aims to investigate and resolve a complex socio-technical problem in the Dutch energy industry. This thesis aims to define the current regulatory framework governing the regional (cluster 6) distribution of hydrogen, given the diverse range of actors, technologies, and processes in the energy industry. After the identification of the framework, the thesis will be used to describe the institutional changes and additions that are required to accelerate the development of these hydrogen networks.

Given the identified issues such as the *Chicken and egg problem* and *The valley of death stage*, it has become evident that the introduction of hydrogen in the energy systems still faces a lot of challenges. Policies can influence the outcome of the introduction of a new technology in the system and must therefore be unambiguous for all actors in the system. The aim of this Master's Thesis is to enhance the understanding of regulatory frameworks for hydrogen and to explore the application of institutional analysis in creating regulatory additions.

This research is aimed at reducing ambiguity in the regulatory framework surrounding regional hydrogen distribution. Besides this, the study will be used to provide insights into possible policy interventions or changes that can increase clarity in the framework and promote the development of regional distribution networks. The results of this thesis will be of interest to policymakers and industry professionals who are involved in the development of these networks.

1.6. Link to Study Program

The problem that has been described is linked to the master Complex Systems Engineering and Management. The Dutch hydrogen network is a complex socio-technical system with a plethora of actors and subsystems. To analyse the regulatory framework that governs this system, many different elements have to be considered. These elements include many different sets of regulations such as storage, prices, market and environment. Next to this, the effects of international policies coming from the EU only add to the complexity of the problem because they create further uncertainty.

What has been established in the paragraph above creates a direct connection between the thesis and the lessons learned from the master's degree in Complex Systems Engineering and Management. The CoSEM program provides students with the abilities and information they require to analyze complex systems. These skills include but are not limited to stakeholder identification, Institutional analysis, and system and analytical thinking. Thus by applying these skills, insightful insights will be produced through this thesis.

1.7. Thesis Outline

The structure of the thesis is as follows. In Chapter 2 the methodology of the research is discussed. It summarizes how the theory and stakeholders can be used to clarify the regulatory framework and provide insights into future regulatory changes. Next to this, the methodology is discussed using institutional analysis techniques that will be used throughout this research. Chapter 3 is used to present the background of the selected case. The role of hydrogen in the Netherlands is discussed alongside several aspects of the hydrogen value chain. Moreover, this chapter will show a list of identified stakeholders operating in the regional hydrogen distribution system in the Netherlands. Chapter 4 is used to perform and present the institutional analysis. In this Chapter all relevant policy documents will be discussed, dissected and analysed according to the institutional analysis theory. In Chapter 5 the hypotheses will be formed, again using the theory of institutional analysis, that will be used to predict stakeholders' perspectives on the state of the regulatory framework. These hypotheses will form the basis of the interviews that will be held with several stakeholders. Chapter 6 is used to present and discuss the stakeholder interviews and their results. Chapter 7 is used to discuss the conclusion, and Chapter 8 is used for the discussion and recommendations on action advice and further research.

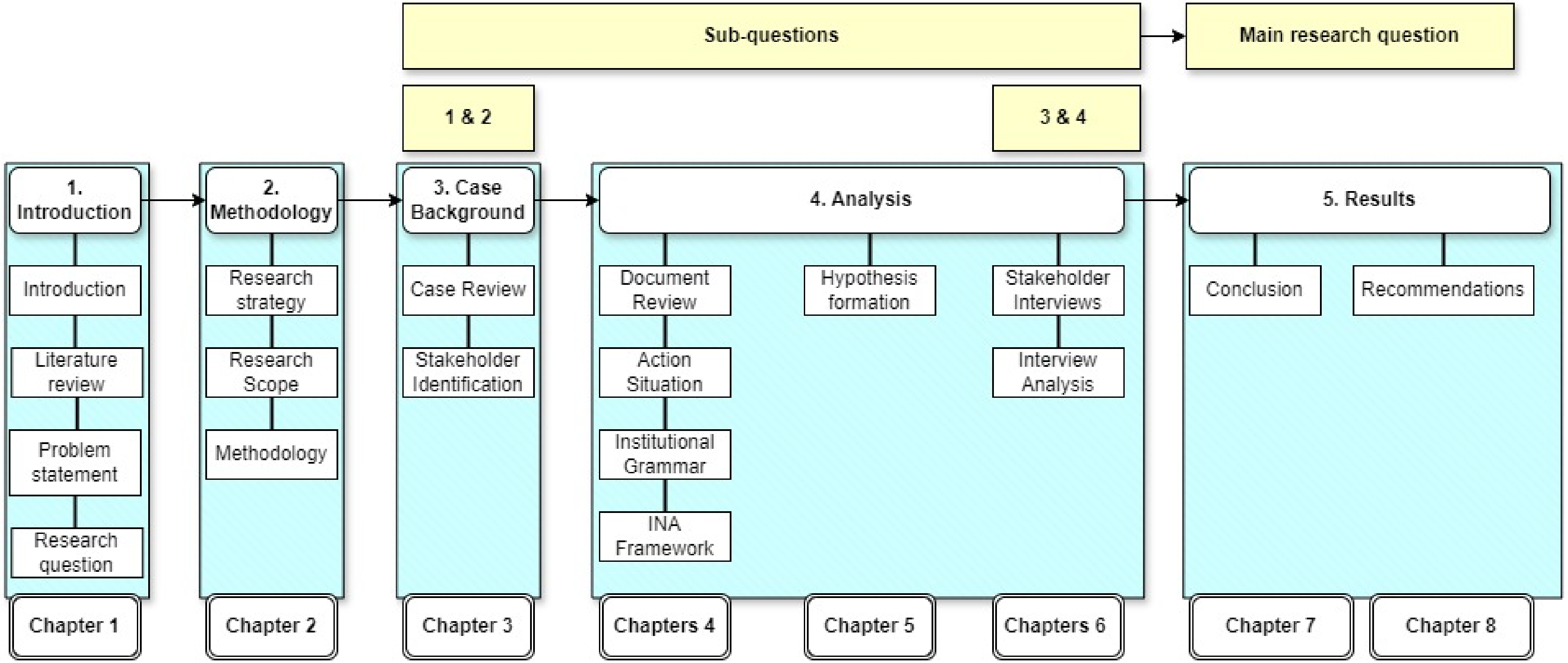

Figure 1.3: Planned Research Flow with Chapters

2 Methodology

The study's approach and methodology are discussed in this chapter. Specifically, Section 2.1 provides an overview of the research methodology, Section 2.1.1 examines the system that is to be analysed, and Section 2.2 summarizes the research steps based on INA and the different techniques used for analysing regulations. Lastly, Section 2.2.4 discusses the interview method to obtain the stakeholder perspectives on current and future regulations.

2.1. Research Approach & Scope

Chapter 1 revealed a knowledge gap, which gave the basis for the development of the primary research question that follows:

How can regulatory frameworks influence the development of the Dutch regional hydrogen distribution networks?

For this kind of RQ, a qualitative approach was best suited. More specifically, the Case Study Approach. This approach can be used to analyse a single system bounded by space and time (Hancock et al., 2021). In the case of this research: the distribution of hydrogen for cluster 6 in the Netherlands. The case study approach allows for an in-depth understanding of situations (Hancock et al., 2021). It offered the possibility to gain insight into the current regulatory framework and formulate recommendations for pathways to break certain hydrogen barriers. Additionally, it provided insights into why one implementation strategy might prove better than another (Crowe et al., 2011).

This approach was not without its weaknesses. For example, if the collected data was of too large a volume and time restrictions would have been tight, the overall depth of analysis could have been impacted (Crowe et al., 2011). Another potential pitfall could have been the lack of a basis for generalisation. Findings from the case might not be applicable to other situations, lowering the overall usability of the research. This could however be avoided if the research is transparent and its findings validated by participants.

2.1.1. The Cluster 6 System

The basic boundaries of the research have already become quite clear from Chapter 1. For this research, the regional distribution of hydrogen was investigated, using cluster 6 as the basis. The Dutch government has already suggested the investigation into Regional Energy Strategies to create local support for the transition to hydrogen (Ministerie van EZK, 2020b). Due to the "chicken and egg" problem, it was necessary to look at the regulations that span the entire value chain. Only then could the regulations be defined in such a way that they can contribute to successful integration into the energy mix (van Zoelen & Jepma, 2022). For cluster 6 a hydrogen network must be established over land and water to transport the hydrogen from central production locations to the involved sectors (Ministerie van EZK, 2020c). As cluster 6 has many different industries, future research must be done into the kind of hydrogen that will be most preferable by the industry. A regulatory standard should be established when that research is done. In Figure 2.1 an overview of the value chain of the regional hydrogen distribution system is shown, based on the stakeholder analysis of Chapter 3 and the background information discussed in Chapter 1.

In Figure 2.1 the overview was separated into two parts. The part outside the dotted line is the national hydrogen production, transportation and distribution, while the inside is the regional system that was analysed in this research.

On the outside, the large-scale hydrogen production and imports were depicted. They feed directly into the hydrogen backbone infrastructure. The hydrogen backbone crosses the separation line as it is needed for both national and regional distribution. Similarly, the regulatory bodies act in both the national and regional regulatory frameworks, for this reason, they were also placed on the edges of the dotted line.

The small part of the hydrogen backbone inside the dotted line represents the necessity of the hydrogen backbone for regional distribution. The backbone feeds into the distribution network to connect large producers with regional industries. This regional distribution network will be operated by a designated DSO. It can also be fed by regional production that does not necessarily need to be connected to the backbone. Storage can both feed and be fed by the distribution network to store hydrogen. Finally, the industrial end-users that were identified in Section 3.2.2 are the end of the hydrogen value chain.

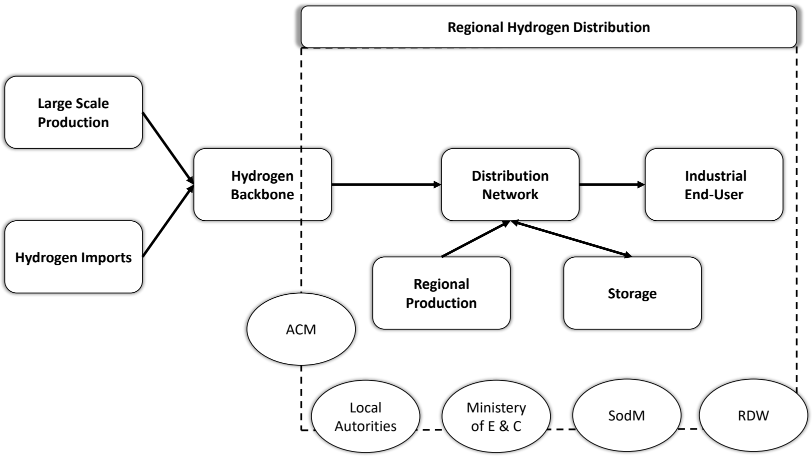

Figure 2.1: Cluster 6 System & Research Scope

2.2. Analysis Methods

Using the case of regional hydrogen distribution in the Netherlands, the steps followed in this research were highly similar to the steps that were taken in the research of (Mesdaghi et al., 2022). The adapted version for this research can be seen in Figure 2.2 The only difference was that in this research the interviews were held after the institutional analysis to gain additional insights into stakeholder preferences. The techniques that were used for this analysis are discussed in the different Sections below.

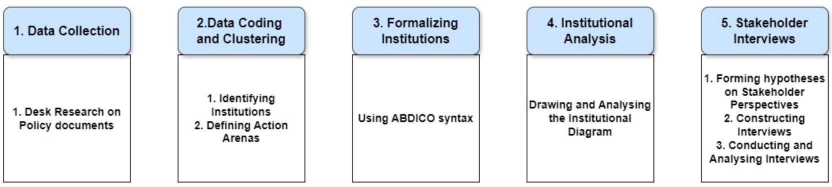

Figure 2.2: Steps for INA, (Adapted from Mesdaghi et al., 2022)

2.2.1. Institutional Grammar

For an effective analysis of the institutional framework, a good understanding of what the regulations are in this framework and how they interact with each other and the environment was needed. The underlying concepts of institutional analysis find their base in the literature described by Ostrom and other political theory and policy analysis scientists (Ostrom, 2011). By bringing together different views, Ostrom, together with Crawford, defined three different approaches to the question of ”what is an institution?” (Crawford & Ostrom, 1995).

1. Institutions as equilibria/strategies, where the focus lies on shared expectations that influence behaviour and outcomes.
2. Institutions as norms, focussing on a shared belief in proper or improper behaviour.
3. Institutions as rules, focussing on the assumption that actions might lead to sanctions if actors do not follow proscribed procedures.

By unifying these approaches under the term *institutional statements*, the institutional grammar (IG) was developed that allowed for identifying structural components of these statements and therefore easier analysis of those institutions. The general syntax contains the following five components:

Attributes, often a participant to whom the statement is applicable.

Deontic, the verb describing the action of the participant. Examples: *may, must or must not*.

a**I**m, the specific outcome that the statement refers to.

Conditions, a particular set of variables that define the what, where or how of an institution.

Or else, certain sanctions that can be imposed if the statement is not followed.

Also known as **ADICO** for short. Only for rules the whole syntax should be present, but for norms it is shortened to **ADIC** and for strategies to **AIC** (Crawford & Ostrom, 1995). This approach to analysing the institutional components is quite comprehensive, however, some issues could still be found. Sometimes uncertainties arise in identifying the Attribute if there is no explicit mention of it. To rectify this, a new element was introduced in the form of the o**B**ject (Siddiki et al., 2011). This new element was helpful when there was no definitive attribute or two actors and ambiguity existed on the rank of the element. An example of this syntax is shown below, this rule is taken from the Environment and Planning Act which will be discussed in Section 3.1.3.

Example:
Attribute Our Minister of Infrastructure and Water Management
Object an obligation to tolerate for the establishment or clearance of a gas distribution network as referred to in Article 39a of the Gas Act
Deontic may
Aim impose
Conditions after consultation with Our Minister for Climate and Energy
Or Else n.s.

This total syntax **ABDICO** helped to dissect all institutions, current or future, but it still did not describe their influence in a system. For this, a broader framework has been developed over the years in conjunction with the rules stated before.

2.2.2. The IAD Framework

The Institutional Analysis and Development Framework (IAD), is an encapsulation of collective efforts to understand the interactions and changes of institutions over time (McGinnis, 2011). The framework provides a basis when studying collective actions in the policy-making process while taking into account other factors such as material or biophysical conditions (Siddiki & Frantz, 2022). The basic component structure seen in Figure 2.3 is a simplified representation of the institutional interactions.

In this figure, the exogenous variables are all contextual factors within a system such as cultural, social or physical environments. The action situation is the ”black box” where policy decisions are made. These policy decisions will be evaluated by actors within the system, and they will have certain outcomes and interactions with one another. Defining the correct action situation in the case of regional hydrogen distribution will be key to understanding the institutional relations and system dynamics. The

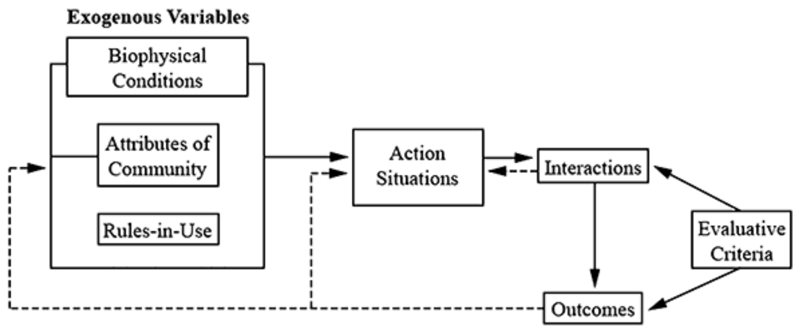

Figure 2.3: Components of IAD framework, (McGinnis, 2011)

nature of the exogenous variables, the action situation, evaluative criteria and the participants are varied and can differ per context that is observed (McGinnis, 2011). For example, when studying the use of natural resources, or in the case of this research, the use of a network, property rights are an especially important form of institution as they define the right to use and benefit from a certain asset (Gibbons & Roberts, 2012).

2.2.3. Institutional Network Analysis

Pathways for climate adaptation are influenced by interdependencies among infrastructures (Mesdaghi et al., 2022). Measures to adapt these infrastructures rely on effective institutions to be put in place. To analyse the issues faced by local governments Masdaghi (2022) also introduces Institutional Network Analysis (INA) to study the dependencies between institutions. They applied this method to analyse climate adaptation methods for the Port of Rotterdam, but can equally be used for regional hydrogen distribution networks.

INA is a tool that visualizes institutional connections and it allows for the identification of issue points in the framework, such as conflicts of voids. The present literature acknowledges the relationships between institutions. One such example is the *institutional complexities*. This relates to how different organizational bodies interact on certain activities (de Bruin et al., 2009). This can include organizational consequences and cooperative relations between the different bodies. Another example that Mesdaghi (2022) states is the notion of *institutional conflict*. These conflicts happen when different regulations exist at different levels of governance, which in turn can lead to conflict in the regulatory structures (Biesbroek et al., 2009). In the case of regional distribution, these complexities will occur between the Dutch national and local governments. INA uses these notions together with IG and the IAD framework to perform analysis and contribute to the knowledge base (Mesdaghi et al., 2022). The representation of an institutional statement is based on IG and can be seen in Figure 2.4. The attributes, Conditions and Objects are the nodes, while the Deontic and Aim are the links.

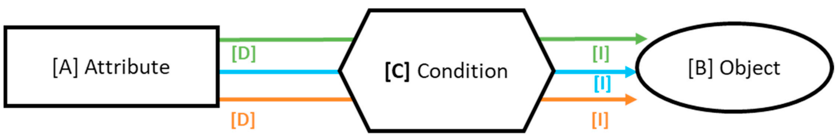

Figure 2.4: Representation of Institutional Statement, (Mesdaghi et al., 2022)

The research was started by collecting data through desk research. In this desk research, open sources were used to review all policy documents applicable to the case of regional hydrogen distribution. These documents helped to define the action situations for analysis. The institutions were formalized using

IG, coded into Excel and represented graphically using the method seen in Figure 2.4.

After the formalization of the institutions, the network diagrams were drawn. An Institutional Network Diagram (IND) is the final representation of the interconnected institutional statements in an action arena. These connections were made from the "Object" of one statement to the "Condition" of another statement as seen in Figure 2.5a. Whenever an actor in the system has not complied with a statement, that statement is linked to a sanctioning statement. An example of this can be seen in Figure 2.5b.

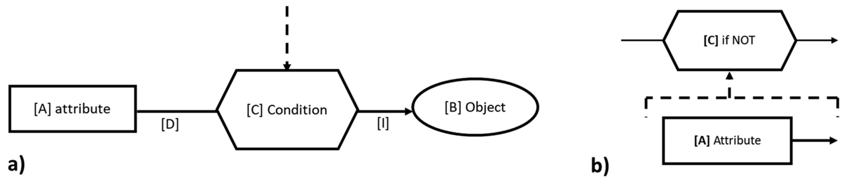

Figure 2.5: Regulatory connection coded using INA, (Mesdaghi et al., 2022)

Points of concern within the network diagram can be represented with a star. This often happens when two identical statements have different objects or aims. Examples of this can be seen in Figure 2.6. Another form of concern might be a missing connection between regulations where one might expect a connection. These points of concern can be used as the basis for the hypotheses formulation that follows.

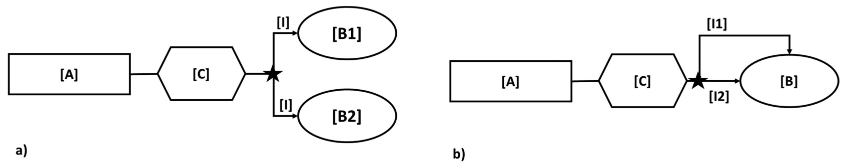

Figure 2.6: Regulatory conflict coded using INA, (Mesdaghi et al., 2022)

2.2.4. Hypotheses and Interviews

After all the data was collected from the policy documents, stakeholders were interviewed. These interviews were used to obtain additional insights into the perceptions of the stakeholders on the current & future regulatory framework as well as their preferences for possible changes or additions to the regulatory framework. This Section first describes the hypothesis formation and gives an example hypothesis. After this, the interview method and possible interview candidates will be discussed.

Hypotheses

The process of hypothesis formulation occurred naturally out of the identified gaps and points of conflict that were found using the INA. Based on the institutional analysis and network diagrams, these hypotheses tried to address what the stakeholders' perceptions of the regulatory framework could have been. It was important to keep the hypotheses invisible from the participants as it could have led to conformation bias (Leyens et al., 1998). Hypotheses only formed the basis of the interview topics. One example of a hypothesis based on institutional analysis is:

"The absence of a regulatory framework for subsidizing hydrogen networks slows down the development of these networks."

This hypothesis fell under the topic of financing, however many more topics surrounding hydrogen distribution networks were used. All different hypotheses were formulated and discussed in Chapter 5.

Interviews

After the formulation of these hypotheses, stakeholder interviews were held to obtain additional information and confirm or reject the hypotheses based on the stakeholder perceptions. Semi-structured interviews were used as the interview structure. This method was chosen because semi-structured interviews are the preferred data collection method when the goal is to obtain an actor's personal, unique perspective on the system (Adeoye-Olatunde & Olenik, 2021). This structure allowed for some guidance on specific topics but left room for open conversations and debate during the interview. Specifically when analysing the actor's behavioural alignment with the institutional framework, this method is useful (Ghorbani et al., 2022).

To obtain insights from all possible angles it was preferable to interview several different stakeholder groups that will be identified in Section 3.2. The goal of this study was to interview regulatory bodies, several companies active in the Dutch hydrogen sector and several DSOs. The complete list of interviewed actors was depicted in the table 2.1. The actors interviewed all have a stake in the regional hydrogen distribution sector but look at the development problem from different perspectives. By interviewing these different actor groups, the goal was to obtain diverse insights into the stakeholder perspectives. As each actor has different goals, they might perceive regulations differently and can have a unique view on what should be changed or added to the regulatory framework.

Actor Group	Respondent
Regulatory Bodies	1. The municipality of Kapelle
DSOs	1. Stedin 2. Alliander
Companies	1. Groenleven 2. ZonXP
Scientists	1. Top Sector Energie

Table 2.1: Interviewed Actors

Out of the actor groups, several participants were approached. The first group are the regulatory bodies. Municipalities where hydrogen projects are currently active or planned will be interesting regulatory bodies as they deal with hydrogen pilots. One such municipality is the municipality of Kapelle. The second groups are the companies. When interviewing companies it was important to consider the whole value chain. Regulations govern the whole system and companies are thus exposed to these regulations at every step. Two companies that were identified are Groenleven and H2XP. They are companies that focus on the production of hydrogen but also the needs of their end-users. They cooperate with end-users to find practical and efficient solutions. As they cover most of the value chain, they can provide insights into the regulations they face during their practices. As the third group, DSOs are a huge stakeholder in the development of hydrogen networks and thus an actor group that needs to be interviewed. As will be seen in Section 3.1.2 several large DSOs govern most of the Dutch electricity and gas grids. As they are likely to play a role in hydrogen distribution networks, they are the prime candidates to be interviewed. Lastly, a scientist who works for an overarching energy organisation was interviewed to get yet another, wider perspective on hydrogen regulations.

Because of the small interview pool, some risks do apply to this method. Due to fewer participants, there is a higher chance that the outcomes will be influenced by individual biases (Noble & Smith, 2015). Secondly, the small interview pool may not represent the broader population, making it difficult to generalize the findings to a wider context (Button et al., 2013). However, due to the limited time available for this research, these risks were accepted. Future research will need to involve a much broader interview pool to eliminate the mentioned risks.

Contact details of the actors have been obtained using the Stedin network. Each actor was approached using an email explaining the research, their role in it, and possible interview times. After their approval, a consent form was given to them and signed. This form explains how their data was handled and what it was to be used in the research. The interviews were held via the platform Microsoft Teams, which was used to record the interviews. After the recording, the interviews were transcribed and summarized. This summary was sent back to the respondents for their approval and put into Appendix E. The results of the interviews are discussed in Chapter 6.

As discussed the methodology of this research will integrate various research methods. Following the steps outlined in Figure 2.2, the analysis will progress from a broad to a focused perspective. Each step will build on the previous one, ensuring a scientifically sound overall research framework. In the next chapter, the background of the case will be discussed, outlining the role of hydrogen in the Netherlands, identifying key actors in the regional hydrogen distribution system, and identifying the most important regulatory documents. The documents will be analyzed using the methods described in this chapter.

3

Case Background

In this Chapter, in-depth background information on the case is presented. The Chapter has been divided into two Sections; Section 3.1 discusses the state of hydrogen, and Section 3.2 is used to present the stakeholders that have been identified as actors in the system of Dutch regional hydrogen distribution.

3.1. The State of Hydrogen

This section describes the current standing of hydrogen. First, hydrogen's role in the Dutch energy mix and its future is discussed. Secondly, the entire hydrogen value chain is dissected. Section 3.1.3 is used to discuss the regulations that currently govern hydrogen in the Netherlands.

3.1.1. Role of Hydrogen in the Netherlands

As mentioned in Chapter 1, due to concerns about climate change and issues with energy security, the Netherlands has set ambitious goals for sustainable energy usage. The primary measure for achieving a carbon-neutral society is the substitution of fossil fuels with renewable energy sources (RES). Due to the intermittency of RES, storage will be needed to compensate for this characteristic. Hydrogen is seen as the prime solution for this problem (Kovač et al., 2021). For grid-scale applications, the storage of green hydrogen, which is made using RES, is the most suitable option (Qudaih et al., 2024). The produced hydrogen can be transported in many different ways, with pipelines being the most cost-effective method (Faye et al., 2022). As was discussed in Chapter 1, a national grid is already being developed in the Netherlands exactly for this purpose.

The hydrogen currently produced can be split into two categories: Hydrogen produced using fossil fuels and hydrogen produced using RES (Qureshi et al., 2023). Nowadays 95% of the world's hydrogen produced is brown or grey and is created through steam reforming with fossil fuels as the energy source (Nikolaidis & Poullikkas, 2017). In the Netherlands, about 80% is produced in this way, the other 20% are by-products of other chemical processes (MilieuCentraal, 2022) The remainder of the world's hydrogen is made up of 4% RES-based green hydrogen and 1% blue hydrogen, which is produced similarly to brown or grey hydrogen mitigating the CO2 using Carbon Capture and Storage (CCS) systems (Lagioia et al., 2023). Green hydrogen is seen as the holy grain in terms of a sustainable energy carrier and a way to decarbonize the energy system. However, for the hydrogen market in the Netherlands to grow, blue and grey are still needed (Alverà, 2021).

Hydrogen has three main ways it can be utilized: as an energy carrier, as a feedstock and as a fuel. (Ishaq et al., 2022). These possibilities allow many sectors to use this resource, with industry, transport, buildings and power being the key sectors for hydrogen uptake (Taibi et al., 2018). As a fuel, hydrogen can replace old-fashioned petrol and possibly even kerosine to still allow for long-range travel using conventional vehicles such as trucks and planes (Farias et al., 2022). As a feedstock, it has been used for ages in the fertilizer industry to produce ammonia (Alverà, 2021), but it can also be used in the most polluting industry: iron and steel manufacturing. Refining is one of the biggest industries in the Netherlands and the second biggest sector in the world utilizing hydrogen at the moment. Here hydrogen is utilized in the processes of hydrocracking and hydrotreating (Nicita et al., 2020). This sector in the Netherlands can account for a quarter of the emission reduction goals (KIVI, 2023). Hydrogen can target many polluting sectors, helping the world lower overall CO2 emissions. However, to integrate hydrogen with these sectors and the energy sector overall, boosting demand and production quantities are essential, necessitating the creation of a supportive policy environment (Kovač et al., 2021).

The vision of the Dutch government for hydrogen is that it will play a vital role in the energy system, mainly to be used in the industry and transport sectors (Ministerie van EZK, 2023). By 2040 the government hopes to have established renewable energy in the form of wind at sea with a capacity of 50 GW (NWP, 2022b) and a total electrolyser capacity of 3 GW for the production of green hydrogen (Ministerie van EZK, 2020a). By using the existing gas network and depleted gas fields for storage, the Dutch government already feels they have a head start with the development of a national hydrogen network (NWP, 2022b).

3.1.2. Hydrogen Value Chain

For this research, the hydrogen value chain has been separated into three sections: Production, transportation/distribution and End-Use. Even though this research only focuses on distribution, the other categories are still needed to develop and sustain a transportation network.

Production

In the Dutch hydrogen value chain, production, next to imports, is the first step. As discussed in Section 3.1.1, hydrogen production can be split into two categories: fossil-based and RES-based. A wide variety of production processes can be classified under these two categories (Nikolaidis & Poullikkas, 2017) as seen in Figure 2.1. In this research, only the most used methods in the Netherlands are discussed.

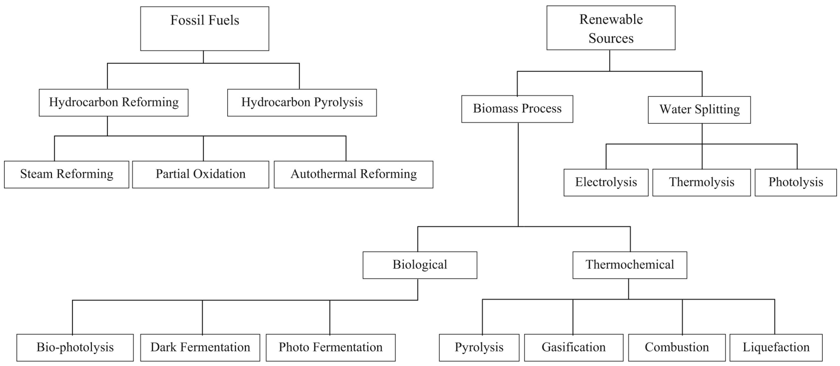

Figure 3.1: Hydrogen production processes, (Nikolaidis & Poullikkas, 2017)

For grey and blue hydrogen production the fossil fuel category is used. Currently, the maximum hydrogen production method for these hydrogen colours is seen using the method of steam reforming (El-Shafie et al., 2019). The method of steam reforming uses a catalytic conversion of hydrocarbons and steam to hydrogen and carbon oxide (Nikolaidis & Poullikkas, 2017). The hydrocarbons most often used in this case are methane and other natural gases. The purity achieved is nearly 100% at a cost of 2.27$/kg for blue hydrogen and 2.08$/kg for grey hydrogen (Bartels et al., 2010).

To obtain green hydrogen, RES must be used. The most established, effective and well-known method for green hydrogen production is electrolysis. The most commonly used technologies are alkaline and the proton exchange membrane (PEM). With this technology, water is split into H2 and oxygen within an electrolyser unit using electricity generated by wind, solar or nuclear sources (Nikolaidis & Poullikkas, 2017). The efficiency of these methods can be up to 73% and at a cost ranging from 5.10 to 10$/kg, depending on what kind of RES is used.

Transportation

Hydrogen at a standard operating temperature of 25 degrees is in a gas state. In this state, 1kg of hydrogen will fill a volume of 11 m^3. Next to this, hydrogen is an extremely volatile compound, making it necessary to consider these properties and safety protocols to transport it properly (Faye et al., 2022). Different methods of transportation have been developed over the years, for in this research, two methods of gaseous hydrogen transportation are discussed.

The first method is transportation by tube trailer. These trailers are similar to the fuel trailers seen on the roads today, the difference will be that the hydrogen in these trailers is compressed, which allows for about 400kg of hydrogen per truck (Qureshi et al., 2023). This method can only be used for small amounts where demand is low or during the initial start-up period of a consumer using hydrogen. The costs of this transport method will be around 2.80$/kg of hydrogen (Faye et al., 2022).

The second method is transportation via pipelines. As discussed in Chapter 1, these pipelines are not very different from those used for the current gas network. These hydrogen pipelines can transport up to 100.000kg/h. These networks are useful to supply high-demand areas but will require an increase in production capacity to ensure a balance between supply and demand (Qureshi et al., 2023). This transportation method is considered the most cost-effective way, at a cost of around 2.70$/kg (Faye et al., 2022). It has already been shown that hydrogen can be mixed into the current gas network with small quantities (Rasul et al., 2022). This will allow for the early development of the hydrogen market. For regional industries in the Netherlands, this method will require more investments in the regional distribution networks to connect industries with producers.

End-Use

The possibilities for hydrogen usage are extremely diverse. Some were already discussed in Section 3.1.1, and because of that, the two maturing usages that are relevant to the Dutch energy sector will be discussed here.

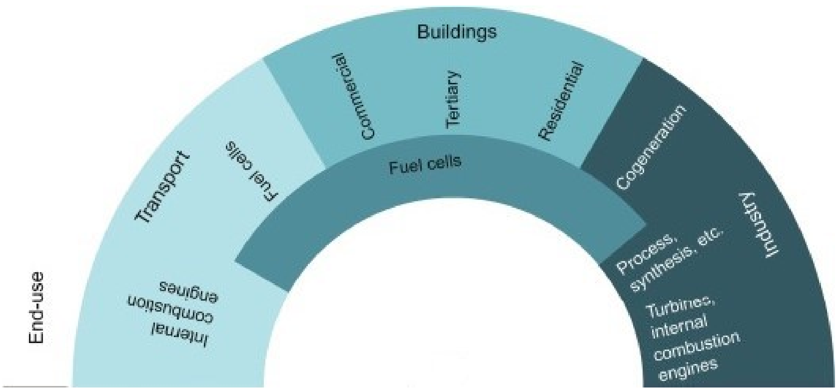

Figure 3.2: Hydrogen Applications, (Adapted from Mansilla et al., 2018)

One of the most direct usages of hydrogen is in the transport sector. Here it can be used as a mixture with fossil fuels in traditional internal combustion engines (Rasul et al., 2022). This still leads to CO2 emissions and is therefore not preferable. The other way to use hydrogen is via a hydrogen fuel cell. This is basically an electrolyser in reverse, using the produced electricity to drive an electromotor. Using hydrogen for transport will drastically reduce the CO2 emissions of the sector. Apart from this, it can be more user-friendly than battery-powered vehicles, due to the much shorter refueling times and lower vehicle weight (Alverà, 2021).

An application that is more relevant for this research is hydrogen usage as a high-heat source. Industries such as steel, ceramics and glass require high heat in their furnaces to melt their raw ingredients (Wulf & Zapp, 2023). Until now fossil fuels are used in this process such as coal or gas. However, hydrogen is being considered to drastically lower the CO2 emissions of these industries (Sundaram, 2022). Studies have been conducted to show the effectiveness of hydrogen to replace natural gas. In steel production it is always effective in reducing CO2 emissions and costs (Marocco et al., 2023). It is mentioned that these scenarios assume a high share of hydrogen, showing the importance of reliable supply and infrastructure.

3.1.3. Hydrogen Regulations

Due to the relative infancy of hydrogen in the energy market, regulations surrounding it are currently either missing or vague (OECD, 2023). The regulations that do exist are mostly focussed on industry under the European Industrial Emissions Directive (Dolci et al., 2019). To allow the hydrogen market to develop a comprehensive regulatory framework is needed. This regulatory framework must provide producers, users, and operators with clarity and direction surrounding the development of hydrogen distribution networks. The goal of this section is to provide initial insights into SQ1: *What specific regulations currently govern the development of regional distribution networks of hydrogen?* The conclusion of these insights will be discussed in Chapter **??**.

Through desk research and conversations at Stedin, the policy documents listed in Table 3.1 were identified as the most relevant to the current hydrogen distribution infrastructure. The criteria that were followed when selecting these documents were: Connection to the Dutch energy system, Connection to Hydrogen, Connection to DSOs, and connection infrastructure development. The most recent of these documents to be implemented is the Environment and Planning Act (EPA). This Act went into effect on January first 2024 and it consolidates old laws and contains rules for what can be seen, heard, and smelled outside (Ministerie van BZK, 2024c). This includes the spatial planning and zoning of the production and transport infrastructures.

Since there is no specific hydrogen legislation yet, the available documents on gas and electricity are the most relevant. This is because they govern both the gas and electricity infrastructure (Ministerie van BZK, 2024b) as well as the role of operators and marker activities (Ministerie van BZK, 2024b) ,(Ministerie van BZK, 2024a). It is therefore the current Dutch governance of their energy system. The Dutch government is currently underway to develop a single legislative bill to substitute both of these policy documents. The so-called Energy Act aims to remove differences between the two and provide a modern framework (Ministerie van EZK, 2019). As this law is not yet in effect it will be analysed as a future regulatory document in Section 4.3. The minister did, however, outline the goals and role of the HNS in a letter to parliament. This letter is useful as it outlines the perspective the government has on the long-term development of the national hydrogen network.

Lastly, to support hydrogen projects currently under development, both the government and the Autoriteit Consument and Markt (ACM) have developed temporary frameworks and guidelines. The Temporary Hydrogen Pilot Framework allows for hydrogen pilots in the built environment as long as the companies conducting them can provide sufficient safety and consumer protection (ACM, 2022). To help with the safety surrounding hydrogen, the Dutch government has provided guidelines that give the companies an anchor for their projects (Ministerie van EZK, 2022a).

Policy Document	**Policy Scope**
Environment and Planning Act (Omgevingswet)	Defines requirements for spatial planning and zoning of production and pipeline transport
Gas Act (Gaswet)	Defines requirements for gas infrastructure operation and role of grid operators
Electricity Act (Elektriciteitswet)	Defines rules and requirements for electricity infrastructure, market and activities.
Letter to Parliament on the Development of a Hydrogen Transport Network	Defines the role of the HNS and goals of national hydrogen transportation network
Temporary Hydrogen Pilot Framework (Tijdelijke kader waterstof pilots)	Describes requirements to support hydrogen pilot projects
Guidelines Hydrogen (Richtsnoeren Waterstof)	Defines Safety regulations for hydrogen projects to substitute missing legislation

Table 3.1: List of Relevant Policy Documents

3.2. Stakeholder Identification

Stakeholders identification and mapping are used to identify the interests, power, and influence of the various stakeholders in a certain system (Aligica, 2006). The influence of stakeholders is strongly connected to the institutional environment within which they interact. Therefore, It is a necessary, useful investigative tool when analysing regulatory frameworks.

In this Section, the stakeholders that are active in the Dutch regional hydrogen distribution networks will be discussed. This system contains both regulatory bodies and policy subjects. For the sake of clarity, these will be discussed separately. Lastly, to show their power and interest in the development of such networks, a power/interest matrix will provide insights into the positions of the identified stakeholders (Newcombe, 2003). The goal of this section is to provide initial insights into SQ2: *Who are the key actors in the Dutch regional hydrogen distribution system for cluster 6?*

3.2.1. Regulatory Bodies

At this moment there is no real specific regulatory framework for hydrogen, but this is being worked on by regulatory bodies such as national and international governments (Ministerie van EZK, 2020b). Because of this, the existing laws on gas, transport and heating apply to hydrogen. One such example is that, outside the general competition law, there are no sector-specific market rules for hydrogen and the transport of hydrogen.(ACM, 2021). The responsibility of hydrogen projects, and thus the development of regional hydrogen distribution, is not controlled by any specific regulatory organization. Rather, several regulators are responsible for different aspects of the activity (CMS, 2022), which, as was seen in Section 2.2.3, can lead to institutional complexity and conflicts. This again highlights the necessity of streamlined and clear regulations for the entire value chain.

In the Netherlands, several different regulatory bodies oversee the hydrogen arena. Their regulatory roles are diverse, ranging from land use, storage (SODM, 2022) and infrastructure, safety (Ministerie van EZK, 2022a) to transport vehicles (RDW, 2024). Clear definitions of the most important regulatory bodies and their role are shown in Table 3.2. Most of the regulatory bodies find their base in the executive branch of the government (McCubbins, 1985), so it stands to reason that the regulatory bodies for regional distribution of hydrogen in the Netherlands are also government entities. Even though EU regulations affect Dutch regulations, no EU entities are considered here. This is because the international regulatory guidelines must be translated to national regulations (Commissie, 2024), mostly done by the entities stated in Table 3.2. As was seen in Chapter 1 local authorities, are in a key position for enabling the transition in regional environments, but they lack the proper skills to guide this transition efficiently. For example, in the development of district heat, their lack of know-how was the source of dependencies on external knowledge (Herreras Martínez et al., 2022). It stands to reason that for the development of hydrogen networks, this will not be very different.

Regulatory Body	**Regulatory Role**
Local Authorities, Municipalities and Provinces	1. Land use regulation 2. Environmental Impact Assessments
State Supervision of the Mines (SodM)	Regulates the safety of hydrogen storage
Rijksdienst Wegverkeer (RDW)	Hydrogen transport vehicles regulations
Ministry of Economic & climate Affairs	1. Regulation of new pipelines 2. Safety Regulations
Autoriteit Consument & Markt (ACM)	1. Regulates the gas network 2. Created framework for Pilot projects

Table 3.2: List of Regulatory Bodies in the Netherlands, (adapted from CMS, 2022)

3.2.2. Policy Subjects

On the other side of this arena are the policy subjects. They are companies or other entities that will have to abide by the policies laid down by the regulatory bodies. They can shape the regulatory framework through political activities (Stenzel & Frenzel, 2008).

In the Netherlands, the stakeholders in the hydrogen distribution sector are plentiful and diverse. In one study, 264 distinct entities were identified and categorized into seven groups (Hasankhani et al., 2024). Most of these groups will in some way also play a role in regional hydrogen distribution. Hasakhani divided the groups as follows: "Primary Producers and Suppliers," "Infrastructure, Storage and Distribution," "Intermediaries," "Technology and Service Providers," "End-Use," "Policy Makers and Regulators," and "Research and Education." As can be seen, policymakers and regulators have already been discussed in Section 3.2.1. The complete holistic view of Hasankhani et al., 2024 can be found in Appendix A. As that view analyses more than the scope of this research, the most important stakeholders for regional distribution will be discussed below.

As this research looks at the hydrogen distribution regulations, the following categories will be discussed a bit more in-depth to clarify the stakeholders in this arena: 1. Primary Producers and Suppliers 2. Infrastructure, Storage and Distribution & 3. End-Users. This ensures a good overview of the stakeholders in the value chain from start to finish. This overview is needed because, as discussed in Chapter 1, problems such as the "Valley of Death" require all stakeholders, such as investors and regulatory bodies, to be included in the entire value chain when analyzing the hydrogen market potential. (van Zoelen & Jepma, 2022).

Producers and Suppliers

The discussed problems of the "Valley of Death" and the "Chicken and Egg" have roots in the supply side of hydrogen. The lack of sufficient hydrogen capacity is often seen as a barrier to hydrogen acceptance (Gegesi-Kiss, 2021). Because of this, producers and suppliers are essential to accelerating the development of hydrogen infrastructures. Most hydrogen producers now still operate in the petrochemical sector, producing grey or blue hydrogen, but green and local hydrogen production capacity is steadily climbing due to the increase in renewable energy sources (Hasankhani et al., 2024). This production capacity will however not be enough for the goals set by the Netherlands and the European Union. That is why the EU hydrogen strategy still relies heavily on imports (Dejonghe et al., 2023). By using the already established ports in the Netherlands and Nothern Europe, this import will be vital for the development of the hydrogen market. The Netherlands has many different projects for hydrogen production. These range from integrated projects offshore, such as the PosHydon project (PosHYdon, 2024), and onshore projects such as Duwaal (HYGRO, 2024) and the Shell Holland-hydrogen 1 in the Port Of Rotterdam (Shell, 2024). All of these projects can help increase national production and supply of hydrogen and therefore large producers can be seen as a key stakeholder group.

However, as long as these imports and large production installations are not connected to regional industries, this will not be useful for cluster 6. That is why local production and supply must also be considered. Some companies are already working with the DSOs to realise this. By investing in renewable technologies and storage solutions H2XP (EnergieXP, 2024) and GroenLeven (Groenleven, 2024) are contributing to the acceleration of the energy transition. Together with the large producers and suppliers these smaller suppliers are a key stakeholder group in the development of regional distribution of hydrogen.

Infrastructure, Storage and Distribution

This stakeholder category is responsible for managing and constructing the infrastructure that is required for hydrogen distribution (Hasankhani et al., 2024). On the National level, this is the Transmission System Operator (TSO). In this case, this is Gasunie's subsidiary HNS. On a regional level, this responsibility falls on the Distribution System Operators (DSOs). The DSOs are seen as key stakeholders, due to their role in developing the energy infrastructure based on the Regional Energy Strategies conducted in the Netherlands (Bochove, 2019). These strategies play a pivotal role in achieving the goals set in the Paris Agreement in 2015, by outlining goals and choices made by the Dutch energy regions (NationaalRES, 2020). In the Netherlands, there are six different DSOs. With Stedin, Liander, and Enexis being the three biggest and Conteq, Rendo and Westland Infra being the three smaller entities (NetbeheerNL, 2024). The regions in which these operators are active can be seen in Figure 3.3. As cluster 6 is spread throughout the country all DSOs may be in some way connected to this cluster. However, due to the small active area of the smallest three DSOs, only Stedin, Liander and Enexis will be considered in this stakeholder identification.

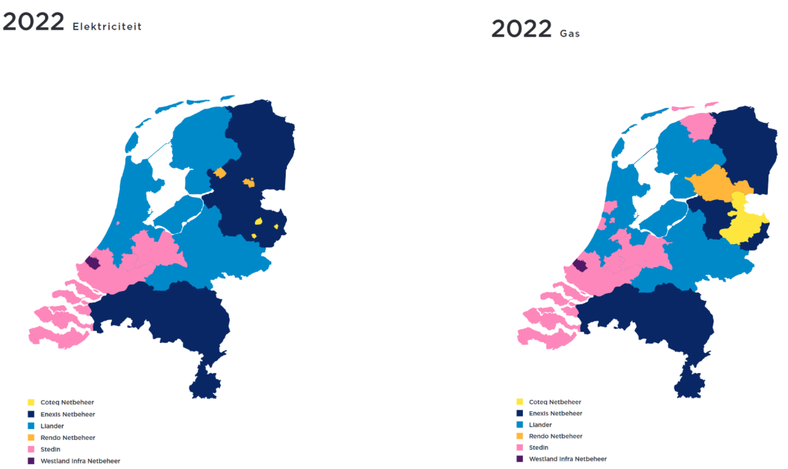

Figure 3.3: Active area DSOs, (NetbeheerNL, 2024)

End users

The end users in the complete hydrogen arena can be diverse, ranging from the large-scale industry to the mobility sector (Ueckerdt et al., 2021). They represent the other side of the problems stated before. If there is no demand for hydrogen, producers and suppliers will not be tempted to invest in their production capacities. The scope of this research does not apply to the large industry and mobility sectors, but rather to the industries active in cluster 6. This cluster is diverse, with 9 different industries (Huneman, 2022). All of these industries could have an interest in hydrogen in one way or another. For example, the glass industry might use it as a heat source for their industrial processes. Because all parties might be interested and are therefore candidates for future interviews, representatives of each industry in cluster 6, are listed below:

1. FNLI: Food Industry
2. FME and Metal Netherlands: Metal Industry
3. KNB: Ceramic Industry
4. NLDigital: ICT Sector
5. NOGEPA: Oil and Gas Exploration Companies
6. VA: Waste and Recycling Sector
7. VNCI: Chemical Industry
8. VNG: Glass Industry
9. VNP: Cardboard and Paper Industry

3.2.3. Power/Interest Grid

When developing a project it is necessary to manage all involved stakeholders (Maqbool et al., 2022). To gain insights into their levels of power and interest in a certain system the Power/interest Grid was developed (Eden & Ackermann, 2013). It is often used to help managers assess which stakeholder needs special attention. This special attention is needed due to their high interest and/or power in the system in which they operate. For this research, identifying stakeholders in this manner is useful as interested stakeholders will provide interesting interview candidates. The grid is divided into four sections as shown in Figure 3.4. These sections categorize the stakeholders into four groups: Crowd, Context setters, Subjects, and Players (Ahsan & Pedersen, 2018).

Players and Subjects are the stakeholders that will be potential interview subjects because they both have a high interest in the regulatory arena. Subjects have low power compared to the Players, making their opinion on the regulations fascinating as their influence on them is limited. Context setters have high power but low direct interest in the arena and finally, the crowd consists of stakeholders with low

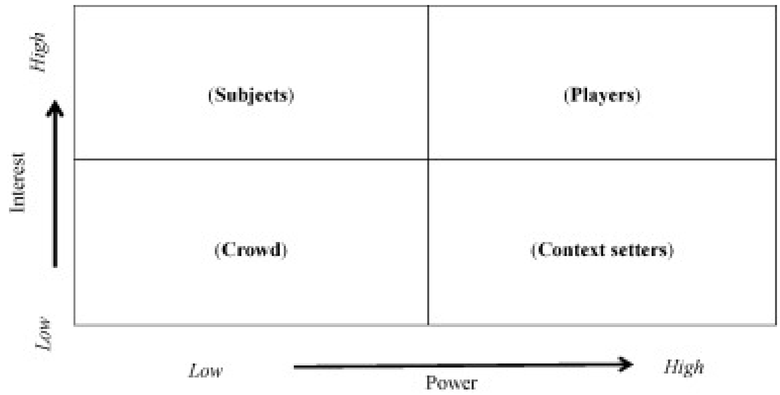

Figure 3.4: Example Power-interest grid, (Ahsan & Pedersen, 2018)

interest and low power. Dividing the stakeholders in a certain system will help to clarify who is most important for the researcher.

In the case of this research, this grid will be used similarly, by using it to identify which stakeholder can prove to be an interesting interview candidate by identifying their power in the regulatory system of regional hydrogen distribution networks. As was discussed in Section 3.2.1 several different regulatory bodies are responsible in the Netherlands for hydrogen regulations. Together with the different groups of stakeholders mentioned in Section 3.2.2, they will form the groups categorized in the power-interest grid shown in Figure 3.5.

Following the identification, it is a logical step to put all the regulatory bodies in the player section of the grid. All the players, Local Autorities (LA), State supervision of the Mines (SodM), Rijksdienst Wergverkeer (RDW), the Ministry of Economic and Climate Affairs (E & C) and the Autoriteit Consument & Markt (ACM) have high interest and power. This is because they are all highly invested in achieving the government's climate goals and are capable of setting regulations that govern the development of the hydrogen distribution network in one way or another.

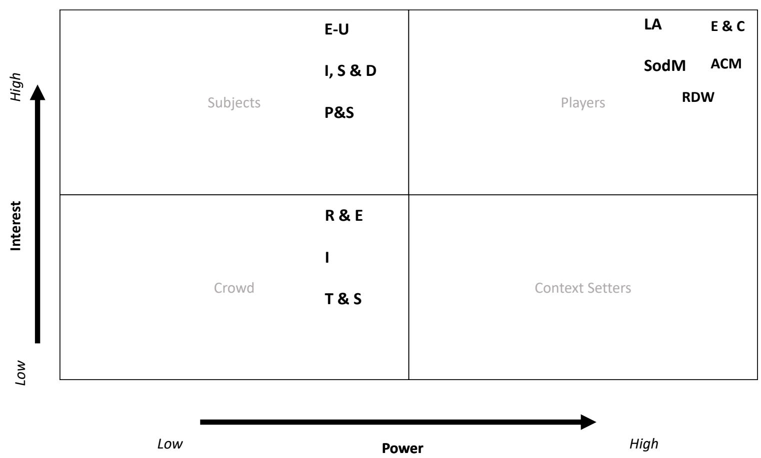

Figure 3.5: Power-Interest Grid Regional Hydrogen Transportation & Distribution

Entities with less power in the regulatory arena are the policy subjects. They still have a high interest in the system because they are directly involved in it. The Infrastructure Providers for Storage and Distribution (I, S & D), in the case of this research the DSOs, must provide the regional infrastructure but cannot directly form regulations, similarly, the End-users (E-U) and Producers/Suppliers (P & S) are at both ends of the value chain but cannot create regulations.

Lastly, the other stakeholder groups that Hasankhani mentions are: research and education (R & E), Intermediaries (I), and the Technology and service providers (T & S). In the case of regional hydrogen distribution, these groups are the crowd. They have no power when it comes to regulation formation and less interest than the active groups discussed before.

Now that the case background has been laid down and the most important current regulatory documents have been identified, the first part of the institutional analysis can be done. The case background revealed several actors who are interested and powerful stakeholders in the system. They are the primary candidates for the interviews. The document identification revealed several policy documents that will be analysed in the following Chapter.

4 Institutional Analysis

The Netherlands has set climate goals as discussed in Chapter 1 in which widespread hydrogen use plays a role. To achieve this goal, regional hydrogen distribution networks are needed. To promote the development of hydrogen distribution networks clear regulations can provide guidance for solving the **Chicken and Egg problem**. This could be regulations and planning, responsibilities and supply guarantees. The analysis aims to clarify where in the current regulations these kinds of agreements are made and if they are sufficient to promote the development of the regional hydrogen networks. It will show gaps in the current regulatory framework and, by analysing upcoming regulations, will show what actions are being taken to fill these gaps.

In this Chapter, all relevant institutions will be discussed and analysed. First, in Section 4.1, the action situation is discussed. In Section 4.2 the current Dutch regulatory framework as identified in Section 3.1.2 is analysed using the proposed methodology of Chapter 2. Section 4.3 will be used to analyse the upcoming regulations following the same method. The goal of this Chapter is to provide a scientific analysis of the identified regulations. This will show how the regional hydrogen regulation framework is currently structured and allow for correct hypotheses formation in Chapter 5.

4.1. Action Situation

The action situations are used to define the institutional landscape for the INA. They ensure structured analysis by outlining the boundaries of the institutional arena to which the different policy documents apply. The action situation will be the same for both the analysis of the current regulations and the upcoming regulations. In the case of this research, the action situation that is analysed is the development phase of the regional hydrogen distribution network. As seen in Section 2.1.1, the system contains many different actors and physical parts. Together with the identified regulatory documents, this will result in an Institutional Network Diagram. This IND is first visualized in Section 4.2.8 and based on the individually coded institutional statements. For the upcoming regulations, the IND is visualized in Section 4.3.3 and based on the analysis of Section 4.3.1 and 4.3.2.

4.2. Current Regulations

To support the constantly evolving world of hydrogen technologies it is necessary to establish new regulations that will help low-carbon hydrogen technology development and adoption (CMS, 2024). As seen in Section 3.1.3 the regulations used in the Netherlands are not yet specified for developing regional hydrogen distribution infrastructure. However, there are elements discussed in the current regulatory documents that apply to the development of regional hydrogen distribution networks.

Elements that could be of interest are for example: Who determines the location of infrastructure? How are property rights arranged? What, if any, are the hydrogen capacity, safety and quality requirements? What are the DSO's connection obligations and how are these arranged? Are there subsidy schemes and who can benefit from these? Are there balancing obligations or minimum production capacity requirements for producers or operators? Has the regional industry been considered in current regulatory documents?

The analysis of the individual document will prove if and how these questions are addressed alongside any other elements that float to the surface. The documents that have been analysed in the current regulatory framework are listed in the table below.

Policy Document	Policy Scope
Environment and Planning Act (Omgevingswet, 2024)	Defines requirements for spatial planning and zoning of production and pipeline transport
Gas Act (Gaswet, 2024)	Defines rules and requirements for gas infrastructure, market and activities.s
Electricity Act (Elektriciteitswet, 2024)	Defines rules and requirements for electricity infrastructure, market and activities.
Letter to Parliament on the Development of a Hydrogen Transport Network (HNS, 2022)	Defines the role of the HNS and goals of national hydrogen transportation network
Temporary Hydrogen Pilot Framework (ACM, 2022)	Describes requirements to support hydrogen pilot projects
Guidelines Hydrogen (Rijksoverheid, 2022)	Defines Safety regulations for hydrogen projects to substitute missing legislation

Table 4.1: List of Analysed Current Policy Documents

4.2.1. Environment and Planning Act

After it was put into effect on January 1, 2024, the Environment and Planning Act (EPA) marked a substantial change to Dutch law relating to the physical environment. This law integrates various existing regulations covering spatial planning, the environment, nature, water, and construction. The Environment and Planning Act is aimed at supporting the physical environment's sustainable development by focusing on both preservation and optimal utilisation of the Dutch physical environment. This in turn helps to improve consistency and clarity in policy, decision-making, and implementation of the rules. The law is used to make managing and improving the physical environment easier as a whole by addressing social needs such as economic growth, sustainability, and safety. Because of its relevancy to planning and construction, it applies directly to the action situation discussed in Section 4.1. As this Act is quite large, several criteria were used to select the most relevant articles. These criteria were: connection to hydrogen, connection to energy infrastructure construction, planning and zoning of those infrastructures, and roles of actors in the system.

Key Actors

In the Environment and Planning Act, various actors play a key role. These actors can be separated using the Regulatory Bodies and Policy subjects defined in Chapter 3. The three that are most prevalent in the EPA are listed below.

1. Local and Regional Governments: As an integrated strategy is essential when developing regional distribution networks local and regional governments are allowed the possibility to customize policies to their unique circumstances in accordance with this law.
2. National Government: Sets general rules and frameworks and ensures coordination at the national level.
3. Businesses and Citizens: Are both users of the physical environment and responsible for complying with the legislation. This puts them in the policy subject group as discussed in Section 3.2.2

Number 1 are the local and regional governments, they are, as discussed in Section 1.3, well positioned to take the lead in the development of regional hydrogen networks but lack the guidance of a well-structured national regulatory framework. That is where the national government steps in. By setting general a general framework, they try to ensure more efficient coordination. These two entities are the most mentioned regulatory bodies in the EPA. On the other side are the businesses and citizens that are subject to the government policies set in the EPA because they are the users of the physical environment.

Relevant Articles

Using the actors and the relevancy of the Act to the planning and construction of infrastructure in the physical environment, articles were deconstructed and coded into institutional statements using IG. The complete list of all institutional statements for all analysed documents can be found in Appendix B.

To start the whole document was scanned to identify the articles, if any, that specifically mention the development of gas infrastructure. After this other articles that include planning, coordination and distribution of responsibilities were taken into account. Lastly, articles that affect the development of gas infrastructure in any other way were added to the analysis. Each statement was given an ID to avoid a cluttered analysis going forward. The selection of relevant articles alongside their subjects can be seen in Table 4.2.

Atricle Number	Statement ID	Article Subject
1.7/7a	EPA1	Activities with Adverse Effects
2.1	EPA2	Exercise of Tasks and Powers
2.2	EPA3	Coordination and Cooperation
2.3	EPA4	General Criteria for Allocation of Tasks and Powers
2.4	EPA5	Environmental Plan
2.6	EPA6	Environmental Ordinance
2.22/23	EPA7	Instruction rules Provinces
10.14.2C	EPA8	Gas Transport Network Establishment or Clearance
10.28	EPA9	Ownership Works General Interest
11.4/5	EPA10	Expropriation Decisions
11.7	EPA 11	Necessity and Criteria for Expropriation

Table 4.2: Relevant Environment and Planning Act Articles

The first relevant article that was identified, EPA1, revolves around activities with adverse effects. It outlines the role of businesses and citizen in their responsibility to prevent, mitigate or undo any negative effects that their projects/activities can have. This can include the development of gas infrastructure as it will generate effects on the physical environment during its construction.

EPA2 to EPA4 discuss how the regulatory bodies exercise their power in accordance with the law and the activities of other regulatory bodies. EPA3 specifically states that these bodies must cooperate if the need arises. This can happen when there are overlapping responsibilities. For regulating, monitoring and developing gas and electricity this kind of cooperation between regulatory bodies is needed, which indicates that it can also be needed for hydrogen networks.

EPA5 to EPA7 outline the different governmental levels that plans have to be made. EPA5 is the lowest level of municipalities. They must form a plan that establishes rules of use of the physical environment for their municipality. EPA6 is the next level, where the province must form an ordinance for their entire province. If the province wants its vision to be taken over by lower levels of government it needs to apply rules in its ordinance that describe how they must be implemented (Ministerie van Infra, 2024b). These plans and ordinances contain the description of the development of infrastructures in their region, which makes them influential in the development of hydrogen networks. EPA7 describes the need for the province to describe these rules to ensure that their goals are met.

EPA 8 is the article that directly specifies the establishment or clearance of a gas network by a duty to tolerate. This tolerance duty provides an initiator with a legal instrument to construct and maintain a work of general interest on someone else's land (Ministerie van Infra, 2024a).

EPA9 discusses the ownership of works that are of general interest to the public. A hydrogen network can fall under this definition similarly to a gas network. The Gas and Electricity Act will further discuss ownership of gas and electricity networks.

EPA 10 and EPA11 are articles that discuss expropriation. Expropriation is the power of the government to take property if the common interest requires it (Rechtspraak, 2024). This could happen for the construction of bridges, roads or railways, but it might be necessary during the development of a hydrogen network as it might require additional pipeline construction on privately owned land.

4.2.2. Gas Act

The Gas Act (GA) provides a framework for controlling the gas market in the Netherlands. This Act is focused on how the gas market should function, how the gas supply is organized, and what the responsibility and authority of different players in this industry are. Statements relating to gas production, transportation, storage, and delivery can be found in the Gas Act with the aim of ensuring an effective and easily available gas supply for all consumers. The Gas Act applies to all aspects of the gas value chain, from production to end-use. It covers regulations for the development and operation of gas transportation networks, gas storage, and gas distribution. To avoid conflicts of interest and to encourage competition, the Act also establishes rules for the separation of gas businesses' transportation and trading operations. All of these factors make it highly interesting for the case of regional hydrogen distribution networks.

Key Actors

As the GA is more focused on one specific area compared to the EPA, other actors play a key role in the institutional arrangements. As expected the actors involve both regulatory bodies and policy subjects.

1. Minister of Economic Affairs and Climate: Responsible for establishing policy and legislation in the field of gas supply.
2. Authority for Consumers & Markets: Responsible for the monitoring of actors' compliance with the Gas Act, regulating the gas market, and protecting the interests of consumers.
3. TSO & DSO's: Responsible for constructing, maintaining, and operating gas transport or distribution networks. Designated by the Minister and under the supervision of the ACM. They are the policy subjects as discussed in 3.2.2.
4. Gas Producers, Suppliers, and Traders: Companies that produce, sell, or trade gas. They are the policy subjects as discussed in 3.2.2.

The first relevant actor is the Minister of Economic Affairs and Climate. They are the main responsible actor for establishing policies that govern the Dutch gas market. The Authority for Consumers and Market (ACM) gives guidance to actors operating in the system. They monitor the actions of companies such as gas suppliers and protect consumer interests by regulating the gas market. The TSO is responsible for the construction, maintenance and operation of the national gas grid, while the DSO is responsible for the regional grids. Lastly, the companies that are producers and sellers of gas are the last large actors. They must follow the regulations laid down by the regulatory bodies.

Relevant Articles

Similar steps to those used for the EPA were used to analyse the GA. First, any connection to hydrogen was investigated. Secondly, the definition of who can be a network operator was looked into. Lastly, the tasks that this operator has for a gas infrastructure had to be found. Using all the found articles shown in table 4.3, a good picture can be drawn of the responsibilities and institutional arrangements in the Dutch gas network. The IG coding of each statement can be found in Appendix B. The criteria for the article selection were: connection to hydrogen, connection to gas infrastructure construction, roles of actors in the system, gas definition, investment responsibilities and ownership regulations.

GA1 is used to describe the definition of gas in the Act. It states that it should be a methane gas or a gas with similar properties to methane. In the act, no specification about hydrogen and its characteristics is made.

GA2 defines the designation of the network operator for the national gas network. It states that the Minister of Economic Affairs and Climate is responsible for the designation of a network operator for the national network. Even though it is not specifically for region networks, it is still useful to understand the overall context of the regulations.

Article number	Statement ID	Article Subject
1b.1/2	GA1	Definition of Gas
2	GA2	Designation of Network Operators
2a	GA3	Exemption for Designation
2.8	GA4	Designation for Regional Network Operators
2c	GA5	Restrictions of Network Operators
3	GA6	Non-designation of Gas Producers
3b	GA7	Economic Ownership of Gas Transportation Networks
7a	GA8	Investment Plan by Network Operators
10	GA9	Tasks of Network Operator
10a	GA10	Obligation of Network Operator
102-e	GA11	Construction of Other Infrastructure
14	GA12	Obligation to Transport Gas
39b	GA13	Coordination for Construction/Expansion Gas Infrastructure

Table 4.3: Relevant Gas Act Articles

GA3 talks about exemptions to GA2, based on technical, safety or other reasons. The ACM is the party responsible for granting these exemptions.

GA4 till GA7 discuss who can and cannot be appointed as smaller network operators. Entities that already operate in the gas market in another capacity, such as producers, are prohibited from being appointed as network operators. This is done to avoid conflicts of interest in the gas system.

GA8 till GA12 discuss the different responsibilities that a network operator has. For example, GA 8 mentions the necessity for the operator to present a periodic investment plan for the expansion or replacement of the network. This is a task that will need to be done similarly for the development of a hydrogen network. Another example is GA12, where the obligation of the operator to offer a connection to a requesting party is defined. This connection is complemented with any other supporting services needed for a function connection to the grid. The only article in the whole act that specifically mentions hydrogen is GA11. Here the construction of other infrastructures, including hydrogen pipelines, is allowed for an entity connected to the network operators.

GA13 is again focussing on the national infrastructure. As the gas network is seen as a project of national importance, the Minister must ensure that this is developed in a structured manner.

4.2.3. Electricity Act

The Dutch Electricity Act (EA) governs the generation, distribution, and transmission of electricity inside the Netherlands. It stems from 1998 but has since undergone several amendments. The law stresses environmental and economic concerns while attempting to guarantee the supply of power sustainably and efficiently. The integration of renewable energy sources, stakeholder roles, and power market governance are important parts of the Act similar to those mentioned in the GA.

Key actors

The Electricity Act is almost identical when it comes to the key actors in the Act. Again this act contains both regulatory bodies and policy subjects.

1. Minister of Economic Affairs and Climate: Responsible for the overall implementation of the law and oversees energy reports and designation of operators in the system.
2. ACM: Enforces the Act, ensures compliance of policy subjects, and oversees the functioning of the electricity market.
3. TSO & DSO's: Responsible for constructing, maintaining, and operating the electricity transport networks. Designated by the Minister and under the supervision of the ACM. They are the policy subjects as discussed in 3.2.2.
4. Electricity Producers, Suppliers, and Traders: Companies that produce, sell, or trade electricity. They are the policy subjects as discussed in 3.2.2.

The two most prominent regulatory bodies are the Minister of Economic Affairs and Climate and the ACM. They fulfil the same roles as in the GA, only here are they responsible for the electricity market and networks. As seen in Section 3.2.2, the DSOs operate almost always in the same areas for both gas and electricity. Lastly, the companies that sell electricity finish of the stakeholders in this Act.

Relevant Articles

For the EA the same criteria were used for article selection as for the GA. The first step was again to look for any connection to hydrogen. Secondly, the designation and tasks of the network operators were analysed. After this, any sections on monitoring were also deemed to be useful in creating a better picture of the overall context. This was done because monitoring will be needed to ensure a properly functioning system. Lastly, any other articles that can prove useful to describe or support the action situation were taken into the analysis.

Article Number	Statement ID	Article Subject
2	EA1	Energy Reports and Monitoring
5	EA2	Execution and Monitoring
10	EA3	Designation and Tasks of Network Managers
10.9	EA4	Designation for Regional Network Operators
10a1	EA5	Economic Ownership of Electricity Transportation Networks
16-1a	EA6	Operating Task of Network Operator
16-1e	EA7	Connection Task of Network Operator
17c-2e	EA8	Construction of Other Infrastructure
21	EA9	Investment Plan by Network Operators
77h	EA10	Penalties
95a	EA11	Licensing for Electricity Production

Table 4.4: Relevant Electricity Act Articles

EA1 and EA2 discuss the monitoring tasks of both the Minister of Economic Affairs and Climate and the ACM. The ACM monitors the energy market, while the Minister must monitor and report on the overall state of the energy system once every four years. With the current speed that the energy system and its transition are developing, this might not be often enough.

Statements EA3 and EA4 discuss the designation of the national and regional network operators. These statements are identical to those of the GA, with the exception that they refer to electricity networks instead of gas networks.

EA5 to EA9 outlines the different tasks of a network operator. These tasks are highly similar to those discussed in the Gas Act. The statements mention the obligation to provide connections to customers and the investment plan that an operator must periodically develop. Again only one article especially mentions hydrogen, for the Electricity Act this is statement EA8. In essence, this statement is identical to GA 10, identifying an entity connected to the network operator to be responsible for the construction of other energy infrastructures, which include hydrogen.

EA10 is the article that states that the ACM is responsible for fining any party that breaches agreements outlined in the Act. For the Gas Act, this construction is the same, so it stands to reason that for a hydrogen-based Act, the construction will be the same also.

The last article, EA11, mentions the necessity for energy-producing entities to require a licence to produce. This licence will only be given when certain environmental, technical, efficiency and safety conditions are met.

4.2.4. Guidelines Hydrogen

The Guideline on Hydrogen (GH) is a policy document that establishes safety guidelines for hydrogen usage in the energy transition. The Minister of Economic Affairs and Climate announced in 2020 that several different policies are in the making for hydrogen. Before these policies take effect, these guidelines have been drafted, on the instruction of the minister, to provide some support for smaller initiatives. The guidelines focus on managing the safety risks associated with hydrogen's different applications. It's essential since existing laws and regulations do not cover all aspects of hydrogen use. The guidelines are formulated in such a generic way that they serve as a ”coat rack” under which other frameworks for more specific situations can be hung. As this document and the following documents are much smaller than the EPA, EA and GA, all regulatory statements in these documents were analysed.

Key actors

Three actors have been identified in the document. In the list below, their roles are discussed briefly.

1. Minister of Economic Affairs and Climate: The Minister is the initiator and announcer of the guideline, they can also play a role during the evaluation of the the effectiveness of the guideline.
2. Initiating Party: This is the actor who wants to start some kind of project relating to hydrogen. Examples can be producers or DSOs.
3. State Supervision on the Mines (SodM): This entity cooperates with the Minister to supervise safety.

For hydrogen projects, there can be different parties involved. The key actor from the policy subject side is the initiating party. This can be producers who want to build a hydrogen production facility or DSOs who want to experiment with hydrogen distribution systems. The regulatory body not yet mentioned so specifically in the documents before this is the State Supervision of the Mines (SodM). As discussed in Section 3.2.1 this body mainly focuses on the safety of hydrogen storage. They work together with the Ministry to regulate the safety of hydrogen projects.

Relevant Articles

The document of the hydrogen guidelines is not comparable to a real regulatory document such as the Gas Act. It does not follow the same structure as the GA with articles outlining one specific regulation or requirement. It instead discusses the areas in which it aims to have an effect and it outlines several general guidelines based on these goals. These seven general guidelines can be seen in table 4.5 and their coding can be found in Appendix B.

Application	Statement ID	Subject
Generic Guidelines	GH1	Safety Comparison
	GH2	Increase in Safety
	GH3	Risk Policy
	GH4	Role of Government
	GH5	Assistance of Government
	GH6	Communication
	GH7	Learning after Incidents

Table 4.5: Relevant Guidelines for Hydrogen Articles

GH1 and GH2 discuss the safety goals that hydrogen projects must follow. GH1 states that the new energy supply i.e. hydrogen must be at least as safe as its fossil fuel comparison. GH2 on the other hand defines the goal should be that hydrogen should be made even safer than its fossil fuel equivalent. This shows that not only does the government want to use hydrogen to lower CO2 emissions, but it should also add to the overall safety of the energy system. For example, a normal gas boiler can produce lethal carbon monoxide. Hydrogen boilers should be made safer to ensure such poisonous gasses do not form. For the risk policies in GH3, it is made clear that scientific research should form the basis of policy formation. The role of the government is outlined in GH4 and GH5. The guidelines state that the government is required to share all new information on risks and safety with participants and that they should help to find solutions when obstacles or deficiencies in regulations are discovered. Transparency in communications is defined in GH6. It states that all parties must be open in their dialogue about the chances, risks, and benefits of the projects. Lastly, GH7 defines the protocol to follow if incidents arise. It makes sure that lessons will be learned from the incidents before the continuation of the projects. These guidelines are the first step in substantiating regulations for hydrogen in the Netherlands. It outlines only the very basic requirements, but it can serve as a foundation for further policy documents such as the temporary framework discussed below.

4.2.5. Temporary Framework Hydrogen Pilots

This temporary framework for hydrogen pilots (TFHP) offers a comprehensive guideline for both customers and operators. The ACM has developed it to manage pilot programs that deal with the delivery of hydrogen in built environments. This hydrogen is only used for heat production in homes. Since hydrogen is anticipated to be a key component of a sustainable energy supply, pilot programs are necessary to obtain real-world experience and influence future safety and regulatory frameworks. The pilots are designed to provide learning opportunities for all stakeholders, which is essential for integrating hydrogen into the energy mix effectively as was discussed in Chapter 1. This framework is based on the generic guidelines for hydrogen discussed in Section 4.2.4.

Key actors

Six different key actors were identified during the reading of the Temporary Framework for Hydrogen Pilots (TFHP). Three regulatory bodies and three policy subjects are defined as key actors in this document.

1. ACM: The regulatory body that manages the compliance with the pilot framework.
2. The Ministry of Economic Affairs and Climate: They are in charge of establishing the general guidelines and safety requirements for hydrogen pilot programs.
3. The State Supervision of Mines: Pilot safety is overseen by this regulatory body.
4. DSOs: Organizations in charge of the pilots' hydrogen distribution systems.
5. Other Pilot Parties: These can be producers or traders of hydrogen.
6. The Customer: The receiver of the hydrogen in the project.

The regulatory bodies as well as the DSOs in this document have all been identified before and therefore do not require any more discussion. For the policy subjects, one actor has not been named in the preceding documents. The customer, they are the receiver of the hydrogen. In the case of this document, these customers are households as this document is aimed at projects in the build environment. The other actor is similar to the initiating parties mentioned in the GH.

Relevant Articles

Because the TFHP is not an official regulatory document like the GA or EPA, it does not have the same article structure as these documents. Instead similar to GH, it discusses the goals, requirements and regulatory guidelines laid down for different areas in hydrogen pilots. These different areas are used to divide the rules in Table 4.6. The complete coding of the individual rules into institutional statements can be found in Appendix B.

Application	Statement ID	Subject
Generic Generic	TFHP1	Pilot Application
	TFHP2	Role of Network Operator
	TFHP3	Goal Pilot
	TFHP4	Result Sharing
Security of Supply	TFHP5	Delivery of Hydrogen
	TFHP6	User Protection when Hydrogen Loss
Costs and tariffs	TFHP7	Costs Distribution
	TFHP8	Cost Payment
	TFHP9	Cost Explanation
	TFHP10	Cost Guarantee
Contract Conditions	TFHP11	Agreement Clarity
	TFHP12	Agreement Security
	TFHP13	Connection Obligation

Table 4.6: Relevant TFHP Articles

The TFHP is a follow-up document of the GH, building on its generic guidelines. The document was analysed and divided into 4 different application areas. The first area is the generic conditions and contains the statements TFHP1 to TFHP4. In the statements TFHP1 and TFHP3 the the goals and application of the pilot are outlined. TFHP2 states that a network operator must perform its duties of constructing, operating and maintaining the network, similarly to their duty in the gas and electricity systems. TFHP4 is directly taken from GH6, stating that the network operator must communicate timely and openly about the results of the pilot to every party involved.

The second application area is the security of supply and consists of two statements. The first statement in this area, TFHP5, outlines the necessity of pilot parties such as producers and operators to ensure a supply of hydrogen similar to that of natural gas for the customer. TFHP6 is a form of consumer protection, for when the production of hydrogen is lost. This can happen for example when a production facility goes bankrupt or is disrupted during its production.

The third application area is the costs and tariffs and consists of four statements. TFHP7 & TFHP9 state the necessity of clear communications to the consumer on cost calculation and distribution before the start of the pilot. The payment calculation and payment are discussed in TFHP8. It states that it cannot be more expensive than a reasonable alternative and should be calculated using both fixed and variable cost elements. TFHP10 guarantees the consumer that all parties in the pilot will have to agree on a fixed cost should problems arise such as the loss of a supplier.

4.2.6. Letter to Parliament on HNS

In this letter to parliament, a comprehensive strategy for creating a national hydrogen transport network in the Netherlands is presented. This network is essential to the long-term viability of a hydrogen supply chain as well as the mission to reduce carbon emissions. The transportation network will serve as a link between port regions, offshore wind farms, storage facilities, and eventually the international market. The hydrogen backbone as it is called was shown in Section 1.1.2, and will be used as the main national transportation method for hydrogen. The Dutch government mentions in the document that it has set aside up to €750 million to finance the development of the backbone. As discussed in Section 1.1.2, Gasunie's subsidiary, the HNS, is tasked with developing and managing the transport network. Their role, the development plan, the system perspective and several regulatory guidelines, are discussed in this document.

Key actors

Four different actors were identified during the reading of the HNS letter. Two regulatory bodies and two policy subjects stood out.

1. Ministry for Economic Affairs and Climate: Provides the oversight and policy framework for the development of the hydrogen transport network in the letter. The Ministry is responsible for aligning the project with national and European energy and climate goals.
2. ACM: They will be needed to regulate the emerging hydrogen market, and access to the network.
3. HNS: The responsible party to build, maintain and operate the Dutch national hydrogen network.
4. Industrial Stakeholders: All different interested parties in a connection to the hydrogen network. In the Netherlands, these are currently the 5 industrial clusters.

Both regulatory bodies, the Ministry and the ACM, have been seen in previous documents. It can be said that they are the most influential when it comes to the development of the Dutch hydrogen networks and market. The first policy subject is the HNS. As discussed in Section 1.1.2 this is the actor responsible for the national hydrogen network. Lastly, there are the industrial stakeholders. At the beginning of the HNS development, these are the companies that operate in the 5 major industrial clusters in the Netherlands. However, in the letter cluster 6 is also mentioned to have some interest in the development of the hydrogen backbone. It is likely that the companies that have expressed this are already close to the hydrogen backbone infrastructure as that will require less investment in additional pipelines.

Relevant Articles

Similar to the GH and TFHP, this letter is not structured as the first couple of policy documents. The Minister outlines their intentions and goals with the development of the hydrogen backbone and after that outlines several principles that the HNS has to follow. These principles are differentiated in different application areas that can be found in Table 4.7. The statements have been formed based on the description of the Minister and coded in Appendix B.

Application	Statement ID	Subject
EU-based conditions	HNS1	Non-Discriminatory Service
	HNS2	Third Party Access
Tariffs and Access	HNS3	HNS Responsibility
	HNS4	Cost of Connection
	HNS5	Standard Requirements
Governance of Network	HNS6	Multiyear Investment Plan
	HNS7	Yearly Investment Plan
	HNS8	Revisit the Development Plan
Hydrogen Quality	HNS9	Hydrogen Quality Requirement
Financial support	HNS10	Transport Tariff
	HNS11	Eventual Tariff Calculations

Table 4.7: Relevant HNS articles

Similar to the TFHP the letter for HNS has been divided into several application areas. The first area is conditions based on European proposals. HNS1 and HNS2 are statements that ensure fair service by the operators and access for all parties in all EU member states. These propositions ensure that all countries follow the same market structure, keeping competition fair.

The second application area is tariffs and Access, which consists of three statements. HNS3 describes the obligation of HNS to be open to conversation with any requesting party for a connection. HNS4 defines who bears the costs of facilitating the connection to the backbone. In the letter, the Minister says that the requesting party will be the one responsible for these cost payments. HNS5 outlines the standard requirements that HNS has to follow such as transparent services. This ensures non-discriminatory behaviour to requesting parties.

HNS6 to HNS8 make up the third application area. These statements regulate in some way the overall governance of the development of the hydrogen backbone. HNS6 require the HNS to draw up a multiyear investment plan for the development of the hydrogen backbone. Next to this, HNS7 states that the HNS must also come up with a yearly investment and budget plan that complies with its multi-year plan, and HNS8 requires the HNS to revisit their development plan and investment plans. By resisting and reassessing these plans the Minister hopes to keep the development of the backbone aligned with the developing market and society.

A small statement is made that clarifies the purity of hydrogen used in the system. HNS9 states that the hydrogen injected into the system has to be at least 98mol% purity.

The last area of application is the financial support. In the letter, the Minister describes the investments planned and already made by the Dutch government. Next to these, they outline the way that the transport tariff should be structured. HNS10 states that this tariff will be calculated on the made costs plus a reasonable return, it does not further divine what this reasonable return is. To ensure that the costs will be covered during the start-up period the Minister has set aside 750 million euros as a subsidy. Lastly, HNS11 defines the role of the ACM in calculating the eventual tariffs after the start-up period.

4.2.7. Institutional Coding & Visualisation

Now that the relevant institutions have been identified and discussed it is necessary to code them using institutional grammar described in Section 2.2.1. To do this the statements were analysed and each component was defined. These components were then coded into an Excel sheet to clarify each part of the syntax. The coding of all statements can be found in Appendix B. When all the statements were coded the visualisation followed naturally.

Using the representation method discussed in 2.2.3, each relevant statement for the development of regional hydrogen distribution networks was visualised and connected in the network diagram. All the statements that were visualized for the network diagram can be seen in Appendix C. To show how each statement was built up, one example will be given in Figure 4.1.

Figure 4.1: Visualisation of Statement EPA8

In Figure 4.1 statement EPA8 has been visualised. Using institutional grammar, the Attribute is depicted as a rectangle, the Conditions as a hexagon and the Object as a circle. Both the Deontic and the Aim are green arrows that connect the different shapes and thus the different components. Using several of these visualised statements will create a network with links between them. This network is depicted and discussed in the following section.

4.2.8. Action Situation Network Diagram

The action situation for this network diagram is the development of regional hydrogen distribution networks. As the identified Acts and statements revealed, in the current regulations not much has been specified for the development of hydrogen distribution networks. In Figure 4.2 the statements that mention the development of infrastructures for gaseous substances and the operation of hydrogen infrastructure have been considered.

The statements used in the diagram are EPA8, GA3, GA10, EA10 and TFHP2. In the legend on the right side, all parts of the diagram are described following the method from Section 2.2.3. The shapes and arrows represent the different components of the institutional syntax. The dotted line represents a connection between the object of one statement to the condition of another. This connection is made when the subject of these components is present in both. The black star represents an institutional conflict, but none were identified in this action situation. Lastly, the dotted line around an Attribute represents the Or else mechanism. This line is then connected to a condition of a penalty mechanism.

Both the objects from EPA8 and GA10 are connected to TFHP2, this is because they mention the construction or operation of gaseous/hydrogen infrastructure. In the current regulatory framework responsibility for hydrogen infrastructure is defined only in this way. The pilot documents did speak about safety and communication, but not on who is responsible for spatial planning or ownership of the networks. For this reason, it was assumed that old gas regulations apply. TFHP2 is in turn connected to the penalty mechanism defined by EA10. This penalty mechanism applies to all parties that participate in the hydrogen sector but for the sake of clarity, only one connection was shown. EA10 shows that ACM will be responsible for monitoring and fining parties that break agreements and regulations that are currently in play.

Network diagram Wrap-up

This network diagram was made to visualise the current regulatory framework. Following the diagram, it is still unclear from current regulations exactly who decides where hydrogen distribution networks will be built, who will pay for all the construction costs and how a hydrogen market will be formed, regulated, balanced and operated. The current regulations, therefore, do not solve the chicken and egg problem that lies at the basis of the slow development of hydrogen distribution networks. Analysis of upcoming regulatory documents is needed to show what governmental actions are being taken to develop a more comprehensive framework and to show what more can be done to support the development of regional hydrogen distribution networks.

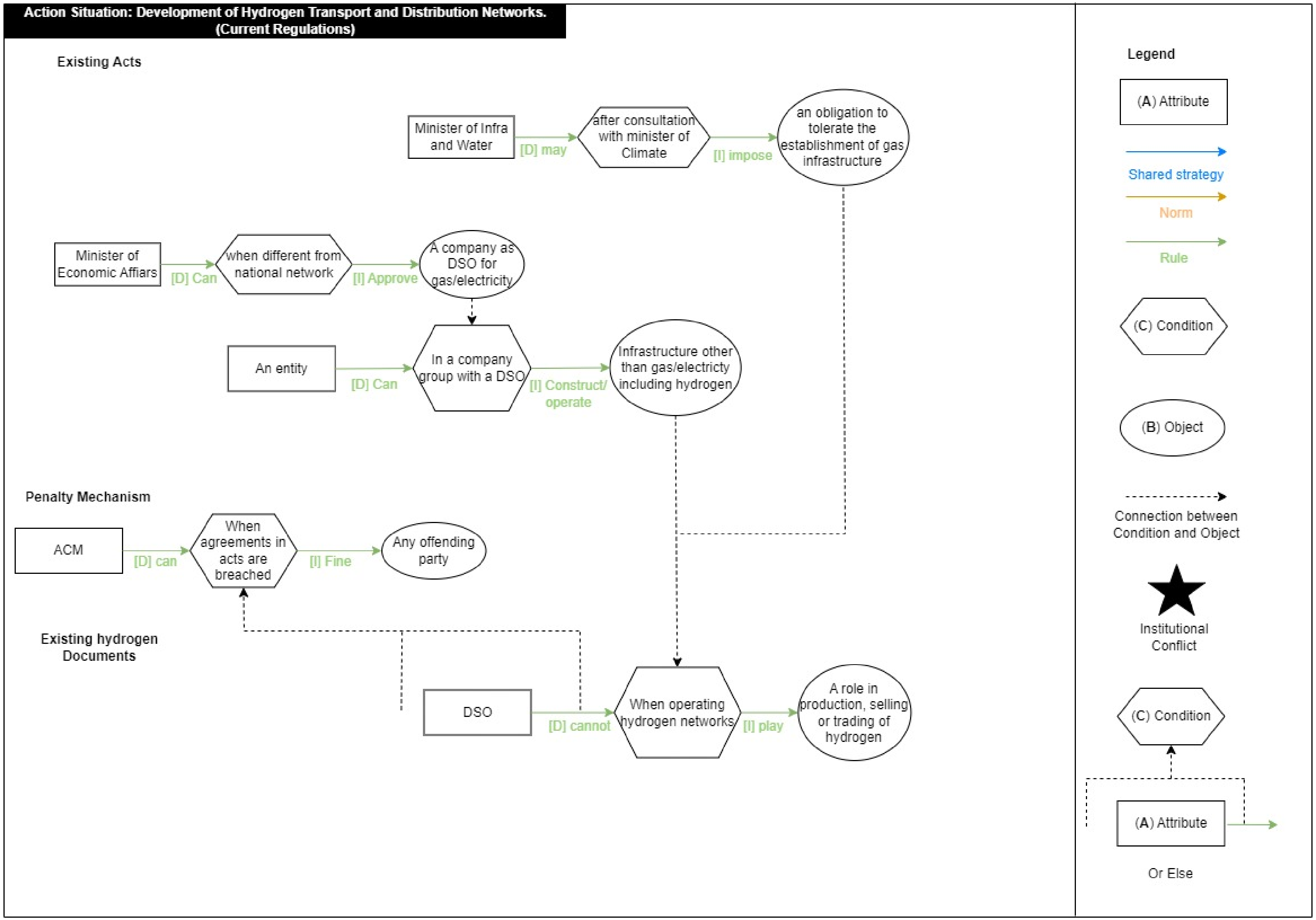

Figure 4.2: Action Situation of Current Regulations

4.3. Upcoming Regulations

This Section is highly similar to Section 4.2, using the proposed analysis method to break down regulatory documents. In this section, upcoming regulatory changes will be analysed. Several examples of questions that were used as a guideline when analysing the documents are:

How can the new EU package and the Dutch Energy Act be applied within the Dutch framework, which problems/missing agreements do they address? In what way are hydrogen distribution networks discussed in these new regulatory documents? Does the new package create more ambiguity or clarity, if so, where? How do institutional relations change within the network due to these new regulations?

As was done before, the different documents were analysed and coded. The documents are listed in Table 4.8. The criteria for selecting these documents were: their connection to hydrogen and the Dutch energy system. In the following sections, the analysis is discussed in-depth. The outcomes of this analysis can have an impact on the network diagram discussed in Section 4.2.8. Therefore, a new network diagram will be formed and discussed at the end in Section 4.3.3.

Policy Document	Policy Scope
Energy Act (Energiewet, 2024)	Revision of regulations that govern the energy system. Combines GA and EA and adds several definitions for hydrogen.
Eu-decarbonisation Package (2021/0425(COD), 2023) & (2021/0424/COD, 2023)	Consists of two separate documents: a Regulation text and a Directive text. They Contain detailed articles on the hydrogen market and network development.

Table 4.8: List of Analysed Upcoming Policy Documents

4.3.1. Energy Act

The Energy Act (ENA) of the Netherlands is a comprehensive revision of the regulations concerning the energy market. It combines the GA and EA discussed in the previous sections. Currently, the act has been accepted by parliament but still needs to be passed by the Dutch Senate. The Act adds new forms of energy such as hydrogen to these existing regulations. Hydrogen is defined as a separate gas in the Act, together with other definitions or storage and terminals. In the Act, the role that DSOs must play concerning hydrogen is a bit more defined than in the GA and EA. Similar to the GA and EA the ACM plays a crucial role as the national regulatory authority. It is charged with implementing and enforcing the act and ensuring consumers have access to electricity and gas at competitive prices by overseeing the market and competition.

Key actors

In the ENA three actors have been identified as playing the most influential roles. Because the ENA is a conjuncture between the GA and EA, no new relevant actors were found. The three that are recurring the most have been listed below.

1. ACM: As the regulatory authority, the ACM plays a key role in supervising and enforcing energy market regulation.
2. TSO & DSOs: Responsible for managing transmission and distribution systems for both electricity, gas and other energy forms, such as hydrogen. They are the main policy subjects in this Act.
3. Ministry of Economic Affairs and Climate: The main responsible actor charged with establishing policies and regulations aimed at the energy market, including the implementation of the Energy Act.

Relevant Articles

The ENA is a regulatory document that has not yet been accepted into the Dutch framework. Because of this several amendments have been made to the document during its conception which have been taken into the analysis. Because there are a lot of similarities between this act and the GA and EA, only articles that directly mention hydrogen have been taken into account. All the articles can be found in Table 4.9 and their coding can be found in Appendix B. As the ENA is an evolution of the GA and the EA, similar criteria were used to select the relevant articles: connection to hydrogen, connection to hydrogen infrastructure construction, roles of actors in the system, hydrogen definition, investment responsibilities, market regulations and ownership regulations.

Article number	Statement ID	Article Subject
1.2	ENA1	Administrative Order
3.10	ENA2	Restrictions of Network Operators
3.19	ENA3	Actions of Infrastructure Company
3.19.4e	ENA4	Terminals and Storage
3.21	ENA5	Shares of Infrastructure Company
3.21.5a/e	ENA6	Rules by Administrative Order
3.48	ENA7	Input/Output Specs Hydrogen

Table 4.9: Relevant Energy Act Articles

The first statement, ENA1, is a general order that allows for a broader application of the act. It states that the act can be applicable, under an administrative order, to other gasses than natural gas. What gasses are meant by this is unclear, but the act does go on to add more articles specifically for hydrogen.

ENA2 is almost identical to GA4. It states that either a TSO or DSO cannot be a part of a group including entities engaged in the production, supply or trade of hydrogen. This vertical unbundling will be essential to avoid a monopoly in the hydrogen market and ensure free entry for third parties, competition in the system and fair prices for users.

ENA3 and ENA5 are related to the actions that a distribution infrastructure company A.K.A. a DSO can do in the hydrogen system. They can primarily perform actions related to managing the distribution system but are not allowed to manage terminals or storage facilities. Apart from that they can also only hold shares in the DSO company group. The task of managing hydrogen terminals and storage is allocated to a company in a group with the TSO according to statement ENA4.

For hydrogen production facilities, the act makes it possible for the Minister to declare rules on these facilities by administrative order. ENA6 states that this action is possible but does not specify what these rules are. Lastly, ENA7 states that both the TSO and DSOs must ensure that the hydrogen in the system meets the specifications set by ministerial regulation. Most of these statements are similar to those already set for gas and electricity system operators. By clarifying these for hydrogen, it has become a bit clearer who is allowed to do what for hydrogen infrastructures, but nothing has been defined for market formation, third-party access, tariff formation, and safety regulation for example. The upcoming EU-Decarbonisation Package can provide further clarification on these topics.

4.3.2. EU Hydrogen and Decarbonisation Package 2023

To help the EU meet its decarbonization targets, regulations for hydrogen are one of the main features of the EU Hydrogen and Decarbonization Package, to be referred to as the package from now on. The package focuses on reforming the laws regulating the internal markets for natural and renewable gases. The version of the package analysed in this study is the December 2023 version. The package consists of two policy documents: The renewable and natural gases and hydrogen regulation, hereafter referred to as the Gas Regulation text and the Gas Directive text. On May 21, 2024, the European Council adopted the final version of the package. It is important to mention that the gas Regulation text directly applies to Dutch law. In contrast, the gas Directive text must first be implemented by the Minister of Economic Affairs and Climate into Dutch law. By establishing new rules such as the separation of TSO and DSOs, consumer rights, and hydrogen network development plans the package aims to enhance market clarity and support the development of a sustainable European energy market and infrastructure.

Key actors

Because this package is a European document the actors found are different than those discussed in earlier documents. In the list below the four most prominent in the document are listed and discussed below.

1. European Commission: They are the initiator of the proposal. They are involved in guiding the legislative process and ensuring alignment with broader EU strategies.
2. European Network of Network Operators for Hydrogen (ENNOH): This entity will be established to develop codes and recommendations relating to cooperation between operators. Other tasks include monitoring hydrogen quality and adopting non-biding development plans.
3. Member States: They are responsible for implementing the Directive document into their regulatory frameworks. The Regulation has a direct impact on their regulatory frameworks.
4. TSO & DSO: As seen before they are key stakeholders in the gas infrastructure. In this document, they are made responsible for following the implementation of the new framework, and the operation and development of gas and hydrogen networks.

The first three actors can all be defined as regulatory bodies only on different levels. The European Commission is the highest level as they are responsible for the proposal. As discussed the member states, in particular the Minister of Economic Affairs and Climate, are responsible for the implementation of certain parts of the package. The ENNOH is an entity that will be set up especially to regulate the new hydrogen market and players within this market. Cooperation between this entity and national entities such as the Dutch TSO & DSOs will be vital for creating an efficient hydrogen system.

Relevant Articles Gas Regulation Text

Both documents of the EU-Decarbonisation package will be discussed separately. First, the Regulation text will be analysed to show what will be directly applicable to the Dutch system. Secondly the Directive text will help to show what the Minister can implement further to support the development of the Dutch hydrogen transportation and distribution systems. Out of both documents, only the articles that directly mention or affect hydrogen transportation systems have been analysed. Table 4.10 mentions all articles from the regulation text and Table 4.11 mentions all articles from the directive text. Again all coded statements can be found in Appendix B.

Article Number	Statement ID	Article Subject
3	EUGR1	General Principles
4.2a	EUGR2	Cost Spreading
6	EUGR3	Third Party Access
36	EUGR4	European Entity for Distribution System Operators
38k	EUGR5	Mechanism for Support of Hydrogen Market Development
39a	EUGR6	Cooperation between Hydrogen DSOs and TSOs
40	EUGR7	European Network of Network Operators for Hydrogen
42	EUGR8	Tasks of ENNOH
43	EUGR9	10 Year Network Development Plan
59	EUGR10	Penalties

Table 4.10: Relevant EU Gas Regulation Articles

The first statement, EUGR1, outlines the responsibilities of all active actors in the system to follow certain principles. These principles include but are not limited to price transparency, customer-centred service, and cooperation.

EUGR2 can be important for the feeling of security for DSOs. It states that they shall be allowed, by the EU member states, to spread the costs over time over all their users to ensure fair contributions to the development of the network. This mechanism can help accelerate the development of hydrogen networks as it gives operators tools to ensure the cost recovery of their initial investments. Other mechanisms will also be put in place, as stated in EUGR5. Examples of mechanisms that are discussed are data collection on hydrogen flows, hydrogen demand and supply and the ability of member states to guarantee hydrogen availability.

EUGR3 is similar to statement HNS3, where the operators are required to offer services to any requesting party or user of the network. EUGR3 further highlights under which conditions this must happen.

All operators will be required to communicate clearly on tariff calculations while taking system integrity, safety and efficiency into account.

EUGR4, EUGR6 and EUGR7 are all statements that aim to increase the level of cooperation between member states, TSOs and DSOs. EUGR4 states that hydrogen DSOs can cooperate at the union level through the European entity for distribution system operators. This entity will be formed after the implementation of the package and is aimed at promoting optimal network management and coordination of distribution system operation. EUGR6 further specifies this requirement of cooperation by DSOs, and it includes conditions such as data sharing. EUGR7 entails the formation of the ENNOH. All hydrogen TSOs will cooperate through this entity to promote cross-border trade, development of the networks and ensure a functioning internal market. The tasks of the entity are stated in EURG8 and they entail the development of codes, recommendations and development plans in cooperation with the European entity for distribution system operators as well as the gas and electricity network operators.

EUGR9 describes what the ten-year union-wide development plan should include to ensure an effective development of the hydrogen infrastructures. This plan shall include modelling of the integrated network, scenario development and an assessment of the resilience of the system. It must build on national hydrogen network development and the consistency between the plan and national development will be checked by the Agency for the Cooperation of Energy Regulators (ACER).

Lastly, EUGR10 lays down the responsibility of member states to lay down rules on penalties. These penalties must be applied when any party breaks agreements made in the regulation document. No penalties are specified in the document, so member states are free to fill in exactly how they will penalise infringements.

Relevant Articles Gas Directive Text

In the table below all the articles that were analysed have been listed along with their subjects. The discussion per article will continue below the table.

Article Number	Statement ID	Article Subject
3	EUGD1	Market Approach of Member States
4	EUGD2	Market Based Supply Prices
9	EUGD3	Technical Rules
10	EUGD4	Contract Rights
31	EUGD5	Third Party Access to Hydrogen Networks
39	EUGD6	Designation of Hydrogen Distribution Network Operators
42	EUGD7	Unbundling of Hydrogen Distribution Network Operators
46	EUGD8	Tasks of Hydrogen Network Operators
47	EUGD9	Derogation for Existing Hydrogen Networks
48	EUGD10	Geographically Confined Hydrogen Networks
51	EUGD11	Integrated Network Planning
52	EUGD12	Hydrogen Distribution Network Development Plan
52b	EUGD13	Gas Network Decommissioning
72	EUGD14	Duties and Power of Regulatory Authority

Table 4.11: Relevant Gas Directive Articles

As the directive text still needs to be implemented into Dutch law, it allows for some leeway in interpretation and implementation. It is, however, an important text because it outlines the basis that will govern the hydrogen distribution networks in the Netherlands. EUGD1 is similar to EUGR1 because it outlines the approach that a member state shall ensure in the hydrogen market. It also states that the member states are required to comply with union law when this market is formed and maintained.

EUGD2 outlines the price formation method that suppliers will be allowed to follow. They can determine the price that they want to sell hydrogen at freely but under the supervision of authorities such as the ACM. This will ensure that prices are fair for all parties involved.

Hydrogen DSOs will be required to publish reports on how they calculate the tariffs and technical requirements. These reports, as stated in EUGD3, will be supplied to the regulatory authorities to ensure a fair, transparent and objective system.

EUGD4 to EUGD7 encompasses several steps that the member states need to take for the development of the hydrogen market and its infrastructures. EUGD4 ensures that customers are entitled to hydrogen subject to the agreement made with the supplier. The supplier must follow the applicable trading, balancing and security of supply rules. The third-party access to the network is noted in statement EUGD5. It is the responsibility of the member states to implement a system that regulates access to the hydrogen networks. The ACM will likely monitor this system. EUGD6 is the final designation of a hydrogen distribution system operator. Similar to gas and electricity, the member states will appoint a company responsible for the distribution system in a certain area. They must be, according to EUGD7, separate legal entities from the vertical undertaking.

EUGD8 outlines the tasks that an appointed hydrogen DSO will have. Not very different from those for gas and electricity, they are to be responsible for operating, maintaining, developing, or re-purposing a reliable infrastructure for hydrogen distribution.

EUGD9 and EUGD10 are regulations specifically designed for networks that can be exempt from the requirements laid down in the rest of the document. The first, EUGD9, is aimed at hydrogen networks that already exist. They can be operated and be exempt from statements EUGD5,6, and 7. However, this exemption will end when it is connected to other hydrogen networks when its capacity or length increases by more than 5% or when a regulatory body decides that the continued application of the derogation would carry the risk of impeding competition or adversely affecting the efficient deployment of hydrogen infrastructure. EUGD10 is aimed at geographically confined networks. They are also exempt from EUGD7, but this also ends when it is connected to other hydrogen networks that do not benefit from this statement.

EUGD11 and EUGD12 are focused on the planning that needs to be done to effectively develop the Dutch hydrogen distribution systems. The hydrogen DSOs will be required to submit their development plans with both the TSO, as stated in EUGD11, and with the regulatory authorities as stated in EUGD12. By sharing these plans the overall cooperation will be increased between all interested parties.

The idea is that, when hydrogen production and consumption increases, gas consumption will decrease. This will lead to the decommissioning of gas networks. Statement EUGD13 ensures that member states will develop plans for this decommissioning in cooperation with gas, electricity and hydrogen DSOs. It might be useful for the hydrogen DSO to repurpose the network for hydrogen, to save costs.

Lastly, EUGD14 outlines the duties of the regulatory body, in the Dutch system most likely the ACM. They will be authorised to ensure an open, transparent, efficient and inclusive process when the plans from EUGD11 and 12 are developed.

4.3.3. New Action Situation Network Diagram

In this section, the new diagram is discussed. This diagram is formed using only the ENA, EUGR and EUGD statements. This shows how the implementation of these documents affects the institutional framework. The action situation in this diagram is still the same: the development of regional hydrogen distribution networks. As the coding and visualisation of the statements are done in the same way as discussed in Section 4.2.7 no example will be given in this Section. All used and visualised statements can be found in Appendix C. All the statement's content was already discussed in the previous sections, therefore only the connections in the diagram will be discussed in-depth.

Just as in the first diagram, the legend showing the different parts and their meaning is shown on the right side. Statements that can be considered to have the same function as those in the first diagram have been highlighted in red. These highlighted statements are present in both the current and upcoming regulations. The first thing that stands out in the new diagram is its highly complex nature. This new diagram consists of 20 statements, some of which have been combined for clarity. The plethora of connections between objects of statements and conditions of other statements highlight the increased interconnectivity and purpose of these regulatory documents. As all these statements come from policy documents, the connections between the attributes, conditions and objects are all rule-based.

At the centre of the network, we find statement EUGR1. It is logical to have this statement presented in the centre as it lays down the general principles that all actors will have to follow. The statement has many different connections. To start, it has the *or else* structure connecting to statement EUGR10. This is done to symbolise the penalties that actors face if they do not follow the principles laid down in statement EUGR1 and all other agreements made in the EU-decarbonisation package. Secondly, it has 3 different connections from its object to different conditions. The first connection is to the right which leads to statements EUGR4&6 and statements EUGD11&12. These statements all revolve around the development of hydrogen networks and markets and will be discussed later. The second connection is to the left leading to statements ENA2 and EUGD7. This combined statement and all other statements to the left of the centre revolve around the operation of the hydrogen network and will be discussed separately. Lastly, the third connection is to statement EUGR2, whose object immediately circles back to EUGR1's conditions. EUGR2 states that operators are allowed to spread their costs over time to allow for fair distribution to all hydrogen network users. This can be seen as a general principle but is put as a separate statement as DSOs need to know how they finance their networks. The connections back to the conditions of EUGR1 show that different statements need to follow the general principles. One such connection is the statement EUGD5 seen in the bottom center of the diagram. This statement outlines the role of the member states to ensure an objective and non-discriminatory third-party access system. Overall the highly connected nature of statement EUGR1 shows the importance of all actors to agree on the general principles, which include prices, transparency and cooperation.

As stated before the left side of the network is focused on the operating conditions of the hydrogen network. The statements and their connections that make up this part of the network will be discussed here. Starting with EUGD6, stating the procedure that member states will have to follow to designate a hydrogen operator. This statement's object is then connected to the condition of combined statements ENA2 & EUGD7. These statements were combined because they have the same attributes and conditions but different objects. The object of statement ENA2 is connected back to EUGR1, creating a second loop in the network. Another connection from the ENA2/EUG7 statement is made to the combined statement EUGD9/10. This combined statement is important for forming and operating independent hydrogen networks as it allows for already existing networks and geographically confined networks to be exempt from the act. Statement EUGD8, stating the DSO operational responsibilities, is connected to the conditions of ENA2/EUGD7. EUGR3, stating the service conditions of the DSO is also connected to this condition. These different connections highlight the many different aspects that DSOs have to keep in mind when operating hydrogen networks. Even though the basis is not that different than those from gas and electricity, it is wise to keep in mind the responsibilities, and conditions that they have when operating, developing, maintaining and re-purposing networks. Statement EUGR10 is highly similar to the penalty mechanism in the first network diagram. It can be applied to all statements if the actor breaks the agreement or responsibility. Lastly, on the left side, statement EUGD2 describes the price-setting mechanism that suppliers can utilise. The object of this statement is connected back to EUGR1, again highlighting the need for all actors to abide by the general principles.

The right side describes the development of hydrogen networks. It consists of 5 statements or combined statements. EUGR5 is the highest-level statement that influences the development of hydrogen networks in Europe. It mentions the development of support mechanisms for the hydrogen market using the European Hydrogen Bank. European Hydrogen Bank (EHB) is a financing instrument, set up by the European Commission, to unlock private investments in hydrogen value chains (Commissie, 2022). In the communication to the European Parliament, the commission has outlined the EHB's concept, tasks and structure. The EHB is based on the four pillars of action at EU-level. These four pillars are: 1. Domestic Market Creation, 2. Imports into the EU, 3. Transparency and coordination, 4. Existing Financial instruments both European and International (Commissie, 2023). It created a bidding market where nearly €720 million was awarded to 7 hydrogen projects across Europe. This helps to support the development of hydrogen markets internationally but also serves as an example for member states on how they can support the development of their domestic hydrogen markets. Germany has already allocated €350 million of its national budget to hydrogen projects in a similar fashion (Commissie, 2022). EUGR5 in turn is connected to EUGR4&6. This combined statement states that DSOs have to cooperate, during the development of the hydrogen market, with other national DSOs and internationally through the EU DSO entity that will be created for hydrogen. The DSO must do this to promote optimal management of their networks. The connection of Statement EUGR4&6 with EUGR8 further highlights the necessity of this cooperation. EUGR8 outlines the responsibility of the ENNOH to develop codes, recommendations, plans and reports for the hydrogen network and market development. This must be done in cooperation with the EU DSO entity, and gas and electricity operators. These documents are then used in the development of national development plans, together with DSOs' technical and tariff specifications. This is depicted by the connection between EUGR8 and EUGD3&14. The combined statement of EUGD3&14 is a statement on the national level, outlining the responsibility of an appointed regulatory authority to ensure the correct procedures when setting up national development plans for hydrogen networks and markets. The last statement, EUGD11&12, is also connected to EUGD3&14 and it is the lowest level of where development plans will be formed. It states the responsibility of DSOs to present their development plans to the regulatory authorities in cooperation with other DSOs. This connection does however also lead to some confusion, because who will get to make the final decision on what network should be developed? Is it the DSO's development plan as stated in EUGD11&12 or the regulatory authority as stated in EUGD3&14? Interviews can provide additional insights into this question.

New Action Situation Wrap-up

Overall, the right side of the IND shows a high level of cooperation between different entities at different levels. Hydrogen networks can be supported using international and national financial support mechanisms. How these mechanisms will take shape in the Netherlands is still unclear. Next to financial mechanisms, cooperation at different levels and between many different entities will support hydrogen network development. Because of this highly interconnected nature, it will be needed that the progress is monitored and reassessed frequently, to ensure that all processes happen correctly. The left side outlines the responsibilities of different actors in the system and is quite consistent with the existing gas and electricity framework. By outlining the obligation for all actors to abide by general principles the EU-commission aims to ensure the development of fair, competitive and efficient hydrogen networks and markets.

The institutional analysis conducted in this Chapter highlighted several points. Firstly it was identified that the current regulatory documents and its frameworks are not sufficient to support the development of regional hydrogen distribution networks. Secondly, the upcoming regulatory documents outline a much more comprehensive framework for hydrogen development, both for the infrastructure and the market. Lastly, there are still additions possible. What these additions might be will be investigated in the chapter 6 using the stakeholder interviews. The network diagrams will be used to identify and hypothesise on the stakeholder perceptions of this framework. These hypotheses will be discussed in the following Chapter.

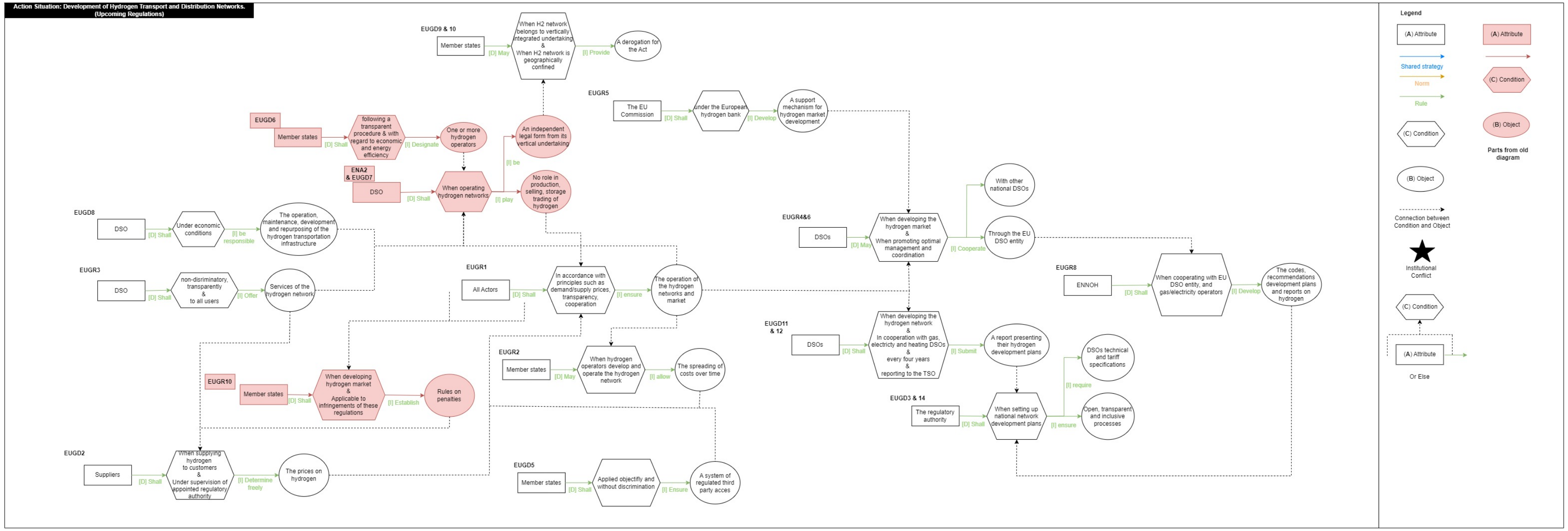

Figure 4.3: Action Situation of Upcoming Regulations

5
Hypotheses & Interview Formulation

In this Chapter, the hypotheses about stakeholder perspectives will be formed. Section 5.1 will discuss several hypotheses based on the analysed institutions, the identified actors, coded statements and network diagrams. Following the hypotheses, Section 5.2 will briefly discuss the interview questions and structure that are derived from the hypotheses. These interviews will give evidence either to support or to reject the hypotheses. The summaries and results of the interviews will be discussed in Chapter 6.

5.1. Hypotheses

Using the conclusions drawn from the analysis in Chapter 4, hypotheses on how stakeholders perceive these regulations can be formed. These hypotheses form the basis for the discussion topics during the interviews. As the regulations were divided into current and future, so will the hypotheses. Each hypothesis will focus on a different part from the concluding analysis of the INDs.

5.1.1. Hypotheses from Current Regulations

The analysis of the current regulatory framework showed that it is still unclear exactly who will decide on the locations of hydrogen distribution networks, who will cover all construction expenses, and how a hydrogen market will be established, controlled, balanced, and managed. It does not help to solve the chicken and egg problem, which makes additional regulation necessary.

Hypothesis 1:
"Unclear planning responsibility in regional hydrogen distribution networks results in their slowed development or stagnation."

This hypothesis addresses the lack of clarity on planning responsibility and its effects on hydrogen network development. The topic under which this hypothesis falls is therefore network development.

Hypothesis 2:
"The absence of clear guidelines on cost spreading lowers stakeholder trust in developing regional hydrogen distribution networks."

This hypothesis addresses the lack of cost spreading regulations for all stakeholders. Because of this, stakeholders are reluctant to invest in regional hydrogen distribution networks. As this hypothesis is focused on costs, it falls under the topic of finance.

Hypothesis 3:
"The absence of hydrogen market regulations slows down the development of hydrogen distribution networks due to market uncertainty."

By addressing the lack of hydrogen market regulations, this hypothesis shows that the development of the networks and the market are linked. One development cannot be seen without the other. As this hypothesis is focused on the development of networks due to the absence of hydrogen regulations, it falls under the topic of network development.

5.1.2. Hypotheses from Upcoming Regulations

The analysis of the upcoming regulations showed that a high level of cooperation between entities will be needed. Hydrogen networks will be supported by financial mechanisms, but how this will be implemented in the Netherlands is still unclear. It will also be the responsibility of all actors to abide by the general principles set out in the EU-decarbonisation package. Punishments for breaking these principles must be devised by the member states and are thus still unclear.

Hypothesis 4:
"The lack of a clear subsidizing scheme slows down the development of regional hydrogen distribution networks."

This hypothesis can be put under the topic of finance. It defines the need for a subsidizing scheme in the Netherlands. Actors who will invest large amounts of money into developing hydrogen distribution networks will want some assurances from the government. For the HNS, this has already been arranged, but for regional networks, this scheme is still lacking.

Hypothesis 5:
"The ambiguous penalty and control system hampers the development of regional hydrogen distribution networks, as stakeholders are uncertain about what is permissible."

By addressing the penalty and control system this hypothesis is more focused on the operation and monitoring of the hydrogen networks and markets. If actors do not abide by the principles laid down in the EU package, they can be punished. However, it is still unclear how member states will arrange this system, leading to stakeholders' uncertainty. This hypothesis can be put under the topic of operation.

Hypothesis 6:
"Despite new regulations increasing clarity, stakeholders will want additional regulations for the development of regional hydrogen distribution networks."

This last hypothesis is focused on the additions that stakeholders might still need and want in the regulatory framework. It is more general than finance or network development. The topic that this hypothesis falls under is the future of regulations. Looking into what stakeholders want can provide crucial insights into what changes can be made to the frameworks identified in Chapter 4.

5.2. Interview Example Questions

The interview topics and questions have a guiding function during the interview as a whole. In Table 5.1 a list of several example topics and questions is depicted. Next to the topics identified in Section 5.1, there are some more general topics and corresponding questions. These are used to gain a better impression of the interviewee, their role and their understanding of the system. The complete template of the interviews with all the topics corresponding to the hypotheses can be found in Appendix D.

Discussion Topic	**Example Questions**
Understanding of Current Regulations	1. What are the key regulations governing hydrogen distribution according to you? 2. Can you explain if and how these regulations have evolved over recent years?
Financial Regulations	1. How do regulatory frameworks impact the economic viability of hydrogen projects in your experience? 2. Are there financial incentives or subsidies available for supporting hydrogen projects?
Barriers & Enablers	1. What Regulations have you perceived as enablers for hydrogen developments in the Netherlands? 2. What are the biggest regulatory barriers currently facing the hydrogen distribution networks in the Netherlands?
Future of the Regulatory Framework	1. Are there upcoming regulatory changes that you are preparing for and how? 2. In what ways could the regulatory framework be improved to accelerate the development of hydrogen distribution networks?

Table 5.1: Interview Topics & Example Questions

With the hypothesis and the interview template that followed it, a solid base for the interviews has been laid down. Building on INA, the interviews will try to answer the hypotheses or identify other gaps that stakeholders perceive in the regulatory framework. Using quotes obtained from the interviews, the stakeholder perceptions will be analysed in the following chapter.

6

Stakeholder Perceptions

In this Chapter, the results of the interviews will be discussed. Several points from the interviews will be highlighted in Section 6.1. The complete interview summaries can be found in Appendix E. In Section 6.2 the results of the interviews will be linked with the hypotheses formed in Section 5.1. With these results possible additions to the network diagram discussed in 4.3.3 will be shown in Section 6.3.

6.1. Interview Results

This Section highlights several important quotes from the interviews. This section has been divided into two parts. The first part discusses perceived barriers and drivers in the regulatory framework and the second part is used to outline several suggested regulatory changes or additions. The quotes will help to answer the hypothesis and potentially lead to additions to the network diagram. The insights will also help to formulate final advice for the policy-makers as well as the DSOs.

6.1.1. Barriers and Drivers

The first part of the interviews was focussed on the perception of stakeholders on the current regulations. More specifically, it was discussed in what ways they see regulatory arrangements as barriers or drivers behind the development of hydrogen distribution networks. The results have been divided into different themes based on the quotes collected in the interviews. Each theme and its quotes are discussed in this Section.

Subsidies and Guarantees for Hydrogen Projects

Subsidies are seen as both a barrier and a driver for hydrogen projects, which include the development of distribution networks. The reasoning behind these characteristics is discussed using two quotes obtained from the interviews.

1. *"The main barriers are the permitting process, subsidy process, and grid congestion."*

In this quote, two regulatory barriers and one physical barrier can be found. For the regulatory barriers both the permits and subsidies do not provide the right incentive for the development of hydrogen distribution networks. For the permits, it is often so that the vision of the Dutch government and provinces is lagging behind that of the companies that are investing time, money and personnel into developing hydrogen installations and networks. This means that permits take a long time or are not given out at all. This hampers the overall development of hydrogen networks in the Netherlands. The same goes for the subsidy requests. The process of getting a subsidy is long and uncertain. This uncertainty, as discussed in Section 1.2.1 can lead to fewer investments in the hydrogen sector. However, the next quote also highlights the enabling side of subsidies. The physical barrier is the grid congestion in the Netherlands. This problem often leads to projects not receiving a grid connection, which is essential for providing a sufficient baseload for hydrogen installations. This will require custom solutions such as the development of independent systems where local RES is used to produce hydrogen that will be used in the region.

2. *"The OWE subsidy is potentially very interesting and positively impacts economic feasibility if awarded. However, the chance of receiving it is low, making it crucial for economic feasibility due to the large investments required."*

This quote shows the necessity of subsidies for investments in hydrogen infrastructure. The stakeholder mentioned that if an OWE subsidy is awarded it can have a huge and positive impact on the development of hydrogen production installations. The OWE subsidy is for companies establishing and using a production facility to produce renewable hydrogen (RVO, 2024). This subsidy affects the beginning of the supply chain and can help solve one part of the chicken-and-egg problem by supporting the development of hydrogen supply. Due to the low chance of receiving the subsidy, it does not yet have the desired impact. Creating a more structured and larger subsidy scheme can help to increase this impact.

Specific Act Issues

Interviewees were asked about the impact of current Acts on hydrogen distribution network development. Two acts were mentioned in the interviews, their quotes are stated and discussed in this Section.

1. *"One major barrier is the Delegated Act, which shifts from monthly to hourly correlation requirements, complicating project synergies. Moreover, assets for renewable energy and hydrogen production must be within three years of each other's age, further complicating project alignment."*

The act talked about in quote 1 outlines detailed rules on the EU definition of renewable hydrogen (Europeese Commissie, 2024) together with rules on renewable energy production (RED3) (Europeese Commissie, 2023). The definition for renewable hydrogen defines the specifications for renewable fuels of non-biological origin (RFNBOs) which include hydrogen. The barrier that the interviewee found is the fact that the production of hydrogen is now hourly correlated with RES production due to the RED3. Together with the age requirement that all assets have to have, this limits the production possibilities for hydrogen.

2. *"The new Environment and Planning Act causes delays because it's new for both us and the authorities. It aims to speed up processes, but we haven't seen much improvement yet."*

The second quote discussed the EPA (discussed in Section 4.2.1). Even though the act is aimed at speeding up processes such as permitting no real impact has been seen yet by stakeholders in the sector. This could be due to the recent adoption of this act, but in practice, it is not much more different than those preceding it. Clearer specifications for hydrogen networks could help to provide certainty for stakeholders.

Lack of Standardisation

Barriers were also discovered on this technical side of regulations. More specifically, the lack of certain technical norms, standards and specifications. Two quotes highlight how stakeholders currently approach the technical side of hydrogen distribution.

1. *"We need to consider all the norms and standards built for natural gas over the past 60 years and determine how they apply to hydrogen. This involves understanding the differences and the additional requirements or measures needed for hydrogen when using natural gas standards."*

When developing hydrogen pilots or networks, currently the GA (discussed in Section 4.2.2) technical rules are used to define a basis for safety norms and standards on hydrogen. As these rules are older and have changed over the past sixty years, it is preferable to redefine a regulatory structure that outlines the standards for this new technology. It creates uncertainty when stakeholders have to interpret old regulations to suit a new technology, which hampers the speed of adoption of this new technology.

2. *"At present, this regulation (GA) specifies methane with 0.2% mol hydrogen, which is insufficient for distributing higher hydrogen concentrations (3-5%) or pure hydrogen."*

The current GA only allows for 0.2%mol of hydrogen to be injected into the gas network. This is a barrier in two different ways. First of all, it slows down the development of production as it keeps the overall demand for hydrogen low. Increasing this injection capacity will automatically increase the demand and will therefore positively affect the business case of production facilities. Secondly, it also does not allow for the distribution of pure hydrogen, which makes the development of a dedicated hydrogen network in the public area near impossible as it would need some form of exemption to the current regulations.

6.1.2. Suggested Regulatory Reforms

Aside from the current barriers and drivers in the regulatory framework in the Netherlands, stakeholders were also asked about their vision for the future. What they see as needed regulatory reforms to support and accelerate the development of regional hydrogen distribution networks will be discussed in the Section.

Subsidies and Guarantees for Hydrogen Projects

As seen in Section 6.1.1, subsidies were seen as both a barrier and a driver. Because of this two-sided characteristic, it will be necessary to increase the clarity of the subsidy structure. This will create more certainty for investors due to government guarantees that certain costs will be subsidised by the government.

1. *"Joint subsidies or government guarantees for regional and national projects are essential."*
2. *"Where proven high demand for hydrogen exists, the government could facilitate investment, possibly through loans or encouraging pension funds to participate."*

Both quotes highlight the necessity for a clear governmental-backed subsidy scheme to support the development of hydrogen distribution networks. The first quote states that not only should the HNS be subsidised, but regional networks also need some form of governmental guarantee or subsidising scheme. The second quote also mentions a criterion that should be followed when appointing subsidies. The areas where hydrogen demand is high should be considered first when subsidising and developing hydrogen distribution networks.

Increased Flexibility in Infrastructure Allocation

As technologies develop constantly, so should regulations and governmental approaches. In the interviews, several stakeholders mentioned the necessity for governmental flexibility when developing hydrogen infrastructure. As provincial ordinances often apply for several years, they can block the development of new, innovative solutions such as regional hydrogen production and distribution. A more flexible approach is preferred by stakeholders, as highlighted in the quotes below.

1. *"Recognize that hydrogen installations don't necessarily belong on industrial sites; they can be near solar and wind energy hubs in rural areas. Adjusting provincial environmental regulations to accommodate this would be beneficial."*
2. *"National government support for a more flexible, demand-driven approach to hydrogen installations, rather than a strict focus on large hydrogen users"*

One interviewee suggested that a more flexible approach to provincial environmental regulations such as the provincial ordinance can help to accelerate hydrogen projects. The two quotes above highlight different areas where the government could implement this flexibility. The increased flexibility will allow installations and networks to be developed outside industrial areas which can be needed to create so-called energy hubs. These are sites where solar or wind farms are built together with an electrolyzer and transportation or distribution infrastructure. These energy hubs can then help to relieve electricity grid congestion and increase the diversity of the Dutch energy mix.

3. *"Prioritize projects that aim to solve grid congestion in the Energy Act. Projects like batteries or hydrogen installations should move up the list for off-take connections, ahead of company expansions wanting more off-take."*

This quote suggests an addition to the ENA. By prioritising congestion-relieving projects, the interviewee states that they can kill two birds with one stone, on the one hand easing the congestion on the grid and on the other hand creating hydrogen supply and energy storage. This does require an addition to the Act, giving a regulatory body the power to move up certain projects.

Creating Market Certainty and Availability

To address the chicken and egg problem discussed in Chapter 1, the support for the creation of a hydrogen market was investigated in the interviews. Several quotes that show what must be done to tackle this problem are discussed below.

1. *"For hydrogen, you must ensure production meets demand, especially for decentralized networks. This remains a complex issue needing further discussion."*

This quote highlights the complex issue of balancing production and demand. This is the point where hydrogen networks can no longer be compared to gas networks because gas supply is completely different to hydrogen production. Green hydrogen production is dependent on the production of RES and is therefore variable. If a continuous industrial process is connected to such a hydrogen source it will be difficult to balance the system. Storage and additional energy sources should be considered in the development of these networks. If the network is connected to the national grid, imports can provide some form of security of supply as was identified in quote 2.

2. *"It's crucial to develop the entire value chain simultaneously. Prioritization, guarantees, and funding help, but we must ensure balanced development across production, infrastructure, and demand. Importing hydrogen from regions with lower production costs could also help."*

This quote is important as it highlights that the development of a hydrogen system cannot be incremental; instead, all components must be developed simultaneously. This balanced development is crucial as it allows initial production to meet initial demand, enabling the system to grow naturally. However, these early stages involve high risks and significant investment costs, underlining the need for a clear subsidisation structure. Additionally, the quote emphasises the necessity of hydrogen imports to meet future demand. Despite the Netherlands expanding its RES, it is predicted that domestic capacity will be insufficient for the necessary hydrogen production. To support these imports and provide security of supply, the government can establish agreements with countries possessing favourable hydrogen production climates, such as those in North Africa or the Middle East.

3. *"Future regulations might require industries to blend in a certain percentage of green hydrogen, which could drive demand."*

Lastly, this quote supports the analysis made after quote 2 of the Lack of Standardisation section. Allowing for a larger blending percentage can create the initial demand that will in turn drive investment in more production facilities and a bigger distribution network.

Supporting Industrial Clusters

The statement EUGD10 in Section 4.3.2 mentioned the exemption under which the geographically confined networks can be operated. The importance of support for these networks is discussed in this section.

1. *"Encouraging smaller entrepreneurial clusters to develop their infrastructure could be key, allowing faster progress without waiting for network operators. Flexibility in infrastructure management could spur innovation and accelerate the energy transition."*

This quote is related to EUGD10 as it states that support is needed for these geographically confined clusters. It would allow for the decentral development of smaller hydrogen networks where demand is high. This support can be in the form of subsidies or technical support by experienced parties such as a DSO. Other support mechanisms could be the increased flexibility in permitting the construction of regional hydrogen infrastructure as discussed before at the Increased Flexibility in Infrastructure Allocation quotes.

2. *"One major issue for us as distribution network operators is the definition that a hydrogen terminal cannot be connected to a distribution network. This is a missed opportunity, especially in the Amsterdam port area."*

This quote states that a change has to be made to the upcoming EU regulations. The interviewee views the fact that hydrogen terminals cannot be connected to distribution networks as a limiting factor. This is because this would prohibit the networks in areas such as ports to connect to the hydrogen imports that are much needed to balance the system. Changing this so that they can be connected can help to support the development of hydrogen distribution networks in such locations.

Fair and Clear Access Conditions

Several statements that were analysed in the upcoming regulatory documents already mentioned Access conditions, cost spreading and contract rights. They do not, however, go into detail on these subjects. The quote below shows that working out every part is required to ensure a fair and efficient system.

1. *"The key is ensuring third-party access and reasonable tariffs. Whether private or public, it matters less as long as costs, access, safety, and maintenance are well-regulated."*

It seems that for all different networks both private and public, correct regulations on the most important issues are required. It will be the job of the regulatory bodies to include the most important stakeholders such as DSO, but also consumers in the development of these regulations. Only this way will it be a fair and reasonable regulatory framework that supports the development of the regional hydrogen distribution networks.

Integration with Existing Networks

This topic connects directly to the Supporting Industrial Clusters topic and the EUGD9 statement. EUGD9 mentions the already existing hydrogen networks, often found in industrial areas can be exempt from the Directive document. However, if these networks are connected to a larger overall network, this exemption is revoked. This allows for interesting opportunities for DSOs.

1. *"If it starts small but has the potential to grow, it's wise for an appointed distribution network operator to manage it or support the development of such a regional network. Otherwise, you create isolated areas that need to connect to someone else with different starting points and network characteristics."*

When developing regional hydrogen distribution networks, already existing networks, often industrially managed cannot be forgotten. These private networks can be managed and developed by these private entities. However, a consulting role for DSOs could still be needed to help these smaller clusters with issues such as safety and technical requirements. If these smaller clusters are to be connected to a bigger network in the future, homogeneous specifications of these networks are necessary. Something which DSOs can provide with their expertise. Secondly, the DSOs will become responsible for these bigger, interconnected networks as stated in the Directive text. It is however important to notice, that the text does not specify that existing gas & electricity DSOs will fulfil this role. Other companies could also jump on the chance to become operators of these hydrogen networks. For the selection procedure it will be necessary to present comprehensive investment and development plans to the government. This way the minister of Economic Affairs and Climate will be able to chose the most capable party.

6.2. Hypotheses Discussion

In this section the hypotheses formed in Section 5.1 will be discussed briefly using the information obtained from the interviews. Section 6.2.1 will be used to review the current regulation hypotheses and Section 6.2.2 to review the Upcoming regulation hypotheses.

6.2.1. Current Regulations Hypotheses Review

Hypothesis 1 outlined the unclear planning responsibility and its influence on network development. As discussed in Section 6.1.1, the EPA has not yet had the influence on the development of these networks as expected by interviewees. This shows that additional regulations have to be formed to clarify these responsibilities for hydrogen networks. Next to this, it was shown that to efficiently develop the hydrogen system, simultaneous action across the value chain is needed. This will require detailed planning and perhaps even overarching governmental guidance.

Hypothesis 2 outlined the lack of a clear cost-spreading structure and its effects on investments. While many stakeholders mentioned the need for a clear subsidizing scheme, due to the underdeveloped nature of the hydrogen market it was still difficult to say anything specific about eventual cost structures. The upcoming documents did mention that operators will be allowed to spread their costs over time to allow for fair distribution. This should be used as the preliminary guideline for cost structures. However, for initial investments in hydrogen distribution infrastructure, more guarantees will be needed.

Hypothesis 3 discussed the absence of a hydrogen market and the effect of this uncertainty on the development of hydrogen networks. Many stakeholders expressed the need to ensure the balancing of production and demand. This requires an efficient and effective hydrogen market. A hydrogen market cannot be created without all parts of the value chain which again highlights the need for simultaneous action across the whole chain. The market and the infrastructure cannot be seen separately and it is therefore needed to develop the market in tandem with the infrastructure. By allowing a larger percentage of hydrogen to be injected into the system the foundation of this market can be laid down. This will require the Dutch regulatory bodies to allow for such injection.

6.2.2. Upcoming Regulations Hypotheses Review

Hypothesis 4 discussed the lack of a clear subsidising scheme as one of the factors of the slow development of regional hydrogen distribution networks. As was discovered, subsidising was seen by many stakeholders to be insufficient and uncertain. This in turn makes large investments highly risky and unlikely to be made. Most stakeholders that were interviewed preferred more extensive subsidy schemes and the certainty that these subsidies would last for the foreseeable future. Only then will there be enough trust to actually invest the large amounts needed to develop regional hydrogen networks.

Hypothesis 5 mentioned the penalty system that has not been defined yet for the hydrogen sector. While the penalty system itself was not seen as a barrier or issue, the lack of standardisation was. This ambiguity slows down development because for each project standards have to be developed. One standard document defining safety, technical requirements, tariffs and access conditions can greatly support the development of regional hydrogen networks as well as give clear indications on what is allowed and what is not.

Lastly, hypothesis 6 mentioned the possibility for stakeholders to want additional regulations to better support the development of regional hydrogen distribution networks. This hypothesis encompasses all the results from Section 6.1.2. Stakeholders mostly mentioned the increase in subsidising, but also want a more flexible approach to hydrogen projects, development support across the value chain, and more support for regional cluster initiatives.

6.3. Possible Additions to the Network Diagram

In this Section the diagram formed in Section 4.3.3 is expanded upon. Possible additions to the network diagram have been added in Figure 6.1. The added statements have been given the colour blue to separate them from the rest of the diagram.

The first added statement is used to define the more flexible approach to regional hydrogen projects. The object of this statement is the flexible regulatory conditions created by the member states. It connects to the already existing EUGD6 statement. This is because these flexible conditions will still need to happen transparently and under consideration of economic conditions. The second statement that was added on the top right is used to define the support across the value chain. This must happen when developing the infrastructure and the market, which is why the condition of this new statement has been connected to the EUGR5 statement. The third statement, which outlines the creation of a subsidising framework, has been put in the bottom centre of the diagram. Its object, the robust and clear subsidising structure, connects back to the EUGR1 statement. This has been done, because this new subsidising structure must still follow the principles such as transparency and fairness. The fourth statement connects to EUGD9/10. This statement outlines the necessity for member states to support the regional entrepreneurial clusters when developing hydrogen distribution networks. Lastly, an addition was made to EUGD5's condition. It will be necessary to increase cooperation with all stakeholders when creating the third-party access system.

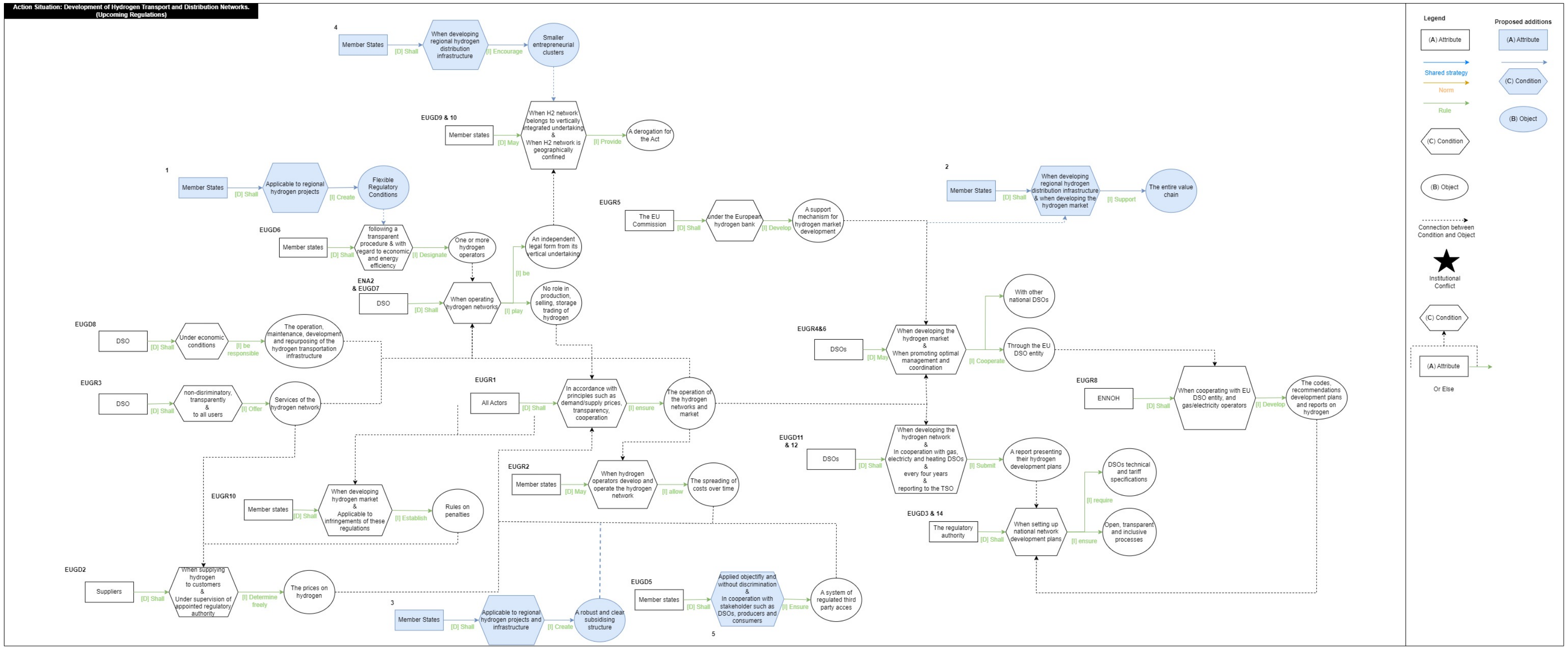

Figure 6.1: Possible Additions to Network Diagram

Now this new diagram shows several possible additions to the regulatory framework. Their effect cannot be seen unless they are implemented or further research is done. However, based on this diagram recommendations for both regulatory bodies and DSOs can be made on what actions they can take right now to support the development of regional hydrogen distribution networks. In the following chapter, this research will be concluded. Following the conclusions of each SQ and the Main RQ, these recommendations will be discussed.

7 Conclusion

In this final chapter, the findings of this thesis are summarised. It presents a comprehensive overview of the results from the sub-questions, which will be used collectively to address the main research question. The goal of this research was to analyse the current and upcoming regulations for regional hydrogen distribution networks, show how these regulations form a cohesive framework and determine what reforms are necessary to help support and accelerate the development of these networks further. To this end, the main research question was formulated as follows:

"How can regulatory frameworks influence the development of the Dutch regional hydrogen distribution networks?"

In order to answer this Main RQ, the sub-questions must first be answered in the sections below. Each SQ will be discussed separately, culminating in the conclusion of the Main RQ.

7.1. SQ1 Conclusion

The goal of Section 3.1.3 was to provide insights into SQ 1:

What specific regulations currently govern the development of regional hydrogen distribution networks?

The regulations that are listed in Table 2.1 are the main regulatory documents currently governing the development of hydrogen distribution infrastructures. The Environment and Planning Act defines administrative bodies' roles and sets spatial planning requirements. The Gas and Electricity Acts have defined the rules and requirements for the current energy system without a specification on hydrogen. Several regulatory initiatives such as the pilot framework and hydrogen guidelines give temporary guidelines surrounding hydrogen projects currently underway or starting.

As the analysis of current policy documents shows, there is still a lack of a framework solely focused on regulating the development of regional hydrogen infrastructures. The current regulations are old and based on an energy system that relies only on gas and electricity. The temporary frameworks that have been developed lack overall long-term vision. Therefore, the government does not provide the security that companies need to invest in hydrogen technologies. Upcoming regulations, both national and international are needed to provide clarity and direction for the whole hydrogen value chain.

7.2. SQ2 Conclusion

The goal of Section 3.2 was to provide insights into SQ2:

Who are the key actors in the Dutch regional hydrogen distribution system for cluster 6?

The actors have been divided into two groups, the regulatory bodies and the policy subjects. The regulatory bodies have their base in the executive branch of government and each governs a different part of the arena. These bodies range from local authorities, that govern the planning of land use, to the ACM, which regulates the gas market. These regulatory bodies have the power to steer the development of the regional hydrogen distribution network and provide the public with the security and clarity they so desperately crave.

The policy subjects are companies that occupy a certain part of the hydrogen value chain that was discussed in Section 3.1.2. The Netherlands is seeing a lot of projects that are aimed at producing green hydrogen, but these will not be sufficient to meet the hydrogen demand. That is why imports and local production need to be considered alongside the large production facilities. On the distribution end, the DSOs that are active in the Netherlands will play a key role. They will likely fulfil a similar role with hydrogen distribution as they play now with gas and electricity. Lastly, the end-users are the industry representatives for cluster 6. These 9 different industries will have different ways they decarbonise for example further electrification but the glass and ceramics sector will be interested in hydrogen infrastructure as they need it for their high-heat processes.

Concluding, the stakeholders in the regional distribution of hydrogen are plentiful and diverse, each with their own interests and goals. The regulatory bodies must lead the way in ensuring a comprehensive regulatory framework that provides guidance and assurance. The policy subjects can help by expressing their interest in hydrogen, investing in the technologies and supporting each other with knowledge and experience sharing.

7.3. SQ3 Conclusion

Section 6.1.1 contains the insights required to answer SQ3:

"To what extent do the actors perceive the current regulations surrounding regional hydrogen distribution networks as barriers or enablers?"

The semi-structured interviews, that were used to obtain the stakeholders' perception of current regulations, started with their opinion on potential barriers or drivers. As was seen in Section 6.1.1 several different topics were identified.

First, the current subsidies were seen as both a driver and a barrier. Due to the uncertainty surrounding the granting of said subsidies and the lengthy application procedure, they are still perceived as a barrier. However, they are also one of the only ways to obtain enough funds to develop these costly networks. Secondly, several issues in specific acts were identified. One major barrier is the Delegated Acts, which complicate hydrogen project alignment due to hourly correlation requirements, asset age regulations and specifications on renewable fuels of non-biological origin. Another barrier was found in the EPA. This act was supposed to speed up planning and zoning processes, but actors have not yet seen this in the system. Lastly, the lack of standardisation slows the development of hydrogen distribution networks. Currently norms and standards for gas must be interpreted to fit hydrogen specifications. This slows down projects and can create confusion if different parties use different standards. The lack of a higher injection standard slows the creation of a hydrogen market, as the volumes are too low to drive more production and demand side investments.

In conclusion, stakeholders in the Dutch hydrogen sector still face issues due to the regulatory framework in place. Barriers are the subsidy scheme, lack of standardisation and ineffectiveness of acts such as the EPA. Subsidies are also seen as a driver, due to the high investment costs for hydrogen infrastructure, but they are insufficient.

7.4. SQ4 Conclusion

Section 6.1.2 contains the insights required to answer SQ4:

"What are possible additions to the regulatory framework for regional hydrogen distribution networks that will support the development of these networks?"

The last part of the semi-structured interview was used to obtain stakeholders' vision on future regulatory reform or additions. In Section 6.1.2 several topics were identified.

Subsidies and guarantees for hydrogen projects are seen by interviewees as one of the most important factors to support the development of hydrogen infrastructures, including regional distribution networks.

The high-demand regions should be served first by facilitating investments through loans or pension funds. A second topic was the need for increased flexibility in allocation procedures. By recognising that hydrogen installations should not only be placed on industrial sites, regional energy hubs can be created. Next to this, by prioritising grid congestion-solving projects such as hydrogen installations, stakeholders believe they have an impact on current energy problems as well as the future energy mix. The third topic addresses the need for market certainty. This can be done by developing the entire value chain simultaneously, which helps to balance production with demand. Where production is still lagging, the government can step in by creating import deals with countries that have a better hydrogen production climate. The government should also support smaller industrial clusters to develop their infrastructure independently. This will create local production which can service any willing customer in the area. These smaller networks can later be connected to the larger distribution system, which is when the DSO will take control. The DSO can play an advisory role when these small networks develop, ensuring that they all meet similar specifications, which will make integration easier later on. Lastly, the access conditions to the distribution network should be developed in tandem with stakeholders in the system and create a fair and efficient system.

In conclusion, a more robust subsidy framework is needed that provides the certainty that investors crave. Changes to the provincial ordinance regulatory structure and EA can help increase allocation flexibility which can drive hydrogen projects and infrastructure development in the region. Providing certainty across the value chain is needed to create an efficient hydrogen system. Higher injection percentage can create the initial demand and imports can help to create security of supply for the initial hydrogen market. Government support for regional entrepreneurial clusters can increase regional hydrogen production, spurring innovation and accelerating the energy transition.

7.5. Main RQ Conclusion

With the results of all the SQs gathered, the main research question can now be answered.

”How can regulatory frameworks influence the development of the Dutch regional hydrogen distribution networks?”

The development of a regulatory framework for regional hydrogen distribution networks in the Netherlands is crucial for accelerating the development of these networks. This thesis explored the current regulatory landscape, identified key stakeholders, and evaluated their perceptions to propose potential additions to the framework and conceive action advice for interested stakeholders.

The existing regulations are insufficient and several barriers still exist, which creates uncertainty and slows down the development of hydrogen infrastructure. There is a need for a clear, extensive regulatory framework that aligns international, national and regional policies, ensuring consistency and predictability for all stakeholders involved. The key stakeholders identified include regulatory bodies, DSOs, hydrogen production companies, and local governments. The stakeholders perceive the current regulations as inadequate, mentioning issues such as the absence of sufficient financial incentives, complex permitting processes, and lack of technical standards. The proposed regulatory framework includes the introduction of a robust subsidy structure, additions to permitting and allocation flexibility, and the establishment of standardisation. These changes aim to create a supportive regulatory framework for hydrogen infrastructure development, reducing uncertainties and encouraging investment.

Regional hydrogen network development is expected to be significantly affected by the establishment of a clear regulatory framework. It will encourage technological innovation, provide investors the reassurance they need, and make it easier to integrate hydrogen into the larger energy system.

8
Discussion

This Chapter presents a discussion of the findings of this research. Section 8.1 presents advice for DSOs and any other interested party on what actions can be taken to accelerate the development of regional hydrogen distribution networks. It also states several potential development routes along which the Dutch regional hydrogen distribution networks can develop. Section 8.2 provides concluding remarks about the contribution of this thesis to the scientific landscape, connecting this research back to Section 1.2. To conclude this thesis, Section 8.3 provides the limitations of the thesis and the recommendations for further research.

8.1. Action Recommendations

This section is focused on the action recommendations that can be distilled from the overall analysis and conclusions. This Section has been divided into two sections. Section 8.1.1 is aimed at the regulatory bodies and will contain advice on possible regulatory reforms needed for the acceleration and support of regional hydrogen distribution network development. Section 8.1.2 is aimed at the policy subjects and contains advice on the actions these subjects can take to comply with current and upcoming regulations as well as the support they can give to each other and for the formation of new regulations. Lastly, Section 8.1.3 outlines the different potential development routes that regional hydrogen distribution networks can follow. It discusses the role of the DSO in these routes, what issues these routes can present and how these issues can be resolved.

8.1.1. Regulatory Body Advice

Based on the analysis, interviews and conclusions the list of action points was formulated for regulatory bodies. Considering the interaction between regulation and the planning and development of regional hydrogen networks, and the long lead time for the development of such networks, action on the regulatory framework for regional hydrogen networks must be taken on time (Ministerie van EZK, 2024). To enhance the regulatory framework and accelerate the development of regional hydrogen networks in the Netherlands, cooperation between these regulatory bodies and the policy subjects is necessary and the action lists shown below will provide the basis for this cooperation.

1. Create a clear, robust and future-proof subsidy framework. This will create certainty among stakeholders and investors to make long-term hydrogen investments.
2. Introduce flexibility options in provincial ordinances. This will allow for local hydrogen projects and infrastructure to develop. Which in turn fosters innovation and accelerates the energy transition.
3. Support regional clusters in independent infrastructure development. This can be done via financing this infrastructure and providing exemptions from existing regulations where needed.

Point 1: Subsidy Framework

A clear and structured subsidy framework was the most important regulatory addition that came forward from the interviews. This research proposes different sides to this framework. The first side will be for the development of distribution networks. The government can use the claw-back principle similar to that of the HNS (Ministerie van EZK, 2022b). This principle allows for a subsidy as long as it is necessary but also gives the government the power to get money back if too much money has been given out. This can happen when the development of hydrogen in the Netherlands goes faster than expected and the DSO can already support themselves through the tariffs they put on the use of the network. It is believed that this will be an effective subsidy method for distribution networks as it will support them for as long as possible. Another possibility to support DSOs could be to guarantee them that they can fully write off their hydrogen assets at the end of the regulatory useful life (Ministerie van EZK, 2024). Choosing between these possibilities will depend on the Ministry of Economic Affairs and Climate.

The second side of this subsidy scheme is for production projects and consumers. The projects can be subsidised using a similar claw-back structure. It will be the task of the project management to provide the government with a detailed investment and development plan that showcases the business case and feasibility of the project. Using the claw-back structure will ensure efficient money spending by the government. For the consumer side, it could be possible to subsidise the use of the hydrogen network by setting a maximum tariff (Ministerie van EZK, 2024). This must be done in tandem with the support of the distribution networks discussed in the first side as it directly affects the business case of the DSOs. Lastly, the government should support hydrogen prices in a way that will make them competitive with fossil fuel alternatives. This can be done via tax exemptions or by importing lots of hydrogen from places where the production is much cheaper. Tackling issues in the value chain this way ensures that the whole value chain is covered and can be developed simultaneously.

The Ministry of Economic Affairs and Climate needs to decide the overall extent of the subsidy scheme. The money available will depend on the government's willingness to spend on the energy transition and hydrogen in particular. With a new right-wing government, the interpretation of this is still uncertain.

Point 2: Flexibility Options

The second point of the list can be achieved via ministerial decree if it is properly shown that the projects that benefit from this change are of societal importance. If this cannot be done, a new law needs to be put in place to allow provinces more flexibility in their allocation power of new energy infrastructure such as hydrogen installation, storage and distribution facilities. This will take longer and is dependent on the willingness of the new Dutch government to support laws that influence the energy transition. These flexibility options will be necessary for allowing the development of regional hydrogen production facilities, energy hubs and hydrogen distribution infrastructure that has not been included in provincial ordinances. Increasing flexibility will help keep up with the rapidly developing energy system and its technologies.

Point 3: Regional Cluster Support

The third point of the list can be achieved via subsidies as discussed before or via ministerial decree. If this proves to be none effective, the government can create a new advisory entity that consists of experts on hydrogen, which could include DSOs. This entity will support the regional cluster with knowledge on how to construct, operate and maintain hydrogen infrastructure in their industrial location. Clarity in regulations on what they can build where is also important to give these industrial clusters more certainty.

8.1.2. DSO Advice

Based on the analysis, interviews and conclusions the following list of action points was formulated for policy subjects, in particular the DSOs of the Netherlands:

1. Create convincing investment and development plans. This will ensure that the DSOs that are the most capable will be selected by the Minister of Economic Affairs and Climate to develop the hydrogen distribution networks in the Netherlands.
2. Engage in discussion with governing bodies to create tailored regulations. This will create scientifically backed regulation and efficient governance of the hydrogen distribution networks.
3. Support regional clusters in independent infrastructure development. This support can be crucial in the development of these networks and can help to integrate them into a large system in the

future. DSOs can play a guiding role in the initial development and an operating role should independent networks be connected to the larger system.

Point 1: Development Plans
The first step that a current gas and electricity DSO should take, if they want to be involved in the hydrogen system, is to develop comprehensive development and investment plans. As the government is required to follow a transparent and fair procedure to appoint these DSOs, the plans will need to be convincing and show the capability of the DSOs to develop, operate and maintain hydrogen networks. The plans can include regions where these networks will be first developed, who will be included and how they plan the expansion of the networks.

These plans not only show the government the intent and capability of a DSO but also ensure a long-term vision. This is because the DSOs should include in these plans commitment agreements with producers and users. These agreements could include a minimum supply or uptake promise from the users (Ministerie van EZK, 2024). This will greatly enhance the certainty and balancing capability of the hydrogen distribution networks. An initial example of such an uptake agreement could be connections to a refuelling station. They can provide initially small, but continuous usage of regional distribution networks. The DSO should also ensure that consumers and producers know that the connection costs will fall on the party that requests the connection. These kinds of arrangements need to be worked out in the commitment agreements so that both the DSO and the users have certainty.

Point 2: Active Regulatory Involvement
Aside from trying to become a new hydrogen DSO, the current gas and electricity DSOs should be actively involved in the formation of the Dutch regulatory framework for regional hydrogen distribution. By staying in direct contact with regulatory bodies, the DSOs can ensure that effective regulations will be included in future legislation. This cooperation and transfer of knowledge is crucial for efficient governance of the regional hydrogen distribution networks.

Point 3: Support Regional Clusters
This point is similar to Point 3 from Section 8.1.1. DSOs should be involved in regional cluster development in some capacity. This can be done in consultation with the industries in said cluster. When such a cluster is developing a DSO could adopt an advisory role, transferring knowledge on hydrogen safety, technical norms and network operation to the participants. This can greatly increase the capability of the regional network to be integrated with other networks in the future, due to the homogenous use of these technical norms. Going one step further a DSO can also play the operator role in this regional cluster if the participants do not want to organise this themselves or are incapable. In this instance, an operating tariff will be applied by the DSO to the participants. For such clusters to operate properly, sufficient hydrogen supply and demand will be needed. This must be ensured through commitment agreements and sufficient production capacity installations in the area.

8.1.3. Development Routes

Several development routes for regional hydrogen distribution networks have been identified based on the interviews held with the different stakeholders and the conclusions drawn in Section **??**. This section discusses each route, the potential issues and the role for a Dutch DSO in these routes.

Route 1. Independent Network Formation
The development of independent networks does not rest solely on the implementation of an encompassing regulatory framework. Some independent networks already exist in the Netherlands, such as the DOW-YARA pipeline in Zeeland (DOW, 2018). Networks like these are privately owned and often also privately operated, minimizing the role of a DSO. Small stand-alone networks need to balance the supply and demand of hydrogen, which might require some form of storage (Ministerie van EZK, 2024). Should the owners of such an independent network not be able to operate their network, a DSO that is already active in the region should take over. An operating tariff should be agreed upon by all participating parties but should include costs and a reasonable profit for the DSO. The formation and business case of these stand-alone networks are still uncertain and need further investigation.

Route 2. Independent Formation & Integration

Route 2 is an extension of Route 1. Should the independent networks mentioned in Route 1 grow, for example through increased interest in the region, they can eventually be connected to the larger hydrogen distribution system. It will be required by law for DSOs to take over such a network when independent networks are connected to a larger system. However, due to the lack of standardisation, it is possible that these independent networks will operate with different characteristics and technical standards. Integrating these networks can create problems in the future such as high integration costs. To avoid this, it is proposed that the DSOs create an advisory division that advises and monitors these forming independent networks on operating characteristics and technical standards. This will alleviate problems for the future and allow DSOs to easily integrate these networks into the larger system.

Route 3. Directly Connected to the Backbone

Regional clusters that are relatively close to the backbone can be directly connected to the hydrogen backbone. This will require a DSO to develop the distribution networks for these clusters. They can either create new pipelines for hydrogen or open up current gas pipelines if they become redundant. It is unclear who exactly will pay for a connection between independent networks and the backbone. But as DSOs and the TSO will be required by law to cooperate, it can be arranged to split connection costs between them. Another possibility could be to allow the DSO to spread the costs of connecting to the backbone over all the users in that connected distribution network. The redundant pipelines can be created if another gas pipeline close by can take on the supply task of the redundant pipeline. Subsidy support from the government as discussed in Section 8.1.1 will be needed for the initial development of these networks. A sufficient amount of hydrogen will be needed in the system to balance it properly. This can be achieved in the future by increased hydrogen production capacity funded by the government or large energy producers, however, currently, there is not enough RES to supply the electricity needed. To overcome this, imports will be needed to provide the initial hydrogen supply. Together with the commitment agreements discussed in Section 8.1.2, these will create the certainty needed to effectively develop these distribution networks.

8.2. Contribution to Scientific Landscape

This thesis provides contributions to the scientific landscape by addressing gaps in the regulatory frameworks and offers insights into possible actions for policymakers and industry stakeholders.

One of the primary contributions of this thesis is its comprehensive analysis of existing regulatory frameworks and their impact on the development of regional hydrogen distribution networks. By identifying the specific regulations that govern the development of these networks and investigating their effectiveness through stakeholder interviews, this research fills that knowledge gap in the current literature.

Section 1.2 of this thesis outlined the current state of research on hydrogen regulations, highlighting the influence of regulations on technology and stakeholders. Previous research, such as that by Bergek & Berggren (2014) and Rosenow & Kern (2017), highlighted the need for regulatory frameworks that support the adoption of new energy technologies by providing certainty and guidance. In countries such as Mexico and the US, studies have already been done on the legal structures surrounding hydrogen (Ávalos Rodríguez et al., 2022) (Bade et al., 2024). The Dutch hydrogen sector has been studied to find the current stakeholders and challenges (Hasankhani et al., 2024), but never to identify the complete regulatory framework and its issues. This thesis builds on these concepts by demonstrating how regulatory uncertainties specifically impact the hydrogen sector in the Netherlands, leading to delayed investments and slowed network development.

The use of colours in the network diagrams is a new addition the the INA technique. It can be used in future research into upcoming regulations or research into regulatory reforms needed by actors in a certain system.

By conducting semi-structured interviews with stakeholders in the Dutch hydrogen sector, such as regulatory bodies and DSOs, the thesis provides a good understanding of how current regulations are perceived as barriers or enablers. Next to this, the interviews provided insights into potential regulatory changes proposed by the interviewees.

These proposed changes and the comprehensive analysis of regulatory documents led to the formation of action recommendations for both regulatory bodies and policy subjects. The recommendations for the regulatory bodies are aimed at enhancing the subsidy framework, increasing allocation flexibility, and creating regional support mechanisms. For the policy subjects, the recommendations are aimed at the role of the DSO in the development of hydrogen networks and possible development routes of hydrogen distribution networks.

In conclusion, this thesis contributes to the scientific landscape by addressing regulatory gaps, adding colour-coding possibilities to Institutional Network Analysis, incorporating stakeholder insights into the regulation formation, and offering action recommendations. The outcomes of this research can form an example for hydrogen regulatory framework analysis in other countries.

8.3. Limitations and Recommendations

Although this study provides relevant insights into the regulatory frameworks influencing the development of regional hydrogen distribution networks in the Netherlands, it should be pointed out that there are some limitations. To start, the regional hydrogen distribution networks in the Netherlands' Cluster 6 are the primary focus of this study. As a result, it's possible that the conclusions cannot be applied to other nations or areas with different industrial structures and regulatory frameworks. Secondly, although the study incorporates perspectives from several stakeholders, the sample size for the interviews was small, therefore it might not fully represent the range of perspectives that exist in the sector. This constraint could result in biases or a partial understanding of the perspectives of stakeholders. Lastly, because policy and regulatory frameworks are dynamic, the regulatory environment can change quickly. The information gathered and analysed for this study is a moment in time, which might lower the impact of the findings over time.

Two recommendations for future studies can be made when considering this study's limitations and results. The first recommendation is; that future studies could think about broadening their scope to evaluate different regulatory systems across more countries and regions. This could offer a greater understanding of the difficulties and best practices associated with the development of hydrogen infrastructure worldwide. The second recommendation is; that conducting more in-depth interviews with a wider range of stakeholders or gathering primary data through surveys, could provide deeper insights and reduce the uncertainty due to the small interview pool used in this study. This can also help to validate or contradict the views of stakeholders obtained in this study.

References

2021/0424/COD, 2. (2023). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the internal markets for renewable and natural gases and for hydrogen (recast). Retrieved May 14, 2024, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A804%3AFIN&qid=1640001545187

2021/0425(COD), 2. (2023). Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on common rules for the internal markets in renewable and natural gases and in hydrogen. Retrieved May 14, 2024, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0803&qid=1640002501099

ACM, A. (2021, July). ACM-notitie 'Ontwikkeling en regulering van waterstofinfrastructuur' | ACM.nl [Last Modified: 2021-07-22T11:14:18+0200]. Retrieved March 12, 2024, from https://www.acm.nl/nl/publicaties/acm-notitie-ontwikkeling-en-regulering-van-waterstofinfrastructuur

ACM, A. (2022, July). Tijdelijk kader voor waterstofpilots | ACM.nl [Last Modified: 2022-07-05T12:00:00+0200]. Retrieved May 14, 2024, from https://www.acm.nl/nl/publicaties/tijdelijk-kader-voor-waterstofpilots

Adeoye-Olatunde, O. A., & Olenik, N. L. (2021). Research and scholarly methods: Semi-structured interviews [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/jac5.1441]. *JACCP: JOURNAL OF THE AMERICAN COLLEGE OF CLINICAL PHARMACY*, *4*(10), 1358–1367. https://doi.org/10.1002/jac5.1441

Ahsan, D., & Pedersen, S. (2018). The influence of stakeholder groups in operation and maintenance services of offshore wind farms: Lesson from Denmark. *Renewable Energy*, *125*, 819–828. https://doi.org/10.1016/j.renene.2017.12.098

Aligica, P. D. (2006). Institutional and Stakeholder Mapping: Frameworks for Policy Analysis and Institutional Change. *Public Organization Review*, *6*(1), 79–90. https://doi.org/10.1007/s11115-006-6833-0

Alonso-Travesset, À., Coppitters, D., Martín, H., & de la Hoz, J. (2023). Economic and Regulatory Uncertainty in Renewable Energy System Design: A Review [Number: 2 Publisher: Multidisciplinary Digital Publishing Institute]. *Energies*, *16*(2), 882. https://doi.org/10.3390/en16020882

Alverà, M. (2021). [PDF] The Hydrogen Revolution: A Blueprint for the Future of Clean Energy Free. Retrieved March 8, 2024, from https://www.yumpu.com/en/document/view/67602797/pdf-the-hydrogen-revolution-a-blueprint-for-the-future-of-clean-energy-free

Ávalos Rodríguez, M. L., Alvarado Flores, J. J., Alcaraz Vera, J. V., & Rutiaga Quiñones, J. G. (2022). The regulatory framework of the hydrogen market in Mexico: A look at energy governance. *International Journal of Hydrogen Energy*, *47*(70), 29986–29998. https://doi.org/10.1016/j.ijhydene.2022.05.168

Bade, S. O., Tomomewo, O. S., Meenakshisundaram, A., Ferron, P., & Oni, B. A. (2024). Economic, social, and regulatory challenges of green hydrogen production and utilization in the US: A review. *International Journal of Hydrogen Energy*, *49*, 314–335. https://doi.org/10.1016/j.ijhydene.2023.08.157

Baldwin, E. (2019). Exploring How Institutional Arrangements Shape Stakeholder Influence on Policy Decisions: A Comparative Analysis in the Energy Sector [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/p *Public Administration Review*, *79*(2), 246–255. https://doi.org/10.1111/puar.12953

Bartels, J., Pate, M., & Olson, N. (2010). An economic survey of hydrogen production from conventional and alternative energy sources. *International Journal of Hydrogen Energy*, *35*(16), 8371–8384. https://doi.org/10.1016/j.ijhydene.2010.04.035

Baumgart, M., & Lavrijssen, S. (2023). Exploring regulatory strategies for accelerating the development of sustainable hydrogen markets in the European Union [Publisher: Routledge _eprint: https://doi.org/10.1080/02646811.2023.2257528]. *Journal of Energy & Natural Resources Law*, *0*(0), 1–30. https://doi.org/10.1080/02646811.2023.2257528

Bergek, A., & Berggren, C. (2014). The impact of environmental policy instruments on innovation: A review of energy and automotive industry studies. *Ecological Economics*, *106*, 112–123. https://doi.org/10.1016/j.ecolecon.2014.07.016

Biesbroek, G. R., Termeer, C. J. a. M., Kabat, P., & Klostermann, J. E. M. (2009). Institutional governance barriers for the development and implementation of climate adaptation strategies. Retrieved March 12, 2024, from https://library.wur.nl/WebQuery/wurpubs/387218

Bleischwitz, R., & Bader, N. (2010). Policies for the transition towards a hydrogen economy: The EU case. *Energy Policy*, *38*(10), 5388–5398. https://doi.org/10.1016/j.enpol.2009.03.041

Bochove, S. v. (2019). *The role of distribution system operators in the Netherlands: Exploring the necessary strategies, resources and capabilities of the distribution system operators in the Nehterlands to enable the Regional Energy Strategies* [Master's thesis] [Accepted: 2019-07-22T17:01:32Z]. Retrieved March 20, 2024, from https://studenttheses.uu.nl/handle/20.500.12932/32949

Button, K. S., Ioannidis, J. P. A., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S. J., & Munafò, M. R. (2013). Power failure: Why small sample size undermines the reliability of neuroscience [Publisher: Nature Publishing Group]. *Nature Reviews Neuroscience*, *14*(5), 365–376. https://doi.org/10.1038/nrn3475

CMS. (2022). Hydrogen law and regulation in the Netherlands | CMS Expert Guides. Retrieved February 13, 2024, from https://cms.law/en/int/expert-guides/cms-expert-guide-to-hydrogen/netherlands

CMS. (2024). Hydrogen law and regulation in industry | CMS Expert Guides. Retrieved April 4, 2024, from https://cms.law/en/int/expert-guides/cms-expert-guide-to-hydrogen/hydrogen-uses-laws-regulations-in-industry

Commissie, E. (2022). European Hydrogen Bank - European Commission. Retrieved May 9, 2024, from https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/european-hydrogen-bank_en

Commissie, E. (2023). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS on the European Hydrogen Bank. Retrieved May 9, 2024, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023DC0156&qid=1682349760946

Commissie, E. (2024). Soorten EU-wetgeving - Europese Commissie. Retrieved March 18, 2024, from https://commission.europa.eu/law/law-making-process/types-eu-law_nl

Crawford, S., & Ostrom, E. (1995). A Grammar of Institutions [Publisher: [American Political Science Association, Cambridge University Press]]. *The American Political Science Review*, *89*(3), 582–600. https://doi.org/10.2307/2082975

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., & Sheikh, A. (2011). The case study approach. *BMC Medical Research Methodology*, *11*, 100. https://doi.org/10.1186/1471-2288-11-100

de Bruin, K., Dellink, R. B., Ruijs, A., Bolwidt, L., van Buuren, A., Graveland, J., de Groot, R. S., Kuikman, P. J., Reinhard, S., Roetter, R. P., Tassone, V. C., Verhagen, A., & van Ierland, E. C. (2009). Adapting to climate change in The Netherlands: An inventory of climate adaptation options and ranking of alternatives. *Climatic Change*, *95*(1), 23–45. https://doi.org/10.1007/s10584-009-9576-4

de Flart, S. (2024). Hoe krijgt het zesde (regionale) industrie cluster toegang tot waterstof? - Duurzaam Energie Perspectief - Dep. Retrieved February 12, 2024, from https://www.dep.nl/artikelen/hoe-krijgt-het-zesde-regionale-industrie-cluster-toegang-tot-waterstof/

Dejonghe, M., Van de Graaf, T., & Belmans, R. (2023). From natural gas to hydrogen: Navigating import risks and dependencies in Northwest Europe. *Energy Research & Social Science*, *106*, 103301. https://doi.org/10.1016/j.erss.2023.103301

Detemple, J., & Kitapbayev, Y. (2020). The value of green energy under regulation uncertainty. *Energy Economics*, *89*, 104807. https://doi.org/10.1016/j.eneco.2020.104807

Díaz, P., Adler, C., & Patt, A. (2017). Do stakeholders' perspectives on renewable energy infrastructure pose a risk to energy policy implementation? A case of a hydropower plant in Switzerland. *Energy Policy*, *108*, 21–28. https://doi.org/10.1016/j.enpol.2017.05.033

Dixon, R. K., Li, J., & Wang, M. Q. (2016, January). 13 - Progress in hydrogen energy infrastructure development—addressing technical and institutional barriers. In R. B. Gupta, A. Basile, & T. N. Veziroğlu (Eds.), *Compendium of Hydrogen Energy* (pp. 323–343). Woodhead Publishing. https://doi.org/10.1016/B978-1-78242-362-1.00013-4

Dolci, F., Thomas, D., Hilliard, S., Guerra, C. F., Hancke, R., Ito, H., Jegoux, M., Kreeft, G., Leaver, J., Newborough, M., Proost, J., Robinius, M., Weidner, E., Mansilla, C., & Lucchese, P. (2019). Incentives and legal barriers for power-to-hydrogen pathways: An international snapshot. *International Journal of Hydrogen Energy*, *44*(23), 11394–11401. https://doi.org/10.1016/j.ijhydene.2019.03.045

DOW. (2018). Waterstofleiding Gasunie van Dow naar Yara in gebruik genomen. Retrieved June 11, 2024, from https://nl.dow.com/nl-nl/news/waterstofleiding-gasunie-van-dow-naar-yara-in-gebruik-genomen.html

EC. (2020, August). Hydrogen. Retrieved March 11, 2024, from https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en

Eden, C., & Ackermann, F. (2013, April). *Making Strategy: The Journey of Strategic Management* [Google-Books-ID: UnYWfXigU4UC]. SAGE.

EHB. (2024). The European Hydrogen Backbone (EHB) initiative | EHB European Hydrogen Backbone. Retrieved March 11, 2024, from https://ehb.eu/

Elektriciteitswet, E. (2024). Elektriciteitswet 1998 [Last Modified: 2024-05-09]. Retrieved May 14, 2024, from https://wetten.overheid.nl/BWBR0009755/2024-01-01

El-Shafie, M., Kambara, S., & Hayakawa, Y. (2019). Hydrogen Production Technologies Overview [Publisher: Hydrogen Knowledge Centre]. Retrieved April 2, 2024, from https://www.h2knowledgecentre.com/content/journal2618

Energiewet, E. (2024, May). Regels over energiemarkten en energiesystemen (Energiewet). Retrieved May 14, 2024, from https://www.tweedekamer.nl/kamerstukken/wetsvoorstellen/detail

EnergieXP. (2024). Over ons. Retrieved March 20, 2024, from https://energiexp.nl/over-ons/

Erdener, B. C., Sergi, B., Guerra, O. J., Lazaro Chueca, A., Pambour, K., Brancucci, C., & Hodge, B.-M. (2023). A review of technical and regulatory limits for hydrogen blending in natural gas pipelines. *International Journal of Hydrogen Energy*, *48*(14), 5595–5617. https://doi.org/10.1016/j.ijhydene.2022.10.254

Europeese Commissie, E. C. (2023). Renewable Energy Directive. Retrieved June 11, 2024, from https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en

Europeese Commissie, E. C. (2024). Renewable hydrogen - European Commission. Retrieved June 3, 2024, from https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/renewable-hydrogen_en

Fabrizio, K. R. (2013). The Effect of Regulatory Uncertainty on Investment: Evidence from Renewable Energy Generation. *The Journal of Law, Economics, and Organization*, *29*(4), 765–798. https://doi.org/10.1093/jleo/ews007

Fais, B., Keppo, I., Zeyringer, M., Usher, W., & Daly, H. (2016). Impact of technology uncertainty on future low-carbon pathways in the UK. *Energy Strategy Reviews*, *13-14*, 154–168. https://doi.org/10.1016/j.esr.2016.09.005

Falcone, P. M., Hiete, M., & Sapio, A. (2021). Hydrogen economy and sustainable development goals: Review and policy insights. *Current Opinion in Green and Sustainable Chemistry*, *31*, 100506. https://doi.org/10.1016/j.cogsc.2021.100506

Farias, C. B. B., Barreiros, R. C. S., da Silva, M. F., Casazza, A. A., Converti, A., & Sarubbo, L. A. (2022). Use of Hydrogen as Fuel: A Trend of the 21st Century [Number: 1 Publisher: Multidisciplinary Digital Publishing Institute]. *Energies*, *15*(1), 311. https://doi.org/10.3390/en15010311

Farrell, N. (2023). Policy design for green hydrogen. *Renewable and Sustainable Energy Reviews*, *178*, 113216. https://doi.org/10.1016/j.rser.2023.113216

Faye, O., Szpunar, J., & Eduok, U. (2022). A critical review on the current technologies for the generation, storage, and transportation of hydrogen. *International Journal of Hydrogen Energy*, *47*(29), 13771–13802. https://doi.org/10.1016/j.ijhydene.2022.02.112

Fazeli, R., Beck, F. J., & Stocks, M. (2022). Recognizing the role of uncertainties in the transition to renewable hydrogen. *International Journal of Hydrogen Energy*, *47*(65), 27896–27910. https://doi.org/10.1016/j.ijhydene.2022.06.122

Fung, A. (2006). Varieties of Participation in Complex Governance [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111 6210.2006.00667.x]. *Public Administration Review*, *66*(s1), 66–75. https://doi.org/10.1111/j.1540-6210.2006.00667.x

Garcia-Navarro, J., Isaacs, M. A., Favaro, M., Ren, D., Ong, W.-J., Grätzel, M., & Jiménez-Calvo, P. (2023). Updates on Hydrogen Value Chain: A Strategic Roadmap [_eprint: https://onlinelibrary.wiley.com/doi/pdf/ *Global Challenges*, *n/a*(n/a), 2300073. https://doi.org/10.1002/gch2.202300073

Gasunie. (2023, October). Waterstofnetwerk Nederland. Retrieved February 12, 2024, from https://www.gasunie.nl/projecten/waterstofnetwerk-nederland

Gasunie. (2024). Waterstof door gasleiding: Veilig en duurzaam. Retrieved February 12, 2024, from https://www.gasunie.nl/expertise/waterstof/waterstof-door-gasleiding-veilig-en-duurzaam

Gaswet, G. (2024). Gaswet [Last Modified: 2024-05-08]. Retrieved May 14, 2024, from https://wetten.overheid.nl/BWBR0011440/2024-05-01

Gegesi-Kiss, A. P. (2021, August). Hydrogen supply chains : Barriers and drivers for implementation of the Dutch hydrogen economy [Publisher: University of Twente]. Retrieved March 20, 2024, from https://essay.utwente.nl/88155/

Ghorbani, A., Siddiki, S., Mesdaghi, B., Bosch, M., & Abebe, Y. (2022, April). *Institutional Compliance in Flood Risk Management: A Network Analysis Approach*.

Gibbons, R. S., & Roberts, J. (2012, December). *The Handbook of Organizational Economics* [Google-Books-ID: LY7NBMGEHYsC]. Princeton University Press.

Gordon, J. A., Balta-Ozkan, N., & Nabavi, S. A. (2023). Socio-technical barriers to domestic hydrogen futures: Repurposing pipelines, policies, and public perceptions. *Applied Energy*, *336*, 120850. https://doi.org/10.1016/j.apenergy.2023.120850

Groenleven. (2024). Over GroenLeven | Duurzame energieoplossingen | GroenLeven. Retrieved March 20, 2024, from https://groenleven.nl/over-groenleven/

Hancock, D. R., Algozzine, B., & Lim, J. H. (2021, October). *Doing Case Study Research: A Practical Guide for Beginning Researchers* [Google-Books-ID: e7lLEAAAQBAJ]. Teachers College Press.

Hasankhani, M., van Engelen, J., Celik, S., & Diehl, J. C. (2024). Unveiling complexity of hydrogen integration: A multi-faceted exploration of challenges in the Dutch context. *Journal of Cleaner Production*, *434*, 139927. https://doi.org/10.1016/j.jclepro.2023.139927

Hassan, Q., Algburi, S., Sameen, A. Z., Salman, H. M., & Jaszczur, M. (2024). Green hydrogen: A pathway to a sustainable energy future. *International Journal of Hydrogen Energy*, *50*, 310–333. https://doi.org/10.1016/j.ijhydene.2023.08.321

Herreras Martínez, S., Harmsen, R., Menkveld, M., Faaij, A., & Kramer, G. J. (2022). Municipalities as key actors in the heat transition to decarbonise buildings: Experiences from local planning and implementation in a learning context. *Energy Policy*, *169*, 113169. https://doi.org/10.1016/j.enpol.2022.113169

Hisschemöller, M., Bode, R., & van de Kerkhof, M. (2006). What governs the transition to a sustainable hydrogen economy? Articulating the relationship between technologies and political institutions. *Energy Policy*, *34*(11), 1227–1235. https://doi.org/10.1016/j.enpol.2005.12.005

HNS, H. (2022, June). Kamerbrief over ontwikkeling transportnet voor waterstof - Kamerstuk - Rijksoverheid.nl [Last Modified: 2022-09-06T14:32 Publisher: Ministerie van Algemene Zaken]. Retrieved May 14, 2024, from https://www.rijksoverheid.nl/documenten/kamerstukken/2022/06/29/ontwikkeling-transportnet-voor-waterstof

Huneman, B. (2022). Cluster Energie Strategie van 'Cluster 6' aangeboden aan minister Rob Jetten. Retrieved March 8, 2024, from https://www.verduurzamingindustrie.nl/actueel/nieuws/2185806.aspx?t=Cluster-Energie-Strategie-van-%E2%80%98Cluster-6%E2%80%99-aangeboden-aan-minister-Rob-Jetten

HYGRO. (2024). Duwaal: Producing, distributing, fueling green hydrogen. Retrieved March 20, 2024, from https://hy-gro.nl/project/project-duwaal

Ishaq, H., Dincer, I., & Crawford, C. (2022). A review on hydrogen production and utilization: Challenges and opportunities. *International Journal of Hydrogen Energy*, *47*(62), 26238–26264. https://doi.org/10.1016/j.ijhydene.2021.11.149

KIVI. (2023). Nederlandse raffinaderijen kunnen een kwart bijdragen aan klimaatopgave industrie. Retrieved March 31, 2024, from https://www.kivi.nl/nieuws/artikel/nederlandse-raffinaderijen-kunnen-een-kwart-bijdragen-aan-klimaatopgave-industrie

Kovač, A., Paranos, M., & Marciuš, D. (2021). Hydrogen in energy transition: A review. *International Journal of Hydrogen Energy*, *46*(16), 10016–10035. https://doi.org/10.1016/j.ijhydene.2020.11.256

Lagioia, G., Spinelli, M. P., & Amicarelli, V. (2023). Blue and green hydrogen energy to meet European Union decarbonisation objectives. An overview of perspectives and the current state of affairs. *International Journal of Hydrogen Energy*, *48*(4), 1304–1322. https://doi.org/10.1016/j.ijhydene.2022.10.044

Lee, Y., Cho, M. H., Lee, M. C., & Kim, Y. J. (2024). Policy agenda toward a hydrogen economy: Institutional and technological perspectives. *International Journal of Hydrogen Energy*, *54*, 1521–1531. https://doi.org/10.1016/j.ijhydene.2023.12.129

Leyens, J.-P., Dardenne, B., & Fiske, S. T. (1998). Why and under what circumstances is a hypothesis-consistent testing strategy preferred in interviews? [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.2044-8309.1998.tb01171.x]. *British Journal of Social Psychology*, *37*(3), 259–274. https://doi.org/10.1111/j.2044-8309.1998.tb01171.x

Liu, R., He, L., Liang, X., Yang, X., & Xia, Y. (2020). Is there any difference in the impact of economic policy uncertainty on the investment of traditional and renewable energy enterprises? – A comparative study based on regulatory effects. *Journal of Cleaner Production*, *255*, 120102. https://doi.org/10.1016/j.jclepro.2020.120102

Machado, J. T. M., Flynn, B., & Williamson, I. (2022). The national shaping of Europe's emerging hydrogen strategies: Cooperative or competitive hydrogen Politics? [Publisher: SAGE Publications Ltd STM]. *Competition and Regulation in Network Industries*, *23*(1), 77–96. https://doi.org/10.1177/17835917221082935

Mansilla, C., Bourasseau, C., Cany, C., Guinot, B., Le Duigou, A., & Lucchese, P. (2018, January). Chapter 7 - Hydrogen Applications: Overview of the Key Economic Issues and Perspectives. In C. Azzaro-Pantel (Ed.), *Hydrogen Supply Chains* (pp. 271–292). Academic Press. https://doi.org/10.1016/B978-0-12-811197-0.00007-5

Maqbool, R., Rashid, Y., & Ashfaq, S. (2022). Renewable energy project success: Internal versus external stakeholders' satisfaction and influences of power-interest matrix [_eprint: https://onlinelibrary.wiley.com/doi/p *Sustainable Development*, *30*(6), 1542–1561. https://doi.org/10.1002/sd.2327

Marocco, P., Gandiglio, M., Audisio, D., & Santarelli, M. (2023). Assessment of the role of hydrogen to produce high-temperature heat in the steel industry. *Journal of Cleaner Production*, *388*, 135969. https://doi.org/10.1016/j.jclepro.2023.135969

Martin, N. J., & Rice, J. L. (2014). Influencing Clean Energy Laws: An Analysis of Business Stakeholder Engagement [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/bse.1795]. *Business Strategy and the Environment*, *23*(7), 447–460. https://doi.org/10.1002/bse.1795

McCubbins, M. D. (1985). The Legislative Design of Regulatory Structure [Publisher: [Midwest Political Science Association, Wiley]]. *American Journal of Political Science*, *29*(4), 721–748. https://doi.org/10.2307/2111178

McGinnis, M. D. (2011). An Introduction to IAD and the Language of the Ostrom Workshop: A Simple Guide to a Complex Framework [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1541-0072.2010.00401.x]. *Policy Studies Journal*, *39*(1), 169–183. https://doi.org/10.1111/j.1541-0072.2010.00401.x

Mesdaghi, B., Ghorbani, A., & de Bruijne, M. (2022). Institutional dependencies in climate adaptation of transport infrastructures: An Institutional Network Analysis approach. *Environmental Science & Policy*, *127*, 120–136. https://doi.org/10.1016/j.envsci.2021.10.010

MilieuCentraal. (2022). Waterstof: Welke kansen zijn er? Retrieved March 30, 2024, from https://www.milieucentraal.nl/klimaat-en-aarde/energiebronnen/waterstof/

Ministerie van Algemene Zaken, M. v. A. (2017, January). Duurzame energie - Rijksoverheid.nl [Last Modified: 2023-10-27T15:05 Publisher: Ministerie van Algemene Zaken]. Retrieved February 12, 2024, from https://www.rijksoverheid.nl/onderwerpen/duurzame-energie

Ministerie van BZK, M. v. B. (2024a). Elektriciteitswet 1998 [Last Modified: 2024-03-30]. Retrieved April 2, 2024, from https://wetten.overheid.nl/BWBR0009755/2024-01-01

Ministerie van BZK, M. v. B. (2024b). Gaswet [Last Modified: 2024-03-30]. Retrieved April 2, 2024, from https://wetten.overheid.nl/BWBR0011440/2024-01-01

Ministerie van BZK, M. v. B. (2024c). Omgevingswet [Last Modified: 2024-03-30]. Retrieved April 2, 2024, from https://wetten.overheid.nl/BWBR0037885/2024-01-01/0

Ministerie van EZK, M. v. E. (2019, July). Energiewet [Last Modified: 2023-11-22]. Retrieved April 2, 2024, from https://wetgevingskalender.overheid.nl/Regeling/WGK010483

Ministerie van EZK, M. v. E. (2020a). Government Strategy on Hydrogen - Publication - Government.nl [Last Modified: 2020-04-06T11:45 Publisher: Ministerie van Algemene Zaken]. Retrieved February 13, 2024, from https://www.government.nl/documents/publications/2020/04/06/government-strategy-on-hydrogen

Ministerie van EZK, M. v. E. (2020b, January). Overheid stimuleert gebruik van waterstof - Duurzame energie - Rijksoverheid.nl [Last Modified: 2024-01-18T13:33 Publisher: Ministerie van Algemene Zaken Running Time: 212]. Retrieved February 12, 2024, from https://www.rijksoverheid.nl/onderwerpen/duurzame-energie/overheid-stimuleert-de-inzet-van-meer-waterstof

Ministerie van EZK, M. v. E. (2020c, October). Koploperprogramma Het Zesde Cluster - Publicatie - Klimaatakkoord [Last Modified: 2020-10-21T12:23 Publisher: Ministerie van Economische Zaken en Klimaat]. https://doi.org/10/22/koplopersprogramma-het-zesde-cluster

Ministerie van EZK, M. v. E. (2022a). Richtsnoeren voor veilig omgaan met waterstof. Retrieved March 14, 2024, from https://www.rvo.nl/onderwerpen/richtsnoeren-waterstof

Ministerie van EZK, M. v. E. (2022b, June). Kamerbrief over ontwikkeling transportnet voor waterstof - Kamerstuk - Rijksoverheid.nl [Last Modified: 2022-09-06T14:32 Publisher: Ministerie van Algemene Zaken]. Retrieved March 22, 2024, from https://www.rijksoverheid.nl/documenten/kamerstukken/2022/06/29/ontwikkeling-transportnet-voor-waterstof

Ministerie van EZK, M. v. E. (2023, December). Nationaal Plan Energiesysteem - Rapport - Rijksoverheid.nl [Last Modified: 2023-12-01T16:20 Publisher: Ministerie van Algemene Zaken]. Retrieved March 28, 2024, from https://www.rijksoverheid.nl/documenten/rapporten/2023/12/01/nationaal-plan-energiesysteem

Ministerie van EZK, M. v. E. (2024). Kabinetsaanpak Klimaatbeleid. Retrieved June 10, 2024, from https://www.tweedekamer.nl/kamerstukken/brieven_regering/detail

Ministerie van Infra, M. v. I. (2024a). Gedoogplichten [Last Modified: 2021-03-16]. Retrieved April 12, 2024, from https://www.infomil.nl/onderwerpen/lucht-water/handboek-water/wetgeving/waterwet/aanleg-beheer/gedoogplichten/

Ministerie van Infra, M. v. I. (2024b). Structuurvisie [Last Modified: 2018-12-04]. Retrieved May 1, 2024, from https://www.infomil.nl/onderwerpen/lucht-water/handboek-water/thema-s/ruimtelijke-ordening/oppervlakte-water-en/structuurvisie/

NationaalRES. (2020). Dutch National Programme Regional Energy Strategies. Retrieved March 20, 2024, from https://www.regionale-energiestrategie.nl/english/default.aspx

Neij, L., & Åstrand, K. (2006). Outcome indicators for the evaluation of energy policy instruments and technical change. *Energy Policy*, *34*(17), 2662–2676. https://doi.org/10.1016/j.enpol.2005.03.012

NetbeheerNL. (2024). Onze leden | Netbeheer Nederland. Retrieved March 20, 2024, from https://www.netbeheernederland.nl/onze-leden

Newcombe, R. (2003). From client to project stakeholders: A stakeholder mapping approach [Publisher: Routledge _eprint: https://doi.org/10.1080/0144619032000072137]. *Construction Management and Economics*, *21*(8), 841–848. https://doi.org/10.1080/0144619032000072137

Nicita, A., Maggio, G., Andaloro, A. P. F., & Squadrito, G. (2020). Green hydrogen as feedstock: Financial analysis of a photovoltaic-powered electrolysis plant. *International Journal of Hydrogen Energy*, *45*(20), 11395–11408. https://doi.org/10.1016/j.ijhydene.2020.02.062

Nikolaidis, P., & Poullikkas, A. (2017). A comparative overview of hydrogen production processes. *Renewable and Sustainable Energy Reviews*, *67*, 597–611. https://doi.org/10.1016/j.rser.2016.09.044

Noble, H., & Smith, J. (2015). Issues of validity and reliability in qualitative research [Publisher: Royal College of Nursing Section: Research made simple]. *Evidence-Based Nursing*, *18*(2), 34–35. https://doi.org/10.1136/eb-2015-102054

NWP. (2022a). Home. Retrieved February 13, 2024, from https://www.nationaalwaterstofprogramma.nl/default.aspx

NWP. (2022b). Routekaart Waterstof.

OECD. (2023, July). *Risk-based Regulatory Design for the Safe Use of Hydrogen*. https://doi.org/10.1787/46d2da5e-en

Oldenhof, B. (2020). Zesde cluster van de industrie: Overal in Nederland. Retrieved March 7, 2024, from https://www.kwa.nl/nieuws/zesde-cluster-van-de-industrie--overal-in-nederland

Omgevingswet, O. (2024). Omgevingswet [Last Modified: 2024-05-09]. Retrieved May 14, 2024, from https://wetten.overheid.nl/BWBR0037885/2024-01-01/0

Ostrom, E. (2011). Background on the Institutional Analysis and Development Framework [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1541-0072.2010.00394.x]. *Policy Studies Journal*, *39*(1), 7–27. https://doi.org/10.1111/j.1541-0072.2010.00394.x

Pitelis, A. (2018). Industrial policy for renewable energy: The innovation impact of European policy instruments and their interactions [Publisher: SAGE Publications Ltd]. *Competition & Change*, *22*(3), 227–254. https://doi.org/10.1177/1024529418768491

Pitelis, A., Vasilakos, N., & Chalvatzis, K. (2020). Fostering innovation in renewable energy technologies: Choice of policy instruments and effectiveness. *Renewable Energy*, *151*, 1163–1172. https://doi.org/10.1016/j.renene.2019.11.100

PosHYdon. (2024). Poshydon | Green Hydrogen Energy. Retrieved March 20, 2024, from https://poshydon.com/en/home-en/

Qudaih, S., Bektas, Z., Guven, D., Kayakutlu, G., & Kayalica, M. Ö. (2024). Technology Assessment of Hydrogen Storage: Cases Enabling the Clean Energy Transition [Conference Name: IEEE Transactions on Engineering Management]. *IEEE Transactions on Engineering Management*, *71*, 5744–5756. https://doi.org/10.1109/TEM.2024.3366973

Qureshi, F., Yusuf, M., Arham Khan, M., Ibrahim, H., Ekeoma, B. C., Kamyab, H., Rahman, M. M., Nadda, A. K., & Chelliapan, S. (2023). A State-of-The-Art Review on the Latest trends in Hydrogen production, storage, and transportation techniques. *Fuel*, *340*, 127574. https://doi.org/10.1016/j.fuel.2023.127574

Rasul, M. G., Hazrat, M. A., Sattar, M. A., Jahirul, M. I., & Shearer, M. J. (2022). The future of hydrogen: Challenges on production, storage and applications. *Energy Conversion and Management*, *272*, 116326. https://doi.org/10.1016/j.enconman.2022.116326

RDW. (2024). Bedrijfsauto's licht: Waterstofinstallatie. Retrieved March 18, 2024, from https://apk-handboek.rdw.nl/bedrijfsautos-licht/motor-en-brandstofsystemen/waterstofinstallatie

Rechtspraak. (2024). Algemene informatie over onteigening. Retrieved April 12, 2024, from https://www.rechtspraak.nl/Onderwerpen/Onteigening/Paginas/default.aspx

Rèfle, J.-E., Fischer, M., & Maggetti, M. (2022). Informal Europeanization processes and domestic governance networks [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/epa2.1138]. *European Policy Analysis*, *8*(1), 33–50. https://doi.org/10.1002/epa2.1138

Rijksoverheid. (2022). Richtsnoeren voor veilig omgaan met waterstof. Retrieved May 14, 2024, from https://www.rvo.nl/onderwerpen/richtsnoeren-waterstof

Rosenow, J., & Kern, F. (2017, October). EU energy innovation policy: The curious case of energy efficiency [Section: Research Handbook on EU Energy Law and Policy]. In *Research Handbook on EU Energy Law and Policy* (pp. 501–518). Edward Elgar Publishing. Retrieved May 17, 2024, from https://www.elgaronline.com/edcollchap/edcoll/9781786431042/9781786431042.00039.xml

Rountree, V., & Baldwin, E. (2018). State-Level Renewable Energy Policy Implementation: How and Why Do Stakeholders Participate? [Publisher: Frontiers]. *Frontiers in Communication*, *3*. https://doi.org/10.3389/fcomm.2018.00006

RVO, R. (2024). Subsidieregeling Opschaling volledig hernieuwbare waterstofproductie via elektrolyse (OWE). Retrieved May 24, 2024, from https://www.rvo.nl/subsidies-financiering/owe

Sergeeva, N. (2019). Towards more flexible approach to governance to allow innovation: The case of UK infrastructure [Publisher: Emerald Publishing Limited]. *International Journal of Managing Projects in Business*, *13*(1), 1–19. https://doi.org/10.1108/IJMPB-10-2018-0216

Shell. (2024). Maak kennis met: De Holland Hydrogen I | Over ons. Retrieved March 20, 2024, from https://www.shell.nl/over-ons/nieuws/nieuwsberichten-2021/maak-kennis-met-holland-hydrogen-I.html

Siddiki, S., & Frantz, C. (2022). The institutional grammar in policy process research [_eprint: https://onlinelibrary.wiley.co *Policy Studies Journal*, *50*(2), 299–314. https://doi.org/10.1111/psj.12466

Siddiki, S., Weible, C. M., Basurto, X., & Calanni, J. (2011). Dissecting Policy Designs: An Application of the Institutional Grammar Tool [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1541-

0072.2010.00397.x]. *Policy Studies Journal*, *39*(1), 79–103. https://doi.org/10.1111/j.1541-0072.2010.00397.x
SODM, S. (2022, November). Waterstof - Staatstoezicht op de Mijnen [Last Modified: 2023-12-21T14:59 Publisher: Ministerie van Economische Zaken]. Retrieved March 14, 2024, from https://www.sodm.nl/onderwerpen/waterstof
Stedin. (2018). Waterstof in Rozenburg met Power2Gas. Retrieved February 13, 2024, from https://www.stedin.net/over-stedin/duurzaamheid-en-innovaties/een-nieuw-energiesysteem/power2gas
Stedin. (2020). Bestaande aardgasnet en woningen voor het eerst in Nederland overgezet naar waterstof. Retrieved February 13, 2024, from https://www.stedin.net/over-stedin/pers-en-media/persberichten/bestaande-aardgasnet-en-woningen-voor-het-eerst-in-nederland-overgezet-naar-waterstof
Stenzel, T., & Frenzel, A. (2008). Regulating technological change—The strategic reactions of utility companies towards subsidy policies in the German, Spanish and UK electricity markets. *Energy Policy*, *36*(7), 2645–2657. https://doi.org/10.1016/j.enpol.2008.03.007
Sundaram, S. K. (2022, June). *82nd Conference on Glass Problems, Volume 270* [Google-Books-ID: lWl6EAAAQBAJ]. John Wiley & Sons.
Taibi, E., Miranda, R., Vanhoudt, W., Winkel, T., Lanoix, J.-C., & Barth, F. (2018). Hydrogen from Renewable Power: Technology Outlook for the Energy Transition [Publisher: Hydrogen Knowledge Centre]. Retrieved March 30, 2024, from https://www.h2knowledgecentre.com/content/policypaper1306
Tseng, P., Lee, J., & Friley, P. (2005). A hydrogen economy: Opportunities and challenges. *Energy*, *30*(14), 2703–2720. https://doi.org/10.1016/j.energy.2004.07.015
Ueckerdt, F., Bauer, C., Dirnaichner, A., Everall, J., Sacchi, R., & Luderer, G. (2021). Potential and risks of hydrogen-based e-fuels in climate change mitigation [Publisher: Nature Publishing Group]. *Nature Climate Change*, *11*(5), 384–393. https://doi.org/10.1038/s41558-021-01032-7
van Zoelen, R., & Jepma, C. (2022, May). *D7A.3 Summary for policymakers: Hydrogen value chains in the Netherlands* (tech. rep.). Zenodo. https://doi.org/10.5281/zenodo.6523339
West, W. (2009, October). Inside the Black Box: The Development of Proposed Rules and the Limits of Procedural Controls - William F. West, 2009. Retrieved May 17, 2024, from https://journals.sagepub.com/doi/abs/10.1177/0095399709339013?casa_token=NdFdvZXIT7kAAAAA:WZnwTw2O3a4YAoCV_Qc8Mdz9NX7giiOXFY6vx_qikXMcNFvvEblbfb0WA6B3UFozln4JXVmUdPGBdw
Wulf, C., & Zapp, P. (2023). Environmental Impacts of Using Hydrogen for Defossilizing Industrial Specialty Glass Production [ISSN: 2589-4943], 538–550. https://doi.org/10.2991/978-94-6463-156-2_35

A

Holistic view on Stakeholders

This is the Holistic view on stakeholders as defined by Hasankhani et al., 2024

Table A.1: A holistic view of the stakeholders, presenting their categories and roles.

Number	Stakeholder Categories	Stakeholder Name	Stakeholder Role
1	Primary Producers and Suppliers	Petrochemical Industries	Produce hydrogen as a byproduct in large-scale chemical processes such as fertilizer or polymer production.
		Chemical Industries	Involved in various hydrogen production methods, including electrolysis and steam methane reforming.
		Energy Utilities (Gas, Power)	Incorporate hydrogen into their energy portfolios for electricity generation or energy storage.
		Renewable Energy Provider	Utilize renewable energy sources like on and offshore wind, solar, biomass, and geothermal to produce green hydrogen through electrolysis.
		Oil and Gas Suppliers	Produce hydrogen as a byproduct of operations like steam methane reforming.
2	Technology and Service Providers	Hydrogen Technology Providers	Develop crucial technologies (electrolyzers, fuel cells, storage systems, storage tanks, hydrogen compressors, and other necessary equipment) for the production, distribution, and use of hydrogen.
		Public and Private Research and Development Institutions	Conduct essential R&D to advance hydrogen technology.
		Equipment and Component Manufacturers	Specialize in the design and manufacturing of hydrogen-specific equipment, components, and systems.

Continued on next page

Table A.1 – continued from previous page

Number	Stakeholder Categories	Stakeholder Name	Stakeholder Role
		Engineering, and Technical Service Providers	Provide expertise and services to design, plan, install, and maintain hydrogen technologies and infrastructures.
		Startups and Small Enterprises	Develop innovative technologies and solutions for the hydrogen industry.
		Information and Communications Technology (ICT) and Automation providers	Providing ICT solutions for hydrogen supply chain control and automation.
3	Infrastructure Providers for Storage and Distribution	Power and Gas Network Operators	Manage the infrastructure for delivering energy supplies, including hydrogen.
		Supply Chain Logistics	Manage the entire supply chain, ensuring efficient and timely delivery of hydrogen from producers to end users.
		Storage Providers (material based, physical)	Manage the large-scale storage of hydrogen using a variety of methods such as salt caverns, depleted oil & gas reservoirs.
		Seaport Authorities	Supervise port activities, crucial for importing and exporting hydrogen.
		Transportation Companies	Handle the logistics for long-distance hydrogen transport.
		Hydrogen Infrastructure Accelerators (HIA)	Provide strategic support, funding, and expertise to expedite the implementation of hydrogen infrastructure projects.
		Construction Companies, Housing Associations	Build the physical infrastructure necessary for hydrogen production, storage, and distribution.
		Project Developers	Plan and manage hydrogen-related projects.
		Energy Aggregators (Energy Hub Operators)	Aggregate the demand or supply of hydrogen energy among customers, playing a role in balancing and optimizing energy markets.
		Fuel Station Operators (Mobile, Stationary)	Run stations where hydrogen can be dispensed for use in fuel cell vehicles and other applications.
		Regional fuel suppliers	Distribute hydrogen within specific geographical regions.
		Hydrogen Retailers	Sell hydrogen to end users.
		Energy Retailers	Distribute hydrogen to end users.
4	End-Use	Mobility sector (Heavy-light duty vehicles buses, shipping, aviation)	Employs hydrogen as a fuel source in vehicles, ships, aircraft, trucks, and heavy machinery.

Continued on next page

Table A.1 – continued from previous page

Number	Stakeholder Categories	Stakeholder Name	Stakeholder Role
		Petroleum Refining	Utilizes hydrogen to remove impurities from crude oil.
		Industries (Steel, cement, glass, industrial gas)	Employs hydrogen as a feedstock or energy source in their processes.
		Semiconductor	Uses hydrogen in manufacturing processes to provide ultra-clean environments and for etching.
		Pharmaceutical Industry	Employs hydrogen in various stages of drug production and research, including synthesis of chemical compounds and powering manufacturing plants.
		Agriculture	Uses hydrogen for energy needs, potentially for producing fertilizers, or powering machinery.
		Food Industry	Uses hydrogen for energy generation or in waste-to-energy solutions using organic waste.
		Water Treatment	Produces hydrogen from wastewater through electrolysis, providing a clean energy source.
		Waste Management	Uses hydrogen for energy needs or produces it from organic waste via waste-to-energy solutions.
		Built Environment	Utilizes hydrogen for heating and power generation in historical, residential, and commercial buildings, local communities, and islands.
		Energy Cooperatives	Use hydrogen as a power source or feedstock.
		Private Consumers	Could use hydrogen for various energy needs.
5	Intermediaries	Industry Associations	Represent the interests of various groups within the hydrogen industry.
		Consultancy and advisory firms	Provide expert advice and guidance on various aspects of hydrogen infrastructure integration and management.
		Safety and Regulatory Service Providers	Ensuring safe and compliant hydrogen technology operation.
		Certification Organizations for Hydrogen Facilities	Validate and certify the safety, performance, and quality of hydrogen technologies and facilities.
		Environmental and Resource Management	Assess and manage the environmental impact of hydrogen technologies.

Continued on next page

Table A.1 – continued from previous page

Number	Stakeholder Categories	Stakeholder Name	Stakeholder Role
		Water Management	Involved in managing water resources.
		Partnership Initiatives	Collaborative stakeholders pursuing shared hydrogen goals.
		Banks and Financial Institutions	Provide financial support for hydrogen projects, such as loans or investment.
		Institutional Investors (Pension Funds, Insurance Companies, etc.)	Pool money to purchase securities, real property, and other investment assets, potentially including stakes in hydrogen-related companies or projects.
		Legal Firms	Handle legal aspects like contracts, permits, patents, compliance with regulations, etc.
		Social Impact and Advocacy, NGOs	Advocating, educating, recommending policies, and researching hydrogen energy promotion.
6	Policy and Regulatory Authorities	Policy Makers, Regulators, and Government on Different Scales	Shape the hydrogen industry through policies, regulations, and incentives.
7	Research and Education	Research and development - Training and Skills Development	Advancing hydrogen tech and training professionals.

B

Coded Institutional Statements

This table contains all analysed statements of this thesis. It follows the method of institutional grammar as discussed in Section 2.2.1. The statements are separated using the policy documents. The components of the statements follow the part that they consist of.

Table B.1: All coded institutional statements

Statement ID	Statement Definition
Environment and Planning Act	
EPA1	Individuals and Companies (**A**) must (**D**) prevent, undo or mitigate negative effects (**I**) on the physical environment (**B**) when activities have or may have adverse effects (**C**). Non-compliance can lead to prohibitions of certain activities or required adjustments to operations (**O**).
EPA2	Administrative bodies of municipalities, provinces, the State, and water boards (**A**) must (**D**) Exercise tasks and powers with the objectives of the Environmental Law in mind (**I**). The execution must take into account the coherence of relevant parts and aspects of the physical environment and the interests involved (**C**). n.s.(**O**)
EPA3	Administrative bodies(**A**) must (**D**) exercise tasks and powers in a manner that respects and coordinates (**I**) with both the tasks and powers of other administrative bodies (**B**) when there is a need for coordination or joint exercise due to overlapping or complementarity of tasks and powers (**C**) n.s.(**O**)
EPA4	Administrative bodies of municipalities, provinces, and the State (**A**) must (**D**) exercise a task or power effectively and efficiently (**I**) considering municipal, provincial or national interest (**B**) unless other rules apply (**C**). n.s.(**O**)
EPA5	Municipal Councils(**A**) must (**D**) establish rules for the physical environment to regulate land use and zoning (**I**) in a single plan (**B**) unless other rules apply (**C**). The absence of an environmental plan can hinder or illegalize development projects (**O**).
EPA6	Provincial states (**A**) must (**D**) establish rules for physical environment (**I**) in a single ordinance (**B**) unless other rules apply (**C**). The absence of an environmental plan can hinder or illegalize development projects (**O**).

Continued on next page...

Statement ID	Statement Definition
EPA7	Provincial Authorities (**A**) must (**D**) set rules to achieve environmental values (**I**) on the physical environment (**B**) When developments have an impact(**C**) n.s. (**O**)
EPA8	Our Minister of Infrastructure and Water Management (**A**) may (**D**) impose (**I**) an obligation to tolerate the establishment or clearance of a gas transport network (**B**), after consultation with Our Minister for Climate and Energy (**C**), n.s. (**O**)
EPA9	Article 20, paragraph 2, of Book 5 of the Civil Code (**A**) applies correspondingly to (**D**) works of general interest (**B**) that are constructed, maintained, altered, or relocated (**I**) under the application of a tolerance duty decree (**C**) n.s. (**O**)
EPA 10	City council, water board, provincial states, or the relevant minister (**A**) may (**D**) make Expropriation decisions **I** for the development of the physical living environment, including gas infrastructure. (**B**) When necessary for the public interest, it is urgent and after following the correct procedures (**C**. n.s. (**O**)
EPA11	Authorities that expropriate (**A**) must (**D**) ensure that expropriation takes place based on necessity and according to set criteria (**I**) according to set criteria (**B**) In the event that development cannot take place without expropriation (**C**). n.s. (**O**).
Gas Act	
GA1	The Minister of Economic Affairs and Climate (**A**) can (**D**) designate a company (**I**) as network operator for the national gas transport network for 10 years (**B**) based on a decision by the ACM that meets certain conditions (**C**). n.s.(**O**)
GA 2	ACM (**A**) can (**D**) grant an exemption from article 2 (**I**) to an owner of a gas network (**B**) due to technical, safety reasons, or fewer than 500 customers (**C**). n.s. (**O**).
GA3	The Minister of Economic Affairs and Climate (**A**) can (**D**) approve (**I**) a company as a network operator (**B**) when different from the national network (**C**). n.s. (**O**).
GA4	Network operators (**A**) are prohibited (**D**) from being a part of (**I**) a group involved in the production, purchase or supply of gas (**B**) when designations are being decided (**C**). n.s. (**O**).
GA5	Legal entities engaged in gas production, purchase or supply (**A**) is prohibited (**D**) from being designated as operator of the network (**I**) when designations are being decided (**C**). n.s. (**O**).
GA6	Network operators (**A**) must (**D**) have economic ownership over (**I**) the managed gas transport network (**B**) upon designation (**C**). n.s. (**O**).
GA7	Network operators (**A**) must (**D**) periodically deliver (**I**) an investment plan detailing necessary expansion and replacement (**B**) when the investment plan is to be reviewed and approved by relevant stakeholders and authorities, including the Authority for Consumers & Markets (ACM) and the Minister (**C**). n.s. (**O**).
GA8	Network operators (**A**) must (**D**) ensure efficient, reliable and safe transport (**I**) of gas (**B**) in their role as network operator (**C**). n.s. (**O**).
GA9	Network operators (**A**) must (**D**) perform expansion, balancing, renewal, integration and other additional tasks (**I**) of the network(**B**) under their users' needs (**C**). n.s. (**O**).
GA10	A entity (**A**) may (**D**) construct or operate (**I**) infrastructure other than gas networks under which pipelines or installations for hydrogen (**B**) when in a company group with a DSO(**C**). n.s. (**O**).

Continued on next page...

Statement ID	Statement Definition
GA11	Network operators (**A**) must (**D**) offer transportation and supporting services of gas (**I**) to any requesting party (**B**) when request is received (**C**) n.s.(**O**)
GA12	The Minister of Economic Affairs and Climate (**A**) must decide (**D**) on projects of national significance (**I**) to ensure structured development of national infrastructure (**B**) under their technical specifications (**C**). n.s. (**O**).
GA13	The holder of a permit (**A**) must (**D**) ensure reasonable tariff for the delivery of gas (**I**) for any willing user (**B**) under certain requirements (**C**). n.s. (**O**).
Electricity Act	
EA1	The minister of Economic Affairs and Climate (**A**) shall (**D**) establish at least once every four years (**I**) an energy report (**B**) in cooperation with relevant administrative bodies and organizations (**C**) n.s.(**O**)
EA2	ACM (**A**) must (**D**) monitor (**I**) on the electricity market (**B**) based on goals set with relevant administrative bodies and organizations (**C**). n.s. (**O**).
EA3	The Minister of Economic Affairs and Climate (**A**) shall (**D**) designate as operator of the national network (**I**) a company (**B**) when a decision by the ACM that meets certain conditions (**C**). n.s. (**O**).
EA4	The Minister of Economic Affairs and Climate (**A**) can (**D**) approve a company (**I**) as a network operator (**B**) when different from the national network (**C**). n.s. (**O**).
EA5	Network operators (**A**) must (**D**) have economic ownership over (**I**) the managed electricity transport network (**B**) upon designation (**C**). n.s. (**O**).
EA6	Network operators (**A**) must (**D**) perform expansion, renewal, integration, balancing and additional tasks (**I**) of the network (**B**) under their users needs (**C**). n.s. (**O**).
EA7	Network operators (**A**) must (**D**) provide a construction from the grid (**I**) to individual properties or producers (**B**) compliant with safety and technical requirements (**C**). n.s. (**O**).
EA8	An entity (**A**) may (**D**) construct or operate (**I**) infrastructure other than electricity networks under which pipelines or installations for hydrogen (**B**) when connected to a Network operator (**C**). n.s. (**O**).
EA9	Network operators (**A**) must (**D**) periodically deliver (**I**) an investment plan detailing necessary expansion and replacement (**B**) when the investment plan is to be reviewed and approved by relevant stakeholders and authorities, including the Authority for Consumers & Markets (ACM) and the Minister (**C**). n.s. (**O**).
EA10	ACM (**A**) must (**D**) fine(**I**) any offender (**B**) after a breach of agreements set in the Act (**C**) n.s. (**O**)
EA11	Producers (**A**) must (**D**) Obtain a license to produce (**I**) electricity (**B**) compliant with environmental, technical, and efficiency requirements (**C**). Face penalties or refusal of license (**O**).
Guidelines Hydrogen	
GH1	The new energy supply (**A**) must (**D**) be at least as safe (**I**) as current supply-based fossil fuel (**B**). Applying precaution when dealing with uncertain risks (**C**) n.s.(**O**)
GH2	The new energy supply (**A**) should (**D**) become safer and healthier (**I**) than the current fossil fuel equivalent (**B**). If possible (**C**). n.s. (**O**).

Continued on next page...

Statement ID	Statement Definition
GH3	Risk handling policy (**A**) should (**D**) be based on (**I**) best available scientific insights (**B**). If new insights arise these should be applied (**C**). n.s. (**O**).
GH4	The national government (**A**) must (**D**) provide (**I**) additional knowledge of risk and reduction (**B**). When new insights arise (**C**). n.s. (**O**).
GH5	The national government (**A**) must (**D**) find solutions (**I**) for the implementation of energy transition projects or policy (**B**). if obstacles or deficiencies are experienced (**C**). n.s. (**O**).
GH6	Communications (**A**) should (**D**) be open (**I**) on risks, benefits and opportunities of energy transition (**B**). During the project (**C**). n.s. (**O**).
GH7	Evaluation (**A**) must (**D**) precede (**I**) policy changes (**B**). If incidents arise (**C**). n.s. (**O**).
Temporary Framework Hydrogen Pilots	
TFHP1	The pilot (**A**) must (**D**) be applicable (**I**) as heat delivery (**B**) in the build environment (**C**) n.s.(**O)**
TFHP2	The Network Operator (**A**) cannot (**D**) play (**I**) a role in the production, selling or trading (**B**) when operating hydrogen network (**C**). n.s. (**O**).
TFHP3	The pilot (**A**) must (**D**) contribute effectively (**I**) to a goal set before (**B**) in conjuncture with other involved parties (**C**). n.s. (**O**).
TFHP4	Network Operators (**A**) must (**D**) share information (**I**) with other parties (**B**) timely, transparently (**C**). n.s. (**O**).
TFHP5	Pilot participants (**A**) must (**D**) establish the security of supply in the pilot agreement (**I**) for the customer (**B**) at the same level as natural gas(**C**). n.s. (**O**).
TFHP6	The customer (**A**) must (**D**) be protected against loss (**I**) of hydrogen delivery (**B**) as discussed in pilot agreement (**C**). n.s. (**O**).
TFHP7	The customer (**A**) must (**D**) receive clear instructions (**I**) on cost distribution (**B**) before start of pilot project (**C**). n.s. (**O**).
TFHP8	The customer (**A**) cannot (**D**) pay more than (**I**) a reasonable alternative (**B**) during the pilot project, based on tariff and calculations for fixed and variable costs (**C**). n.s. (**O**).
TFHP9	The customer (**A**) must (**D**) receive (**I**) clear cost communications (**B**) during the pilot project (**C**). n.s. (**O**).
TFHP10	The pilot parties (**A**) must (**D**) ensure set costs (**I**) for the customer (**B**) if supplier goes bankrupt (**C**). n.s. (**O**).
TFHP11	The agreements made (**A**) must (**D**) be clear (**I**) for the customer (**B**) concerning transport, delivery, installation and maintenance parties (**C**). n.s. (**O**).
TFHP12	The agreements made (**A**) must (**D**) provide security (**I**) for the customer (**B**) for the project duration (**C**). n.s. (**O**).
TFHP13	Network operator (**A**) must (**D**) rebuild (**I**) natural gas connection (**B**) if the connection obligation is applicable to the area and the customer requests it (**C**). n.s. (**O**).
Letter on HNS	
HNS1	Hydrogen network operators (**A**) must **D** offer services(**I**) to all users (**B**) in non-discriminatory fashion **C** n.s. (**O**)
HNS2	EU-member states (**A**) must (**D**) implement (**I**) systemic third-party access methods (**B**) under the supervision of the ACM after 01-01-2031 (**C**). n.s. (**O**).
HNS3	HNS (**A**) must (**D**) be open to conversation (**I**) with any requesting party (**B**) when requested (**C**). n.s. (**O**).

Continued on next page...

Statement ID	Statement Definition
HNS4	The requesting party (**A**) must (**D**) pay all costs (**I**) for a connection (**B**) if requested (**C**). n.s. (**O**).
HNS5	HNS (**A**) must (**D**) offer (**I**) reasonable, transparent and non-discriminatory services (**B**) when operating the hydrogen network (**C**). n.s. (**O**).
HNS6	HNS (**A**) must (**D**) provide (**I**) a multiyear investment plan for the development of the network (**B**) at the request of the state contribution (**C**). n.s. (**O**).
HNS7	HNS (**A**) must (**D**) supply (**I**) a investment and budget plan (**B**) at the start of every year (**C**). n.s. (**O**).
HNS8	HNS (**A**) must (**D**) come up with (**I**) a proposal for the reassessment of the development plan (**B**) each year, if market developments so require (**C**). n.s. (**O**).
HNS9	The hydrogen (**A**) must (**D**) be at least (**I**) of 98mol% purity (**B**) when fed into the system (**C**). n.s. (**O**).
HNS10	The transport tariff (**A**) must (**D**) be based on (**I**) made costs plus a reasonable return (**B**) when calculated (**C**). n.s. (**O**).
HNS11	ACM (**A**) will (**D**) set (**I**) tariffs (**B**) after 2031 (**C**). n.s. (**O**).
Energy Act	
ENA1	This act (**A**) may (**D**) be declared on (**I**) other substances than gas (**B**) under administrative order (**C**) n.s. (**O**)
ENA2	TSO/DSO entities (**A**) shall (**D**) play (**I**) no role in the production, supply or trade of hydrogen (**B**) when operating hydrogen networks (**C**) n.s. (**O**)
ENA3	A distribution infra company (**A**) can (**D**) perform actions in managing (**I**) the hydrogen distribution system (**B**) not including storage or production (**C**) n.s. (**O**)
ENA4	An infra company (**A**) cannot (**D**) perform actions in managing (**I**) hydrogen terminals and storage (**B**) when part of ISO group (**C**) n.s. (**O**)
ENA5	A distribution infra company (**A**) cannot (**D**) hold shares in (**I**) companies not aligned with their activities (**B**) apart from DSO shares (**C**) n.s. (**O**)
ENA6	Rules (**A**) can (**D**) be declared on (**I**) production facilities for hydrogen gas (**B**) using an administrative order (**C**) n.s. (**O**)
ENA7	TSO/DSO (**A**) must (**D**) ensure specifications (**I**) of hydrogen (**B**) set by ministerial regulation (**C**) n.s. (**O**)
EU-Decarbonisation Package: Gas Regulation	
EUGR1	Member States, regulatory authorities, hydrogen system operators, and other actors (**A**) shall (**D**) ensure the operation (**I**) of the hydrogen market (**B**) in accordance with principles such as: price formation via demand and supply, customer-centred and efficient approach, transparency, co-operation (**C**) n.s. **O**
EUGR2	Member States (**A**) may (**D**) allow (**I**) for spreading of recovery costs to ensure contribution to hydrogen development costs over time (**B**) when hydrogen operators develop and operate hydrogen network (**C**) n.s.(**O**)
EUGR3	Hydrogen DSO (**A**) shall (**D**) offer (**I**) their services of hydrogen network (**B**) to all network users on a non-discriminatory basis, with clear communication on all tariffs, taking into account system integrity, safety and efficiency (**C**) n.s.(**O**)

Continued on next page...

Statement ID	Statement Definition
EUGR4	Hydrogen DSOs (**A**) may (**D**) cooperate (**I**) through the European entity for distribution system operators ('EU DSO entity') (**B**) when developing of the hydrogen market and to promote optimal management and a coordinated operation of distribution and transmission systems. (**C**) n.s.(**O**)
EUGR5	The commission (**A**) may (**D**) develop (**I**) a mechanism to support market development of hydrogen (**B**) to be implemented under the EU hydrogen bank including elements such as: Data on infra, flows, supply, en demand (**C**) n.s.(**O**)
EUGR6	Hydrogen DSOs (**A**) shall (**D**) cooperate (**I**) when coordinating the maintenance, network development, new connections, decommissioning and operation of the hydrogen system to ensure system integrity (**C**) with other DSOs and TSOs (**B**) n.s.(**O**)
EUGR7	Hydrogen TSOs (**A**) shall cooperate (**D**) to promote the development and functioning of the internal market in hydrogen and cross-border trade and to ensure the optimal management, coordinated operation and sound technical evolution of the European hydrogen transmission network. (**I**) through the European Network of Network Operators for Hydrogen (ENNOH) (**B**) at union level (**C**) n.s.(**O**)
EUGR8	ENNOH (**A**) shall (**D**) develop (**I**) codes, recommendations, development plans and reports on hydrogen (**B**) cooperating with ENTRSO for Electricity, gas and EU DSO entity (**C**) n.s.(**O**)
EUGR9	The Union-wide ten-year network development plan for hydrogen (**A**) shall (**D**) include the modelling (**I**) of the integrated network, scenario development and an assessment of the resilience of the system (**B**) under the monitoring of ACER (**C**) n.s.(**O**)
EUGR10	Member states (**A**) shall (**D**) establish (**I**) the rules on penalties (**B**) applicable to infringements of this regulation (**C**) n.s.(**O**)
EU-Decarbonisation Package: Gas Directive	
EUGD1	Member states (**A**) shall (**D**) ensure a customer-centred and energy-efficient approach (**I**) in the hydrogen market (**B**) complying with applicable Union and national law including in the fields of environment and safety (**C**) n.s.(**O**)
EUGD2	Suppliers (**A**) shall (**D**) be free to determine (**I**) the price at which they supply hydrogen (**B**) Under regulatory supervision of authorities in the member states when supplying to customers (**C**) n.s.(**O**)
EUGD3	Regulatory bodies (**A**) shall (**D**) require (**I**) the publication of technical rules and connection tariffs from Hydrogen DSOs (**B**) when setting up hydrogen development plans, based on objective, transparent and non-discriminatory criteria (**C**) n.s.(**O**)
EUGD4	Member states (**A**) shall (**D**) ensure that all final customers are entitled to hydrogen (**I**) provided by a supplier (**B**) subject to the supplier's agreement, regardless of the Member State in which the supplier is registered, provided that the supplier follows the applicable trading, balancing and security of supply rules (**C**) n.s.(**O**)
EUGD5	Member States (**A**) shall (**D**) ensure the implementation of a system of regulated third-party access (**I**) to the hydrogen network (**B**) based on published tariffs and applied objectively and without discrimination (**C**) n.s.(**O**)

Continued on next page...

Statement ID	Statement Definition
EUGD6	Member States (**A**) shall (**D**) Designate or require undertakings (**I**) one or more hydrogen distribution network operators (**B**) following a transparent procedure with regard to economic and energy efficiency considerations (**C**) n.s.(**O**)
EUGD7	Hydrogen DSO (**A**) shall (**D**) be (**I**) independent in terms of legal form from its vertical integrated undertaking (**B**) when operating hydrogen networks, under the supervision of regulatory authority (**C**) n.s.(**O**)
EUGD8	Each hydrogen DSO (**A**) shall (**D**) be responsible (**I**) for operating, maintaining, developing, including repurposing a secure and reliable infrastructure for hydrogen transport (**B**) under economic conditions (**C**) n.s.(**O**)
EUGD9	Member states (**A**) may (**D**) provide for regulatory authorities to grant a derogation from requirements in articles 31,42,62,63,64,65 (**I**) for hydrogen networks belonging to vertically integrated undertakings (**B**) at starting date of directive. Derogation expires: when two networks are connected, capacity is 5% expanded, etc. (**C**) n.s.(**O**)
EUGD10	Member States (**A**) may (**D**) provide for regulatory authorities to grant a derogation from Articles 62 and 65 or Article 42 (**I**) for hydrogen networks which transport hydrogen within a geographically confined, industrial or commercial area (**B**) network not including interconnector, direct links to other networks not having a derogation (**C**) n.s.(**O**)
EUGD11	Hydrogen DSO (**A**) shall (**D**) submit (**I**) all relevant information for the development plan (**B**) in close cooperation with gas and electricity operators reporting to the TSO (**C**) n.s.(**O**)
EUGD12	Hydrogen DSO (**A**) Shall (**D**) submit (**I**) a plan presenting the hydrogen network infrastructure they aim to develop (**B**) every four years, in close cooperation with gas, electricity and heating/cooling DSO to the regulatory authority (**C**) n.s.(**O**)
EUGD13	Member States (**A**) Shall (**D**) ensure the development of decommissioning plans for gas infra (**I**) by the DSOs (**B**) when a reduction in gas demand requiring the decommissioning of natural gas distribution networks or parts of such networks is expected. Such plans shall be developed in close cooperation with hydrogen distribution network operators, distribution system operators for electricity, and district heating and cooling operators (**C**) n.s.(**O**)
EUGD14	The regulatory authority designated by a member state (**A**) shall (**D**) ensure (**I**) an open, transparent, efficient and inclusive process (**B**) when setting up of the national network development plan in line with the requirements set out in Article 52 (**C**) n.s.(**O**)

C

Visualisation of Individual Institutional Statements

In this appendix, all statements that were visualised for the formation of the network diagrams are depicted separately.

C.1. Statements First Network Diagram

Figure C.1: Statement EPA8

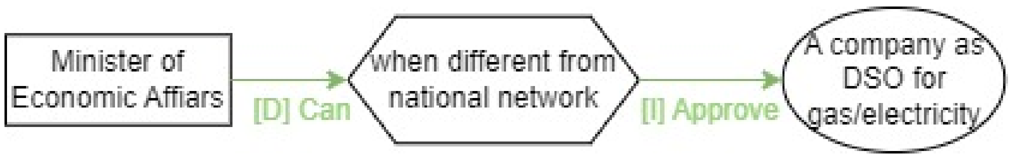

Figure C.2: Statement GA3

Figure C.3: Statement GA10

Figure C.4: Statement EA10

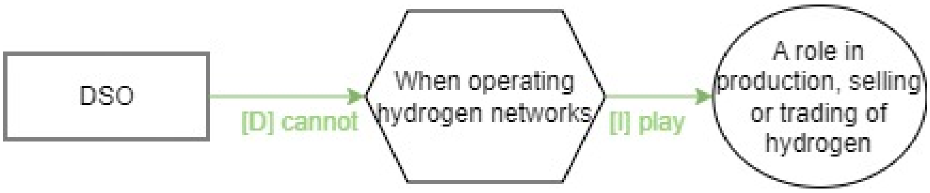

Figure C.5: Statement TFHP2

C.2. Statements Second Diagram

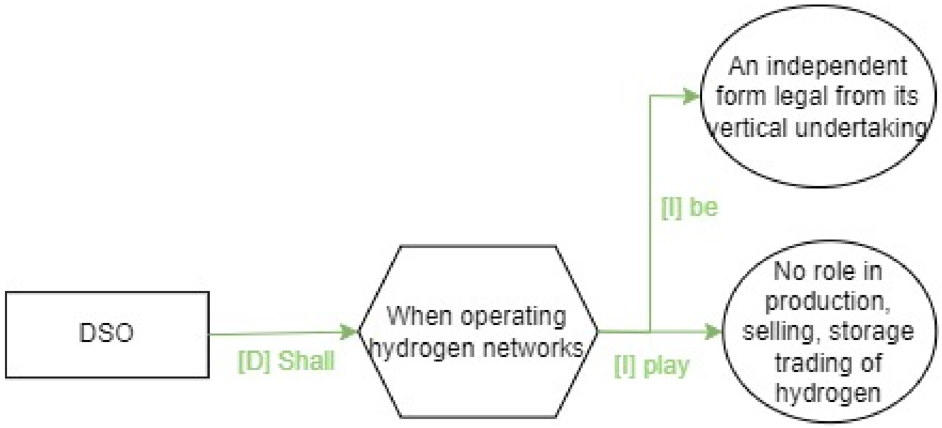

Figure C.6: Statement ENA2 & EUGD7

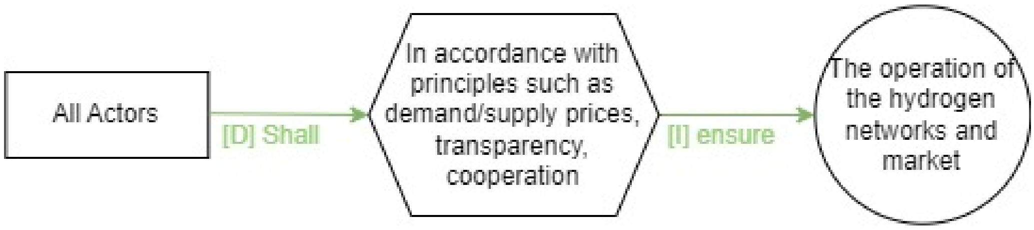

Figure C.7: Statement EUGR1

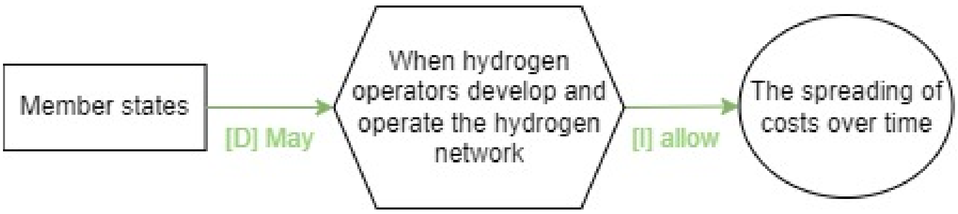

Figure C.8: Statement EUGR2

C.2.1. Proposed Additions

Figure C.9: Statement EUGR3

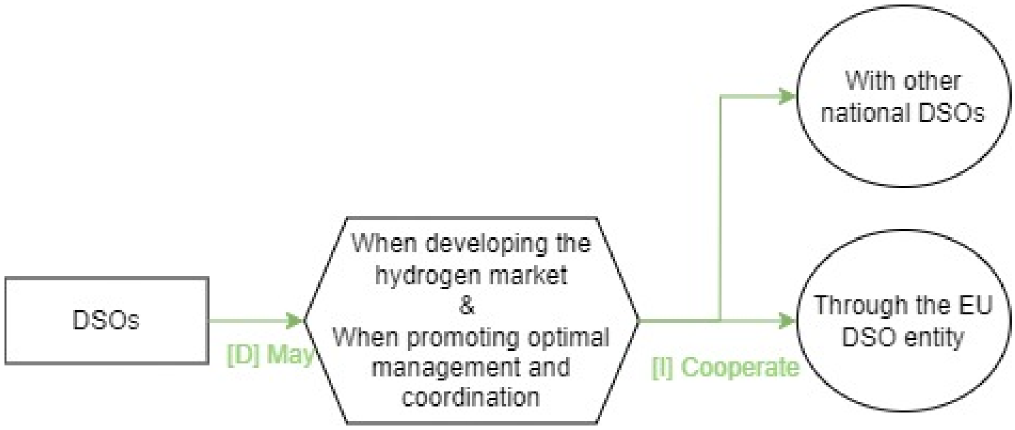

Figure C.10: Statement EUGR4&6

Figure C.11: Statement EUGR5

Figure C.12: Statement EUGR8

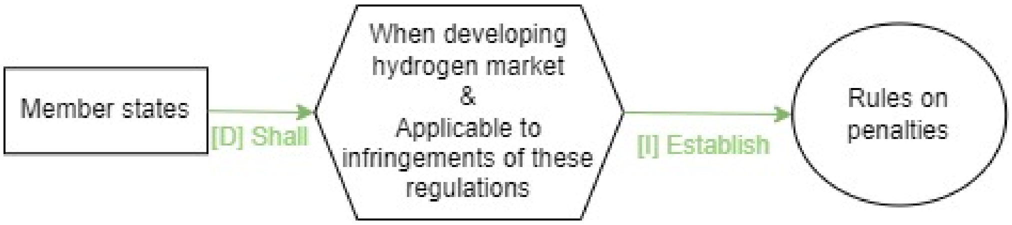

Figure C.13: Statement EUGR10

Figure C.14: Statement EUGD2

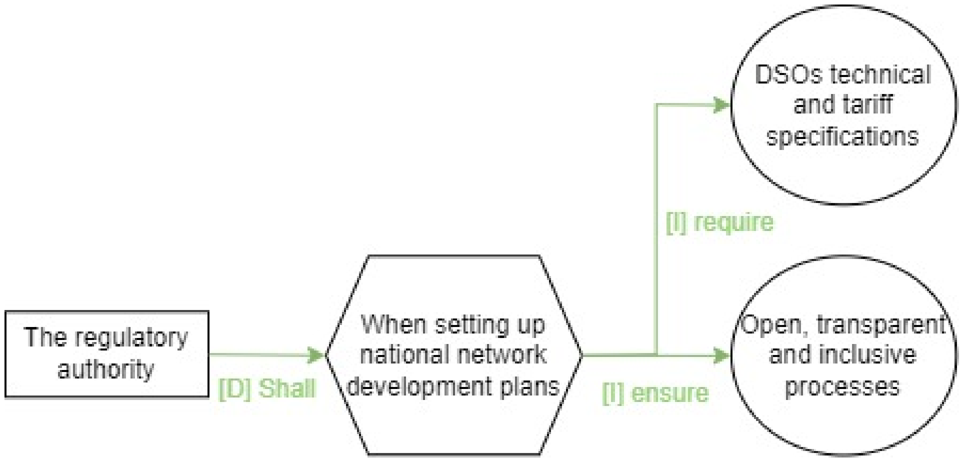

Figure C.15: Statement EUGD3&14

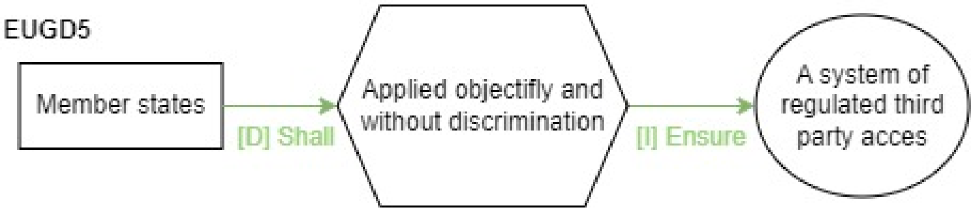

Figure C.16: Statement EUGD5

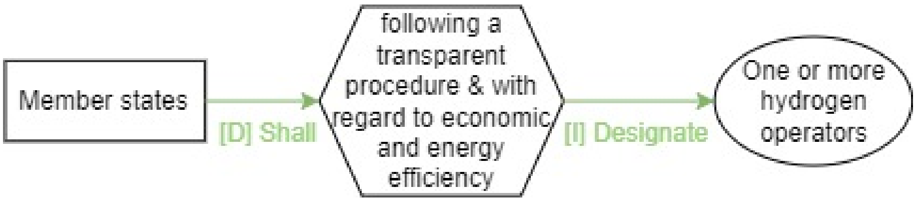

Figure C.17: Statement EUGD6

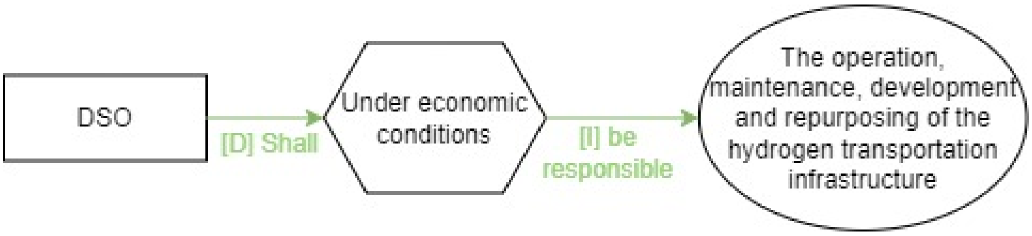

Figure C.18: Statement EUGD8

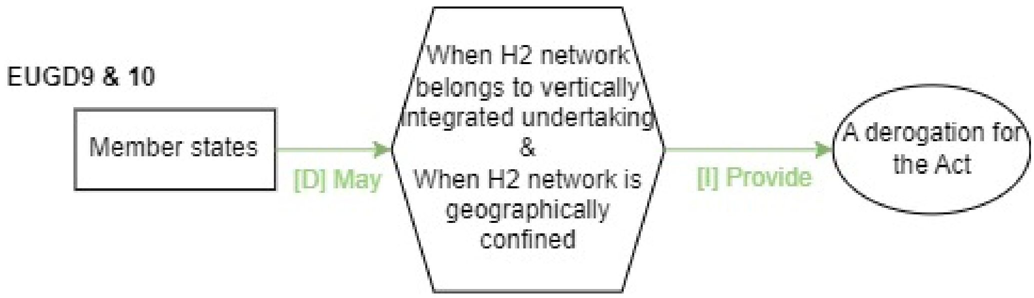

Figure C.19: Statement EUGD9&10

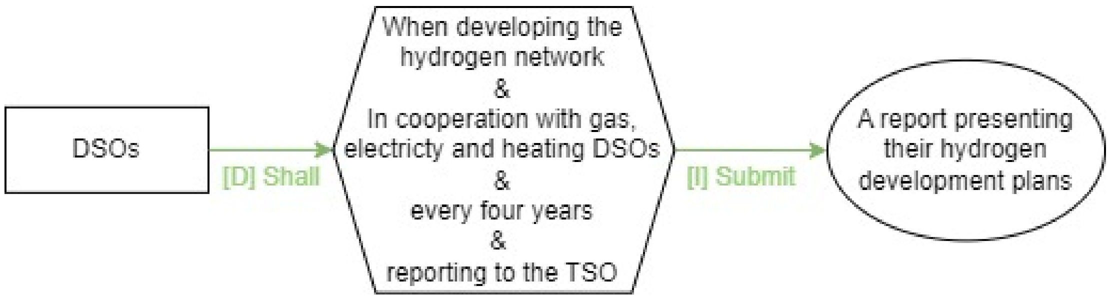

Figure C.20: Statement EUGD11&12

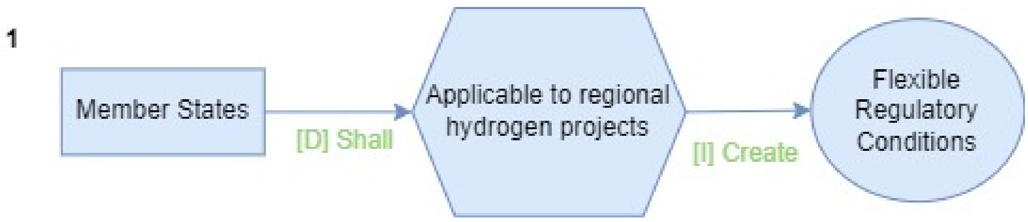

Figure C.21: Addition 1

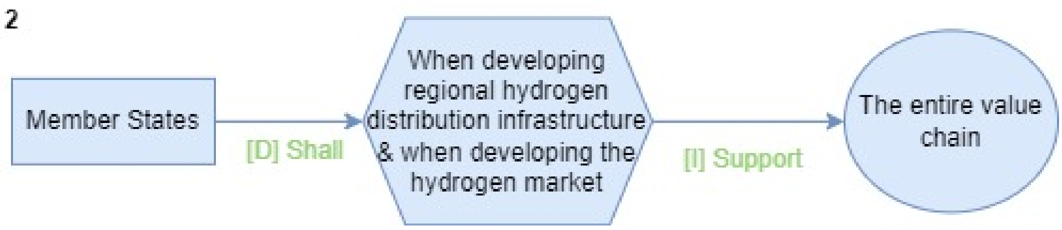

Figure C.22: Addition 2

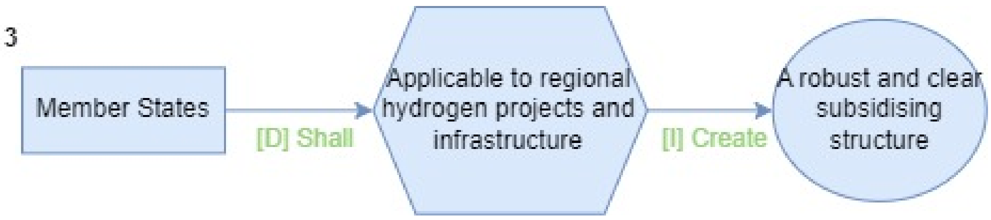

Figure C.23: Addition 3

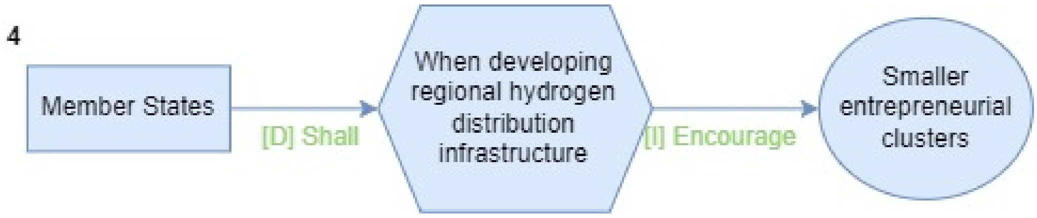

Figure C.24: Addition 4

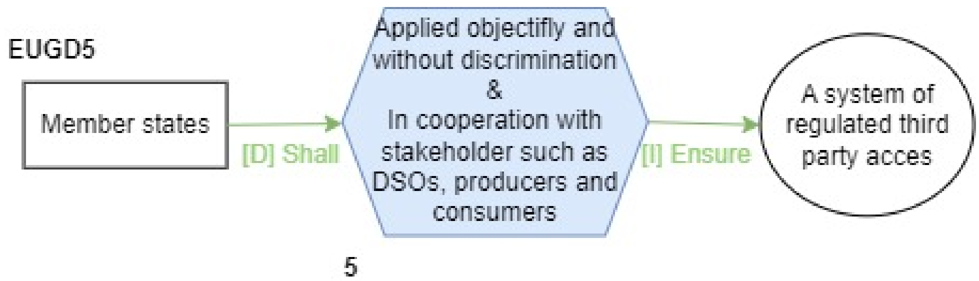

Figure C.25: Addition 5

D

Interview Template

For the interviews conducted in this thesis, a semi-structured approach was chosen. Several different areas were discussed using the template presented in the table below.

Table D.1: Interview Topics and Possible Questions

Topics	Questions
Background and Role	1. Can you describe your role and experience in the Dutch hydrogen sector? 2. How does your organization fit into the hydrogen value chain in the Netherlands? 3. What are the drivers for the projects you do in the Dutch Hydrogen Sector?
Understanding of Current Regulations	1. What are the key regulations governing hydrogen transportation and distribution according to you? 2. Can you explain if and how these regulations have evolved over recent years? 3. What are the infrastructure requirements mandated by the regulatory framework for hydrogen transport and distribution?
Regulatory Impact	1. Have you encountered any significant challenges due to these regulations? 2. What measures does your organization take to comply with the existing hydrogen regulations? 3. Are there any regulations that you find particularly difficult to comply with? If so, why?
Network Development	1. How do planning and zoning regulations affect your actions in the hydrogen sector? 2. Can hydrogen market regulations influence the development of hydrogen transportation networks? If so, how should these be implemented?
Financial Regulations	1. How do regulatory frameworks impact the economic viability of hydrogen projects in your experience? 2. Are there financial incentives or subsidies available for supporting hydrogen projects? How can these be implemented to accelerate the development of hydrogen networks?
Operation	1. How should the operation of hydrogen transportation networks be regulated?
Barriers & Enablers	1. What Regulations have you perceived as enablers for hydrogen developments in the Netherlands?

Continued on next page...

Topics	Questions
	2. What are the biggest regulatory barriers currently facing the hydrogen distribution networks in the Netherlands?
Future of the Regulatory Framework	1. Are there upcoming regulatory changes that you are preparing for and how? 2. In what ways could the regulatory framework be improved to accelerate the development of hydrogen distribution networks?
Generic Ending Topics/Questions	1. What else should be done to accelerate the development of hydrogen transportation and distribution networks besides regulatory changes?

E

Interview Summaries

E.1. Interview Summary ZonXp

Interviewer: How does your organization fit into the Dutch hydrogen system, and what exactly do you do there?

Interviewee: We are a developer of hydrogen installations. Our work involves ensuring that a hydrogen installation can be built, including facets like electricity connection, land position, subsidy, and off-take.

Interviewer: What are the drivers behind your projects? Why do you undertake these types of projects?

Interviewee: We started with solar roofs and moved to solar parks on agricultural lands, providing sustainable energy. Given the grid congestion in the Netherlands, we believe hydrogen can help resolve these issues by developing energy hubs that combine hydrogen and battery storage. We initially developed close to our own sustainable energy sources and are now seeking collaborations with other sustainable energy owners in various locations.

Interviewer: What are the key regulations or laws that you encounter in these types of projects?

Interviewee: The competent authority is the province, so we deal with provincial ordinances. Developing on industrial sites is simpler because it often fits within the zoning plan, but developing near solar and wind energy in rural, agricultural zones is more challenging due to regulations not being tailored for that.

Interviewer: Have you seen over the years that these regulations are being adapted, or is it something that happens gradually?

Interviewee: No significant adaptations have been made. In Brabant, there is talk of adjusting provincial environmental regulations, but hydrogen is rarely mentioned in regional energy strategies. Thus, regulations are lagging behind reality, and there's often a lack of shared vision.

Interviewer: How does the Environment and Planning Act affect a hydrogen project?

Interviewee: The Environment and Planning Act aims to regulate things locally and start from the initiator, but its implementation depends on the decision-makers. The Act does not provide clear relief or allow invoking it to push projects based on the initiator's perspective. It's also relatively new, so there's little precedent.

Interviewer: How do regulations impact the economic feasibility of a hydrogen project?

Interviewee: The cost aspect must be feasible. If the project seems viable, the cost of the permit is negligible compared to the entire business case. However, if it cannot or is not allowed, you might need to reconsider.

Interviewer: Do you think market regulation could positively impact the development of hydrogen projects?

Interviewee: A hydrogen market with supply and demand would help significantly. Subsidies also help a lot, though they are more related to national regulation.

Interviewer: Are there current subsidies that positively influence your projects?

Interviewee: The OWE subsidy is potentially very interesting and positively impacts economic feasibility if awarded. However, the chance of receiving it is low, making it crucial for economic feasibility due to the large investments required.

Interviewer: What are the main barriers in the Netherlands for developing hydrogen, particularly regarding regulations?

Interviewee: The main barriers are the permitting process, subsidy process, and grid congestion. Grid congestion means you often can't get a grid connection, which is essential for providing a sufficient baseload for hydrogen installations. This challenge requires custom solutions.

Interviewer: How should the regulation for hydrogen networks be organized?

Interviewee: Ideally, you supply green hydrogen to companies via the hydrogen backbone. However, not every industrial company is connected to the hydrogen network, making it more challenging compared to electricity and gas networks. This cannot be solved at once and should be considered locally.

Interviewer: How does EU regulation affect your projects?

Interviewee: We must comply with the delegated act defining green hydrogen and its energy sources. There's also talk of dividing the Netherlands into three areas, restricting where green energy can be contracted from, emphasizing local sourcing.

Interviewer: How would you propose improving regulations for faster hydrogen development and distribution?

Interviewee: Recognize that hydrogen installations don't necessarily belong on industrial sites; they can be near solar and wind energy hubs in rural areas. Adjusting provincial environmental regulations to accommodate this would be beneficial.

Interviewer: Does current law need changes for such adjustments?

Interviewee: Yes, provincial environmental regulations would need adjustments. National government support for a more flexible, demand-driven approach to hydrogen installations, rather than a strict focus on large hydrogen users, would help.

Interviewer: Besides regulatory developments, what else could speed up hydrogen distribution networks and installation development?

Interviewee: Prioritize projects that aim to solve grid congestion in the Energy Act. Projects like batteries or hydrogen installations should move up the list for off-take connections, ahead of company expansions wanting more off-take.

E.2. Interview Summary Groenleven

Interviewer: Can you describe your role in the Dutch hydrogen sector and how your organization fits into it?

Interviewee: Our company is generally involved in energy solutions, operating in two main branches: Energy Solutions and Energy Projects. Energy Solutions focuses on everything behind the meter, such as electric vehicle charging, solar panels, and small wind turbines, within large industrial buildings or distribution centers. This is entirely project development.

In Energy Projects, we focus on solar, wind, batteries, and hydrogen. We work in four separate teams, supported by a large team of project managers who oversee projects once they are developed. As a business developer, my goal is to identify companies and locations for hydrogen production and consumption and build a project around it. Most of this project development happens on paper, involving permits, subsidies, land agreements, off-take contracts, and identifying technical suppliers. These projects are consolidated into a special purpose vehicle (SPV), which we then sell to a party interested in owning and operating the installation. This is essentially pure project development.

Our company also has an IPP (Independent Power Producers) branch, which buys projects, mostly our own but sometimes others. We have decided not to purchase our hydrogen projects yet, so we currently sell these projects.

Interviewer: What are the main drivers of your projects?

Interviewee: Our company aims to offer sustainability options. While we've done a lot with solar energy, some companies cannot fully transition through electrification. We see hydrogen as the best alternative, despite being costly and complex to produce and transport. Hydrogen offers a viable solution for a select group of companies and helps stabilize the energy grid, aligning with our company's vision. Additionally, there's a demand for hydrogen production, presenting a good business case for both sustainability and profitability.

Interviewer: From your perspective, what are the most important laws and regulations affecting these projects, especially hydrogen projects?

Interviewee: The most significant regulation we deal with is the Renewable Energy Directive (RED 3). This directive outlines what constitutes green hydrogen, with requirements such as hourly correlation between renewable energy production and hydrogen generation. We must account for these requirements early in project planning to ensure compliance and justify the premium for green hydrogen.

Interviewer: Are there infrastructure requirements in these regulations, or do they not significantly impact you?

Interviewee: Our strategy is to develop projects adjacent to factories, minimizing transportation costs. Some projects at the European and national levels get priority, like the Delta Rhine corridor for transporting hydrogen from Rotterdam to the Ruhr area in Germany, but this is less relevant for us since our projects are primarily local.

Interviewer: Do other regulations, like the Environment Act, impact you?

Interviewee: The new Environment Act causes delays because it's new for both us and the authorities. It aims to speed up processes, but we haven't seen much improvement yet. Additionally, future regulations might require industries to blend in a certain percentage of green hydrogen, which could drive demand.

Interviewer: What do you see as the biggest regulatory barriers in developing these projects?

Interviewee: One major barrier is the Delegated Act, which shifts from monthly to hourly correlation requirements, complicating project synergies. Moreover, assets for renewable energy and hydrogen production must be within three years of each other, further complicating project alignment.

Interviewer: Are there financial regulations affecting your projects?

Interviewee: Subsidies are crucial for making projects viable and attractive to investors by providing a safety net. Currently, subsidies are adequate, but the total available funding is insufficient. For example, almost one billion euros will be available this year, but future funding remains uncertain.

Interviewer: How do you handle the operation of regional hydrogen networks you develop?

Interviewee: Due to hourly correlation requirements, energy contracts bind us to produce hydrogen only when renewable energy is available. This necessitates flexibility, achieved partly through small-scale storage, but we aim to keep projects simple without extensive compression, storage, or transportation.

Interviewer: How are you preparing for upcoming European regulations as a company?

Interviewee: We collaborate with our parent company in Germany and participate in organizations that represent our interests in Brussels, ensuring new regulations are workable and beneficial for our projects.

Interviewer: How could regulations be improved to expedite hydrogen network development?

Interviewee: It's essential to determine who will manage local networks early on to avoid costly future adjustments. Whether market players or semi-public entities manage these networks should be clarified to facilitate seamless integration with the existing backbone.

Interviewer: Besides regulations, what else would you like to see in hydrogen development?

Interviewee: We need more projects to reach the 4,000 MW goal by 2030. Successful examples are crucial for market confidence and growth. So far, only a few small projects and one 200 MW project by Shell have progressed, highlighting the need for more initiatives and market knowledge.

Interviewer: Do you think additional support mechanisms are necessary to achieve these successful examples?

Interviewee: It's hard to pinpoint why investment decisions aren't made, but it likely involves technology readiness and reliable system suppliers. The lack of a hydrogen backbone also limits transportation options for many companies.

E.3. Interview Summary Stedin

Interviewer OK, great. Let's start with a bit of background information. Can you tell me about your role within Stedin and what your organization is currently doing in the energy sector?

Interviewee I work at Asset Management, network strategy. This department is responsible for asset management of the energy infrastructure, which includes both electricity and gas. The strategy department focuses on the long-term developments of the energy systems. My specific task is related to the gas network. I work with colleagues like Imam, Niek van den Boogaard, and Tabex, each specializing in different areas. Imam focuses more on green gas and digitalization, while I am 100% dedicated to hydrogen.

Within Stedin, I am involved in all hydrogen initiatives, pilots, research, and strategic planning. Additionally, we have a national network active in various committees to shape hydrogen development. I also serve as the Chairman of the Networks for Sustainable Gases, where we collaborate with six regional network operators and the national operator to advance hydrogen development.

Interviewer Okay, clear. What do you see as the main drivers for projects in the hydrogen sector?

Interviewee One key driver is the reuse of the gas network. As regulated natural gas distribution network operators in Zeeland, Rotterdam, and Utrecht, we need to know if other materials or gases can flow through the same pipes before taking any action. This involves assessing network management and societal costs. Once a gas network is removed from the ground, it becomes null, and there are challenges related to electricity management that must be addressed. We have climate goals, and I believe the choice is not between electricity or sustainable gases like hydrogen, but rather a combination of both. We need to build knowledge and experience, develop methodologies, and ensure we meet our targets to ultimately integrate hydrogen into the distribution network.

Interviewer Yes, okay. If we specifically look at regulations, what are the main laws and regulations Stedin must comply with regarding hydrogen distribution?

Interviewee Currently, we follow the Gas Act, which states that distribution network operators can distribute gas that meets the ministerial regulation for gas quality. At present, this regulation specifies methane with 0.2% mol hydrogen, which is insufficient for distributing higher hydrogen concentrations (3-5%) or pure hydrogen. Therefore, the first objective is to allow regional network operators to distribute hydrogen. Secondly, we need to consider all the norms and standards built for natural gas over the past 60 years and determine how they apply to hydrogen. This involves understanding the differences and the additional requirements or measures needed for hydrogen when using natural gas standards.

Interviewer Yes, okay. And what about something like the Environmental Act? How do you deal with that?

Interviewee It's important to consider the timeframe. In the short term, it won't be implemented. Standardization can only occur once common practices and extensive knowledge and experience have been established. Therefore, we won't achieve this with short-term pilots alone.

Interviewee For example, in Uithoorn, we converted 14 homes from natural gas to hydrogen, encountering the same issue everywhere. If you want to do something with hydrogen, the competent authority, the municipality, the local fire department, etc., will ask you to prove it can be done safely and controlled. This involves demonstrating safety measures and accepted risks.

We addressed this by defining safety risk contours and examining norms for both natural gas and hydrogen in different environments. We gathered these elements, solved issues, and used applicable articles and standards from various norms to create a safe and justified approach.

Interviewer Does the government have a role in this temporary framework for high-end pilots, or is that something different?

Interviewee That's something different. The ACM (Authority for Consumers and Markets) created a tolerance framework, outlining conditions for safety, reliability, and affordability. Safety falls under SODM (State Supervision of Mines), the safety region, and the local fire department. To get a tolerance framework, you must involve these stakeholders upfront, ensuring they agree with your plans and measures.

Interviewer Okay, so the lack of standardization is currently the biggest barrier to hydrogen development?

Interviewee Yes, that's the biggest barrier for us to apply hydrogen. Another barrier for hydrogen development is the lack of available sustainable hydrogen and its high cost.

Interviewer Are there any existing regulations that support the economic feasibility of hydrogen projects or networks, or is that also insufficient?

Interviewee You need to consider different domains. For the built environment, the ACM has created a tolerance framework for four pilots. For the industry, the government is now investing more time and money, providing guarantees for investments in national hydrogen networks and clusters.

Interviewer So, for developing a regional network, government guarantees are necessary?

Interviewee Yes, because the high risks associated with hydrogen network development, such as full and empty risks, require a long-term investment to be profitable. Gasunie, for example, faces the risk of investing in a network that might be abandoned if a major consumer leaves.

Interviewer How should the hydrogen market be structured to make business cases more feasible?

Interviewee It depends on whether we're discussing national or regional levels. For decentralized businesses, balancing production and consumption is essential. This is challenging with fluctuating energy sources like wind and solar. Without demand, import products won't be realized, and networks might remain underutilized.

Interviewer Can decentralized production sites in the Netherlands be connected later, and what role would Stedin play in that?

Interviewee It depends on hydrogen quality. The national hydrogen network has different purity standards than electrolysis. If markets differ, Stedin might not manage point-to-point connections between producers and consumers. Our role is more suited to managing distribution networks with multiple connections.

Interviewer So you don't see point-to-point connections as economically viable or relevant for Stedin?

Interviewee It's about expectations. If there are multiple electrolysers and customers, we might manage a distribution network. However, managing a single point-to-point connection doesn't add value. Regional and national hydrogen networks with multiple connections and proper distribution will likely be our focus.

Interviewer Does Stedin consider upcoming EU packages, which define hydrogen roles for DSOs, in your planning?

Interviewee Yes, it's already accepted. Publication will take six months, with two years for implementation. We're working on it, but it's not our top priority due to other challenges like congestion. However, we do collaborate with other regional network operators on these issues.

Interviewer Some see hydrogen as a solution for grid congestion. Do you agree, or is it more of an addition to the energy mix?

Interviewee It depends on the timeframe. Current congestion is caused by companies seeking electricity connections. These companies have alternatives to natural gas and will electrify as soon as networks are ready. Hydrogen might mitigate long-term electricity problems, but it's not a short-term solution for congestion.

Interviewer Can companies collaborate regionally to set up hydrogen production?

Interviewee Yes, we're exploring this. For example, in Brick Valley, several nearby brick factories have high energy demands. By working with regional and national network operators, they could develop a hydrogen network, potentially freeing up pipelines for shared investment in infrastructure.

Interviewee Regulatory frameworks need to support this collaborative approach. If we work with Gasunie, the costs and benefits should be balanced to ensure the lowest societal costs.

Interviewer What additional legal or regulatory changes are needed to facilitate this?

Interviewee Joint subsidies or government guarantees for regional and national projects are essential. Presenting a joint plan to EZK (Ministry of Economic Affairs and Climate Policy) for approval can help streamline these investments, ensuring they meet societal needs.

Interviewer Beyond regulations, what else can be done to accelerate hydrogen distribution development?

Interviewee It's crucial to develop the entire value chain simultaneously. Prioritization, guarantees, and funding help, but we must ensure balanced development across production, infrastructure, and demand.

Interviewer Would government control over the hydrogen market help?

Interviewee Yes.

Interviewer Do you think this is possible in the Netherlands?

Interviewee I don't think so, as it would involve dictatorial control. Companies are also concerned about risks, and consumers are not ready to pay a higher price for greener products.

Interviewer So it's about breaking the chicken-and-egg problem, where production and infrastructure investments depend on each other?

Interviewer Is that what you mean?

Interviewee It's more complex than that. The national hydrogen network is being developed by Gasunie, connecting industrial clusters despite the lack of production and demand. Breaking the chicken-and-egg problem here is just the first step. The entire value chain needs to be developed, including production, infrastructure, and demand, with considerations for CO2 emissions and European regulations.

Interviewer So, you want to lower the price of hydrogen and increase the cost of fossil-based production to make hydrogen more attractive?

Interviewee Yes, and also provide market certainty and availability. Importing hydrogen from regions with lower production costs could also help.

Interviewer Could the government guarantee a certain amount of hydrogen imports annually to support this?

Interviewee Yes, but if the government guarantees imports, it might need to guarantee every step of the value chain.

Interviewer So, it should be more of a market-driven development?

Interviewee Yes.

E.4. Interview Summary Top Sector Energie

Interviewer: I am curious about your role and experiences with hydrogen in the Netherlands.

Interviewee: I work for the Topsector Energy, which is essentially a top sector established to stimulate and facilitate innovation. I am the director of a public collaboration focused on this, called TKI New Gas, and in that capacity, I have been involved with hydrogen for many years, previously from a consultancy background. For the past 10 years, I have been the director of this TKI, and we focus on three main areas. Strategically, we aim to set the substantive lines on which innovation should focus—what are the key innovation themes and how do we approach them? Secondly, we assist those who want to innovate by providing information, advice, knowledge, reports, and utilizing our contacts, networks, both nationally and internationally, funding, and subsidies to ensure they get the best advice on how to proceed. Thirdly, we focus on information and communication. We try to highlight where the Netherlands excels in this domain and foster international relationships. For instance, I will be heading to Antwerp soon for a day with Belgian colleagues. We are a relatively small foundation with about 7 or 8 people, amounting to approximately 3 full-time jobs.

Interviewer: Yes, okay, interesting. What are the main drivers for you to undertake such projects in the hydrogen sector? Why do you see it as the next step in the energy mix?

Interviewee: The important thing about hydrogen is that looking towards the future, you will eventually need to produce hydrogen from sustainable electricity or fully climate-neutral sources, which may still include fossil fuels with CCS for now, but ultimately, it needs to be sustainable. This means building your energy system entirely on solar and wind power, hopefully by 2050, though it may take longer. If by then you can produce large quantities of sustainable energy, you can not only meet all the electricity demands and electrify certain objectives, but you can also produce molecules via electrolysis, targeting markets where electrification is not feasible or practical, such as high-temperature heat and raw materials. In this sense, hydrogen is a crucial piece in the energy transition puzzle. To what extent is still uncertain—estimates range from 10%, 15%, to 40%, 50%. I usually estimate it around 20-25%. Hydrogen can fulfill many use cases needing decarbonization and play a vital systemic role by efficiently storing electricity long-term, providing alternatives for transport besides electric lines, like pipelines for hydrogen or ships. This enables imports and delivers the flexibility needed to keep our energy system reliable and affordable. Flexibility is provided within certain limits via electrolysis, although some believe it requires constant regulation, which I disagree with. Nonetheless, it is a critical element in the energy transition.

Interviewer: That's a compelling vision. What are the current laws and regulations impacting hydrogen development in the Netherlands?

Interviewee: Ultimately, the overarching policy is that we aim to be climate-neutral by 2050, as agreed in Paris. This is the anchor, and in the Netherlands, we've committed to achieving a 55% CO2 emission reduction by 2030. Among the various options to achieve this is hydrogen. There are three types of regulations: generic policies like emission trading, where you reduce CO2 and can earn money if you exceed targets or pay if you fall short. Then there are incentives and penalties—the carrots and sticks. You receive innovation or investment subsidies for leading the way, but face penalties if you don't sufficiently reduce CO2 or deploy hydrogen by 2030. Various subsidies stimulate research and concrete investments in hydrogen trucks and stations, while the Renewable Energy Directive from Brussels mandates replacing 42% of grey hydrogen with green by 2030. Additionally, the Alternative Fuel Infrastructure Regulation requires infrastructure for alternative fuels, including hydrogen stations, by 2030.

Interviewer: Yes, and can you elaborate on the development of distribution networks in the Netherlands? What are the current regulations or barriers to establishing these networks?

Interviewee: Currently, there is an energy law replacing the previous gas law, regulating net management as a business in the Netherlands. Until now, only a minimal percentage of hydrogen could be injected into high-pressure networks—0.02%, now increased to 0.5%. The energy law has expanded, allowing hydrogen networks, and the government has tasked Gasunie with establishing a national hydrogen infrastructure, allocating approximately 750 million euros to cover initial costs if the infrastructure is underutilized. Gasunie is also exploring a hydrogen network in the North Sea. This summarises the main developments.

Interviewer: Yes, but regarding regional clusters like Cluster 6, which aren't yet part of the hydrogen backbone, is there any regulation or emerging ideas, or is it lagging behind in your opinion?

Interviewee: There is some progress. The Netherlands Enterprise Agency (RVO) is inventorying promising Cluster 6 areas to connect first once a hydrogen backbone is in place. We are also financing the High Delta project, with Stedin involved, looking at regional demands and the viability of establishing infrastructure where there is significant hydrogen demand.

Interviewer: Yes, and developing that infrastructure regionally—how do you see it being economically and financially managed? Should it be government-funded or handled differently?

Interviewee: Currently, the infrastructure typically falls under regulated domains and state participations. Network operators are often municipally owned, so we don't generally opt for private networks. Some parties may initially lay their own pipelines, but they must guarantee third-party access, and the government may eventually take over the infrastructure.

Interviewer: Yes, and how do you see it working? For instance, private networks in industrial areas producing hydrogen with solar panels and consuming it locally. What role would network operators like Stedin play if these networks were taken over? How should it be regulated?

Interviewee: That's a challenging question. It depends on the structure of such clusters. In Agriport A7, for example, the Energy Cooperative Wieringermeer has established its own electricity and heating networks, as the network operator couldn't or wouldn't do it. Other parties also undertake similar initiatives. The key is ensuring third-party access and reasonable tariffs. Whether private or public, it matters less as long as costs, access, safety, and maintenance are well-regulated.

Interviewer: Do you see the current cost and access arrangements as barriers to development?

Interviewee: The difficulty lies in ensuring supply when laying hydrogen pipelines, unlike natural gas, which always had guaranteed supply. For hydrogen, you must ensure production meets demand, especially for decentralized networks. This remains a complex issue needing further discussion.

Interviewer: Do you think laws or regulations could improve supply security, or is this not a government responsibility?

Interviewee: If it's for a village or small town needing heat, the government must ensure supply through public companies. For industrial clusters investing together, contractual agreements should suffice without much regulatory intervention. They take responsibility for ensuring continuous hydrogen supply.

Interviewer: So, for regional production and consumption, they should make internal contractual agreements?

Interviewee: Yes, ultimately. Network operators lay the networks, ensuring access and tariff regulation. If privatized, parties must ensure hydrogen supply. Forcing everything into public hands stifles innovation.

Interviewer: You can't directly compare hydrogen to the early development of the gas network because of its different characteristics?

Interviewee: That's my inclination. In the 60s, a national gas infrastructure was built. Now, we're considering connecting five industrial clusters and establishing links with Belgium and Germany. But how much regional infrastructure should be laid at public expense needs careful consideration.

Interviewer: So, more research and clear expressions of interest from companies are needed for further development?

Interviewee: Yes, or even concrete contracts. If a company commits to significant hydrogen use, we must ensure its long-term viability.

Interviewer: Do you think adjustments to laws or regulations could accelerate hydrogen network development?

Interviewee: Where proven high demand for hydrogen exists, the government could facilitate investment, possibly through loans or encouraging pension funds to participate. Such measures could already be in place.

Interviewer: Beyond legislation, do you have other ideas to promote hydrogen development?

Interviewee: Encouraging smaller entrepreneurial clusters to develop their infrastructure could be key, allowing faster progress without waiting for network operators. Flexibility in infrastructure management could spur innovation and accelerate the energy transition.

Interviewer: We mentioned Tennet. Some see hydrogen as a way to relieve grid congestion. Do you agree, or is it more of an addition to the energy mix?

Interviewee: It can certainly help. For example, a company with a 100 MW solar park uses some electricity to produce hydrogen when the grid can't absorb all the solar power. This decouples hydrogen production from electricity prices, linking it to the hydrogen market, such as for refuelling stations. This approach is interesting as it allows for more local renewable energy production, converting it into hydrogen for different markets.

E.5. Interview Summary Alliander

Interviewer: What is your role and experience within your organisation and in the Dutch hydrogen sector in general?

Interviewee: I am trained as a technical planner and have worked for 14 years in the government, mainly in the transport and logistics sector. In 2020, I switched to Alliander and immediately started working with sustainable gases such as Biomethane and hydrogen, occasionally dealing with biogas, but mainly Biomethane and hydrogen. Since then, I have been involved in the distribution of hydrogen and how it should be organised. I work in the regulation department at Alliander, so I handle everything related to hydrogen and regulation. In 2020, I was the only one handling this, but you see an increasing focus on sustainable gases. Since last summer, nearly a year now, we have an additional colleague. Besides everything I do within Alliander, I am also active within Netbeheer Nederland. I am a member of the regulation working group and part of the regional hydrogen rollout project team.

Interviewee: Firstly, strategy and vision have been established by Netbeheer Nederland for the regional hydrogen rollout. We started this over a year ago and then started working with Trinomics. They are conducting research for EZK on the regional rollout of hydrogen to bring the information we have, and which we consider relevant for this research, to the research agency in a coordinated manner. Interviewer: What do you see as the main drivers behind hydrogen projects in the Netherlands? Why is it such a hot topic now?

Interviewee: Ultimately, you need distribution transport to bring supply and demand together. So you see mandatory requirements from Europe, such as purchase obligations, and also CO2 targets, and some industries can achieve these with hydrogen. There are other options, but for some industries, hydrogen seems to be the most logical solution. So they are looking at how to purchase hydrogen, which of course also needs to be produced. EZK is trying to accelerate this with subsidies and obligations, particularly on the demand side, and to bring it together, you need transport. If it's large quantities, it's best managed with pipelines. HyNetwork handles the really large quantities, but you also need to cater to smaller industries that require less volume and pressure. That's an area of expertise we have, hydrogen distribution, but you need infrastructure first to bring supply and demand together, so it's the classic chicken-and-egg problem.

Interviewer: What do you see as the most important regulations currently influencing hydrogen development and distribution networks?

Interviewee: In my opinion, it's what has been devised in Europe and what we need to implement via the gas regulation, which has a direct effect, and the directive that must be implemented within two years. This forms the basis for regulating the hydrogen chain. EZK will also strongly consider how the gas sector is regulated in the Netherlands, so everything not determined by Europe will first be looked at under the gas law to see if it works for hydrogen or needs adjustment. With these two components, you have the legal and regulatory foundation. This doesn't address market organisation, such as who can do it. Europe has stated it will be regulated, including distribution. But it could be done by a company like Stedin. In principle, any company could be designated to do it.

Interviewer: How do you see market organisation being regulated?

Interviewee: I think grid operators have a strong position. In the short term, new networks will likely be built by anyone with knowledge of distribution or pipelines. One of those parties with knowledge are the grid operators, but we also see that hydrogen might grow beyond what it is now in the first 10-15 years. The general view is that hydrogen will be scarce and expensive for the first 10-15 years, and the number of distribution networks will be very limited. You could theoretically organise this differently, but because the expectation is that hydrogen will eventually grow, you might reuse existing gas networks, making it easier to have a party in charge that also manages those gas networks. Another argument from the European and Dutch governments is that energy networks in the Netherlands must be publicly owned. If you look at the NPE, the National Energy system Program, where hydrogen is one of the energy carriers, it would make sense for EZK to also keep hydrogen in public hands. Theoretically, you could also appoint other companies like Airliquide, who work with different pressures and pipelines and have knowledge of distribution but from a closed system with different techniques. There are also contractors who lay our networks; we often don't do it ourselves but only do the engineering. They could theoretically also do it, companies like BAM, for example.

Interviewer: What about the Environmental Act? How do you think it will influence the planning of a new hydrogen network?

Interviewee: I am a planner, but I still know the old laws, so I'm not entirely sure. I can't imagine that laying a hydrogen network will be different from a natural gas network under the Environmental Act, at least for distribution networks. For transmission networks like Hynetwork, it's different because of higher pressures and different safety margins, which fall under different safety regulations. This doesn't apply to us, so I don't think it's very different from natural gas. The main derivative from the Environmental Act is the energy visions from provinces, indicating where they want hydrogen, natural gas, and other energy infrastructure. There is more to be gained there than from strict permitting rules.

Interviewer: So, it's ultimately the provinces that decide where to potentially lay a hydrogen network?

Interviewee: Yes.

Interviewer: Do they do this in consultation with you or with consumers? How does that process work?

Interviewee: The process is relatively new to the energy sector, about three years old. On one side, you have the CES, the cluster energy strategies, where demand is collected from the market. Currently, we are working on the P-CES, the provincial cluster strategies, to inventory the demand for hydrogen and other energy carriers. This can then be input for the multi-year energy and climate infrastructure program. Together, this should steer where different types of energy are desired and should be reflected in investment plans.

Interviewer: Exactly, that's what I wanted to move towards. You mentioned subsidies briefly; how are they arranged to make the development of a hydrogen network economically feasible?

Interviewee: There are some subsidies for hydrogen networks, but the main problem with hydrogen networks is the risk of initial uptake and underutilisation. You want to build a network, but you don't know exactly how much demand and supply there will be. Demand and supply will come if they know where the network is. That's why we, as grid operators, have said in Hyregions that you should proactively build the hydrogen chain, just like Hynetwerk is doing with the national hydrogen network. They have been tasked by EZK to build the national hydrogen network, connecting large geographic clusters and storage proactively, without being 100% sure it will be fully utilised. The logic is that the 4 gigawatts of hydrogen production from the sea should fill the backbone. This problem also exists for distribution networks, with companies wanting hydrogen or considering production facilities but needing a place to offload. Starting with trailers is costly. So, you should proactively build hydrogen networks for distribution, but there are significant risks of underutilisation and financial loss, which would be mitigated if the government intervened.

Interviewer: Is this mainly a financial issue, or does it also involve ensuring there is sufficient supply if there is enough demand but not enough production?

Interviewee: The government is working on memoranda of understanding with other countries for import. The hydrogen exchange between the Netherlands and Germany helps too. The grid operator should build only when there is certainty of supply and demand or when connected to the backbone. So, I wouldn't expect much from the government. We ensure transport, but the client must source the hydrogen.

Interviewee: In the H2avennet project, an Alliander project, they have an EVB program manager responsible for hydrogen, sourcing hydrogen from elsewhere and supplying it to customers. Conversely, there could be many electrolysers with nowhere to offload despite having a good network.

Interviewer: So, the biggest risk is the imbalance in the system?

Interviewee: Yes, the risk of underutilisation and financial risk can be mitigated if the government or a grid operator takes the risk. The challenge is balancing supply and demand in a fragmented market. Some people argue it shouldn't be regulated this way because there is no market, suggesting a return to the integrated gas market model where companies did everything, just needing customers.

Interviewer: Do you see this as one of the biggest regulatory barriers to developing hydrogen networks, or are there other major barriers?

Interviewee: The biggest barrier is the uncertainty about how it will be organised. We expect to be able to do it, but nothing is confirmed. We think there will be some form of subsidy from the government, but nothing is certain. Although Europe has established some market structure, nothing is in the Dutch legislation yet. It would be helpful if the legislator clarified this, allowing us to take further steps.

Interviewer: Are MIEK or CES enablers pushing hydrogen network development?

Interviewee: They help, but I don't think provinces have enough leverage to do this financially. Some provinces are richer than others, but EZK should take a more leading role, which I think they will do.

Interviewee: The HyRegions report provides a model analysis of the Dutch hydrogen potential, highlighting about eight concentration areas with potential for distribution networks. The plan is to further develop these areas with a government subsidy program.

Interviewer: How do you prepare for upcoming EU legislation within the company?

Interviewee: Where possible, we do this in Dutch collaboration because it affects all grid operators. Recently, I met with Stedin and Enexis to review the gas regulation, identify relevant points for us as distribution network operators, and work on these within the task group on regulation. We actively try to influence the legislation through various channels, understanding the main points and preparing internally. This involves considering how contracts should look for both demand and supply parties, prompting people to think more concretely about how things should work, and eventually bringing our proposals to EZK or other authorities.

Interviewer: Are there ways this regulation can be improved to better support hydrogen distribution network development?

Interviewee: One major issue for us as distribution network operators is the definition that a hydrogen terminal cannot be connected to a distribution network. This is a missed opportunity, especially in the Amsterdam port area. According to the legislation, LOHC terminals are not hydrogen terminals, so they can connect to the distribution network. However, importing liquid hydrogen is restricted to the transmission network, which could hinder the development of distribution networks.

Interviewer: Besides regulation, what else could be done to accelerate this development, or do you think it's progressing quickly enough?

Interviewee: To accelerate, subsidies or financial support from the national government are needed, along with clarity on market organisation. Over the past year, hydrogen development has become less hyped, and people are thinking more seriously about it. We are in a bit of a developmental lull, but hopefully, we will move to a standard level. It's not urgent to have everything sorted immediately as hydrogen isn't available yet, but clarity on how it will be regulated would help parties prepare.

Interviewer: You need more clarity on your roles and the market structure to develop long-term strategies?

Interviewee: Yes, and to have discussions about it. Currently, we manage internally, but it's complicated with Gasunie.

Interviewer: If an industrial area wanted to set up a standalone hydrogen network, would there be a role for a distribution network operator to connect these small areas in the future? How should that look?

Interviewee: If it starts small but has the potential to grow, it's wise for an appointed distribution network operator to manage it. Otherwise, you create isolated areas that need to connect to someone else with different starting points. If it's a small industrial area managing its own production and consumption, a market party could handle it, similar to closed distribution systems in the gas sector.

Interviewer: So, you need a long-term vision to determine if a distribution network operator's role is necessary if it might grow?

Interviewee: Yes, and for such points, you refer to the gas package allowing less strict rules for geographically confined areas. There will still be regulatory agreements on tariffs and other aspects, even for small areas not part of a larger network.

Interviewer: I understood that these confined areas would need someone like Stedin or Alliander to manage if they grow.

Interviewee: Yes, confined areas cannot connect to a regulated network, such as a transmission network. If they grow, they will eventually need to transition to a fully regulated network management.

E.6. Interview Summary Kapelle

Interviewee: I am involved in several areas of the hydrogen transition, so I am hired by the municipality of Kapelle. We have a company called Actright and we are engaged in the sustainability of the Netherlands, often working with governments, grid operators, housing corporations, CES regions, and there we deal with matters such as the heat transition and grid congestion. Hydrogen is also part of the solution in these areas. I am involved in the hydrogen project in Kapelle. We are looking at the development of an existing business park and the development of a new business park where we partly focus on hydrogen as an energy source, because we primarily have agro-food companies that need reasonably high-temperature energy, thus having a reasonable power demand. We also want to develop the new business park with energy-intensive companies. If I were to knock on Stedin's door now and request a 50-megawatt connection, I don't think Stedin would be very happy about it. However, the development of the backbone, which cuts through the municipality of Kapelle, means that new and existing companies are interested, making it extremely promising to develop something for our region.

Interviewer: Yes, so you think that you can actually connect directly to the backbone with such a network?

Interviewee: Yes, we have several initiatives. We have an initiative running with Groenleven. Coincidentally, we visited a hydrogen factory in Oosterwolde last Friday, but they have a letter of intent with Zeewind. Zeewind is going to develop 40 megawatts of solar and wind power in the Willem Annapolder, which is the same area. They are a preferred party to, say, take 19% of that power and convert it into hydrogen. That is electrolysis and 15 megawatts will produce about 12 tonnes of hydrogen per year, and we are currently looking at 2 large consumers to see if they can take it, allowing them to replace 25% of their gas with hydrogen. The beauty is if we want to develop electrolysis, it can actually only be done on a business park. That is designated in the environmental vision for next year, so they can only participate in the development of new business parks, and we want those companies to connect to it. However, that is insufficient for all companies, so we say we also need a connection to that backbone to offer some supply security. That is important for the parties that will establish themselves here.

Interviewer: Yes, I understand, and you mentioned the provincial regulation. Is that one of the main laws and regulations you encounter in developing such projects, or are there other laws you frequently deal with?

Interviewee: Yes, we encounter that. Such industrial initiatives are not just allowed in the polder, so you are limited in the development possibilities you have. You must use existing business parks or new ones that are made available. We encounter that. What I mainly run into with this development is the legislation that does not yet exist. There is no clear role for grid operators in hydrogen, so we now run into a wall with Gasunie, who say, "We don't have a legal task. We do have a task of connecting the 5 major clusters and looking at how to potentially connect cluster 6, so with Hyregions, and that's where our scope ends." The system integration of regional grid operators to the backbone is not regulated, and that role is also unclear. There is no policy for it, no legal frameworks, and that probably delays the entire process. They are not yet intending to clarify that role.

Interviewer: Yes, that is the biggest problem. And if you look at planning and zoning for such a network, do you encounter issues with the Environmental Law or similar things?

Interviewee: Yes, minimally, we have to secure everything, so in our environmental vision and environmental plans, I have to secure these projects. So, we don't really encounter issues there.

Interviewer: Okay, and when you look at economic feasibility or economic support, do you use subsidies or similar things? Are there enough or too few of them?

Interviewee: Yes, we certainly use subsidies. We are now going to apply for sustainability for future business parks in the province of Zeeland for the part of electrolysis in the municipality of Capelle. That makes use of the OWE subsidy. In addition, there is the offshore subsidy from EZK. The province of Zeeland is also investing once more in the 4 branches of the Backbone. Otherwise, it is impossible to produce good hydrogen without subsidised costs.

Interviewer: No, I understand. And if you have such a network on a business park, it seems to me that it is now a private network because no operator like Stedin is really involved. So how is the operation and balancing of such a network arranged? How do you ensure that if hydrogen is produced somewhere, it is also used?

Interviewee: Well, there is no network yet, so that's the premise, but there are several tracks we are currently following. There are two questions: how will the network develop, and how will the network be balanced? The first part is a good question. We now have a letter of intent with Stedin to investigate the suitability of the existing gas network on that business park. We have two gas networks, one with high pressure and one with low pressure. We are looking at whether it is possible to transfer everything to one of those networks so that the other can be used for blending with hydrogen. That is something we are now jointly investigating to see, and within that, what the role of Stedin is as a grid operator in this hydrogen market. That limits them to their own network because integration involves several discussions with EZK to see what is possible and not possible. In this phase, regional grid operators, but also certainly Gasunie and EZK, need to ask themselves what happens if we do nothing? At the same time, I have to speak with G-tech and Groenleven, who also say, "We can also lay it ourselves," so if you want that, you will get private networks everywhere that are not in the hands of a grid operator, and that might not be a role that a grid operator has in the future hydrogen economy. And that is something where, as a government, you need to have timely policy developed, or the market will surpass you.

Interviewer: Is it still a problem for you that there is no clear standard yet? And how do you deal with such a problem?

Interviewee: Yes, it is currently problematic because it causes a lot of uncertainty. That also causes a lot of uncertainty in the planning process, making parties less likely to take steps. You want to make a certain development as a region, so you need to calculate things and build a business case, but if there is no clarity about how the system will look and what the requirements are, parties are not inclined to take those steps. And that is what we encounter.

Interviewer: Yes, okay, and are there things you now think are already very supportive of hydrogen development, besides subsidies, when you look at laws and regulations? Interviewee: I think what really helps is the P-MIEK. I think it is really good because it emphasises things that are important for certain regions. As soon as it has a public status, it actually has a certain status nationally, allowing you to have faster conversations with bodies that can make decisions. And that is something where the Energy Board sits together administratively to discuss important infrastructure projects, and they all flow into the national clinic. But when a project falls within that status, it has administrative attention from Tennet, EZK, Gasunie, Stedin, and the municipality and province, who meet bi-monthly. And with that, if you encounter administrative issues, you can resolve them. It also has a certain status within the ministry, allowing you to initiate a conversation faster to start a pilot in my case, and with that, you can help your project. So that is something that adds enormous value to the project.

Interviewer: Okay, so that P-MIEK could be significantly expanded with more regional projects to support the development of such a hydrogen system, or do you think that is not possible?

Interviewee: I think if you secure your project well in the P-MIEK, that is sufficient. Yes, because then you can handle all projects and write them nicely there. Then, in principle, your project is well secured with all the sub-projects involved. And furthermore, one thing that does not help is also the cheap fossil stock. So regulating that market and the ETFs should keep expanding. Eventually, you need to create a certain trigger for companies to take steps, and the problem is often financial. However, it is important that this is done at the European level or even globally. Because yes, companies also need to continue to operate, so there must be a certain competitive advantage. So either you need to subsidise hydrogen even more, making it very attractive, or build a lot of activities very quickly, making it a good route again.

Interviewer: So basically, just equalising or making the cost of hydrogen cheaper than fossil fuels. That would help a lot, you think?

Interviewee: That would help a lot, yes, certainly.

Interviewer: Is new regulation from the EU something you are also working on or preparing for with your pilots?

Interviewee: No, no, but it's good that you mentioned it. Which legislation is that?

Interviewer: Yes, that is the Decarbonisation package from the European Union.

Interviewer: So, that should be another question, yes. What do you think is still needed in terms of laws and regulations to better develop hydrogen in the Netherlands? Interviewee: Well, I think the very important thing is indeed the clarity of the role. Clarity on the role of the grid operator. So that it is not also an inhibiting factor because at the moment, the grid operator is an inhibiting factor both in terms of electricity infrastructure and hydrogen. And that is something that does not help in the transition. So, role clarity, clear frameworks within which they must operate, who is responsible for the system requirements. That is something that needs to be clarified quickly. Mainly for the grid operator. To be able to branch off from that hydrogen backbone, otherwise a lot of public money will be lost because Gasunie just tells me, for example, "We have to connect those industrial clusters. And yes, we actually do nothing in between, so we do not take a branch now." While it is much easier to take it along now than later to supply in the pipeline. Now we have to lay a new pipeline here in Zeeland, but due to the lack of laws, regulations, and policy, they would not now do that. When that would be in order, when they would have a procedure and protocol for how the branches are arranged. For integration, regulation is necessary to facilitate the regional energy transition.