Accelerating the execution of green hydrogen value chains with the use of programme management

MASTER THESIS REPORT

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PREFACE

My master's journey at TU Delft which started almost 2 years back marks the completion of a transformative chapter with this graduation thesis. Gratitude fills me as I reflect on the remarkable experiences that have shaped my personal, professional, and academic growth. I would like to thank the university for proving me with this opportunity. This journey has indeed been a roller coaster ride which has been full of amazing experiences. The thesis has itself been an extraordinary journey. It has helped me gain knowledge and confidence. This research journey has been full of challenges and obstacles. But with patience and hard work I was able to tackle them. The saying holds true: "It always seems impossible until it's done." But this would have not been possible without the help of the people who have been a part of this journey.

I would like to thank my graduation committee for their guidance and support throughout my thesis. Thank you all for being flexible and providing your critical insights which improved the quality of my report. I would like to thank Ad for chairing my committee. Thank you for your valuable feedback and suggestions, and always being there when I needed your help. Thank you for helping me look at my research from different perspective. A heartfelt thanks to Erik for agreeing to be my first supervisor and also my motivating supervisor. Finalizing the topic would have not been possible without your support. You always took the time to listen to my problems and break it down for me since day 1. You always boosted my confidence and asked me to believe in myself. A very special thanks to Carl, my company supervisor for providing me with the opportunity to graduate at T&T. Thank you for your unwavering support and guidance. You have always been there to help me whenever I needed you. Your experience, knowledge and expertise enhanced my thesis report. Thank you for not only listening to my doubts, but also for all other problems I had in the world. You have been nothing but sweet, kind and patient with me. Thank you for helping me develop this idea and believing in me even when I did not. I would also like to thank Turner & Townsend for providing me with the opportunity to conduct this research. I want to thank everyone who supported me in this journey be it reading the report or providing their expertise. I want to thank all the participants for providing their valuable insights during the interviews.

I want to express my gratitude to my parents and my entire family for their support throughout my master's journey. I would like to thank my friends from the Netherlands especially the ones from TU Delft for helping me and making the entire journey a memorable one. A heartfelt thanks to Sneha, my friend and roommate for reviewing my report and guiding me. Thank you for your support throughout this journey, be it cooking or listening to me all day. I also want to thank Sai, Bhargavi and all my friends back in India for their encouragement. A special thanks to Riya for always being there for me, motivating me and being my best cheerleader.

Payal Navale

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EXECUTIVE SUMMARY

Background context and research design

One of the most serious issues the world is facing is climate change which needs urgent attention and carbon dioxide emissions are the primary driver of this. The energy sector is one of the major reasons for this and is responsible for the highest amount of share of CO2 emissions. Thus, decarbonising the energy sector and exploring alternatives is urgent. European Green Deal mentions the target of a net carbon-neutral European Union by 2050. The energy transition concerns the shift from fossil fuels in an effort to reduce CO2 emissions by causing a change in the primary energy supply and the gradual shift to a new state of an energy system. As a result of setting the climate goals, various projects and technologies are getting developed that focus on reducing carbon emissions for e.g., Green Hydrogen.

After the Dutch government set out its hydrogen ambitions in the Dutch Climate Agreement 2019, it released its National Hydrogen Strategy (2020). In order to achieve the variety of targets set by the government, the energy transition from conventional fossil fuels into green hydrogen needs to take place and accelerate. In the Netherlands, various projects of the green hydrogen value chain are planned, strategies are laid out, and the execution of some projects in the chain has started with an ambition to use green hydrogen to decarbonise. However, the transition process is seen to be slow as not all these projects of the components of green hydrogen value chain are executed. The problem statement is formulated as: “There is a lack of execution of the projects of the green hydrogen value chains. This is leading to slow energy transition with regards to green hydrogen technology and not meeting the ambitions and goals set.” An opportunity to help address the problem is the use of programme management. Literature shows relations between transition and programme management, and it provides a valuable contribution to transitions. This research hypothesizes that programme management could help in execution of the projects in a green hydrogen value chain. However, its use for green hydrogen value chains is not sufficiently explored. The hypothesis is formulated as: “Application of programme management theory to green hydrogen value chains can contribute to the acceleration of their execution.”

In order to trigger the acceleration of the execution of the GH2 value chains and to address the research gaps, research objectives are drafted as: To provide insights into the challenges faced in execution of green hydrogen value chains; To explore the application of programme management to green hydrogen value chain, and; To develop a model that can incorporate the learnings explored in the research. To achieve the objectives, the main research question of this research is formulated as: *How can the execution of green hydrogen value chain be accelerated with the use of programme management?*

The scope of this research is limited to the green hydrogen value chain in the Netherlands. The methodology used for exploring the topics theoretically is literature study. A major part of the data gathering done for this research is through semi-structured interviews. After gathering and analysing the data, based on the findings, a model is created with an aim to tackle challenges and set up programme of green hydrogen value chain. It links the theoretical findings and the empirical findings, and all this is done through desk research.

Green hydrogen value chain

The research provides detailed understanding of the green hydrogen value chain. This process right from renewable power production until end use-consumption is the green hydrogen value chain. Actors play an important role in executing the value chains. The key actors identified through literature are the private sector being the renewable power producers, the green hydrogen producers and the end users; the semi-public sectors being the electrical and gas TSOs; and the public sector. The Figure 1 depicts the green hydrogen value chain.

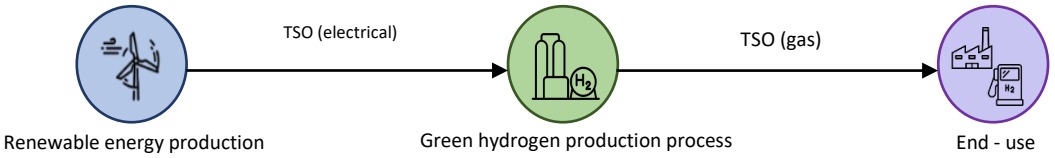

Figure 1: Green hydrogen value chain in the Netherlands

The literature revealed that the entire chain is dependent on each other, and one cannot work without the other. Also, the government acts externally through drafting of the policies. The semi-public sector also are the only TSOs (electricity and gas) and are responsible for providing the infrastructure and for transportation. The private sector needs to make the investments and are responsible to execute the projects. A gap in literature is found in terms of challenges to execute the green hydrogen value chain.

The challenges are explored by conducting semi-structured interviews with the key actors and the company. The challenges in executing green hydrogen value chains observed are categorised as cost, uncertainties, regulation, and actors. The high cost of green hydrogen is a challenge for the green hydrogen producers and the end-users, as it is influenced by several factors such as renewable power prices, electrolyser investment, energy transfer efficiency, and fossil fuel competition. The uncertainty in costs and the added risks surrounding it makes the actors in value chain hesitant to invest. The regulation around green hydrogen is strict and unclear. The definition as to when hydrogen is counted as green is very strict and there is no clarity on the benefit of using green hydrogen. Given its novelty, the technology brings uncertainties like building large-scale electrolysers, lack of knowledge and experience, and demand and supply. There is also an uncertainty if the infrastructures required in the value chain will be ready on time. This leads to the private sector being more hesitant to invest. The end-users cannot make any firm commitments as they have no view on affordable green hydrogen. The actors want to commit to a long-term vision but are only limiting it to achieving short term goals. The highlight of the challenges observed was that the value chains are currently fragmented and lack integration, communication, transparency, and collaboration.

Along with challenges, the potential solutions identified through these semi-structured interviews are cost & demand, government, and actor & integration. Having clarity and surety of the cost of green hydrogen motivates the producers to produce and end-users to buy it. Having certainty reduces the risks. The more the demand and production, lesser will the costs get overtime. Regulation clarity and easing was also needed. A premium given for green hydrogen will drive the actors to invest and use it. Commitment to the roles, timelines and responsibilities from actors is required. There should be an alignment in the timelines of the all the components in the GH2 value chain. Having a long-term thinking and vision, being transparent, sharing and distributing risks, improved communication is noted to be important. The highlight of the potential solutions observed is that the green hydrogen value chain needs to be connected and integrated along with collaboration between actors. More the integration, stronger is the business case.

Programme management

The research further dives deep into the hypothesis. The literature provides the definition of programme management to be 'the management and coordination of related projects to achieve optimum benefits that cannot be realised if the projects are managed separately. It is a mechanism to coordinate a group of related projects.' The literature reflects on characteristics and benefits of programme management. The top 8 key elements form a theoretical model, and they are grouping / integrating, directing, and initiating projects; creating and aligning objectives with the strategic and long goals and achieving them; long-term collaboration; cross-project learning and knowledge sharing; make and achieve complex changes; coordination and interaction between projects; allocating and sharing of resources; and joint decision-making process.

Semi-structured interviews conducted provide information on the application and set-up of programme management on green hydrogen value chain which barely present in the literature. The finding from the interviews updates the theoretical model with the addition of: giving joint feedbacks for all projects in programme; bring different skill sets required together and judge investment plans across the programme, giving a total 9 key elements. Further the interviews revealed that programme management helps the actors develop the commercial models which then drives the behaviour of the investment. It provides a longer term and more strategic view across a number of projects. A programme can help provide better coordination and also take account of complexity and seek to reduce it. In a programme, it is easier to adopt and absorb it and manage the complexity in case of unexpected events. It provides alignment on goals and strategies of individual projects. Considering the integration of cost management and risk management is needed to support the value chain moving forward. Programme management should focus on the strategies and benefits it has to achieve and ensure that the inputs and outputs from each project come together. Better communication and having a platform for it is important. Programme management helps in observing and analysing the economics across each project of the programme. Delivering the chain as a programme by grouping the components will ensure to get it running.

Final Solution

The theoretical and empirical findings presented in the topics of green hydrogen value chain and programme management are used as inputs while developing the solution. The theoretical model of programme management helps address the potentials solutions found in semi-structured interviews. It supports and provides a base for these potential solution with its characteristics and benefits. This collectively helps in tackling most of the challenges that were mentioned before.

After addressing the challenges, the next step is to provide a guideline to set-up a programme for a green hydrogen value chain. Figure 2 shows the model which provides a stepwise guideline for the set-up. The first step is setting up a joint decision-making committee where members from each component of the green hydrogen value chain need to be included. This committee will be responsible for taking the decisions and monitoring the entire value chain. The next step is to set the goals, outcomes, outputs, and the strategies to achieve them. To set these, a process is formulated: Evaluate the current status and needs; Analyse what needs to be done for the value chain as a whole; Define output, outcomes, goals, etc based on that; Develop strategies to achieve them; Execute the strategies and actions developed; and Monitor the programme to ensure if the milestones are achieved. The core of this programme lies by the goals and strategy set for the programme. All members need to abide by those. After this step the third step is to set up the aspects which are: Clear roles and responsibilities; Risk management panel; Reporting; Communication; PMO; Formulating contracts and agreements; Investment plans; and Data and information management. Using the model provides better risk allocation, an opportunity to create a business model, sharing risks, more certainty and control on the price of the end product, transparency by all actors and this overall provides confidence to the actors to make the investments.

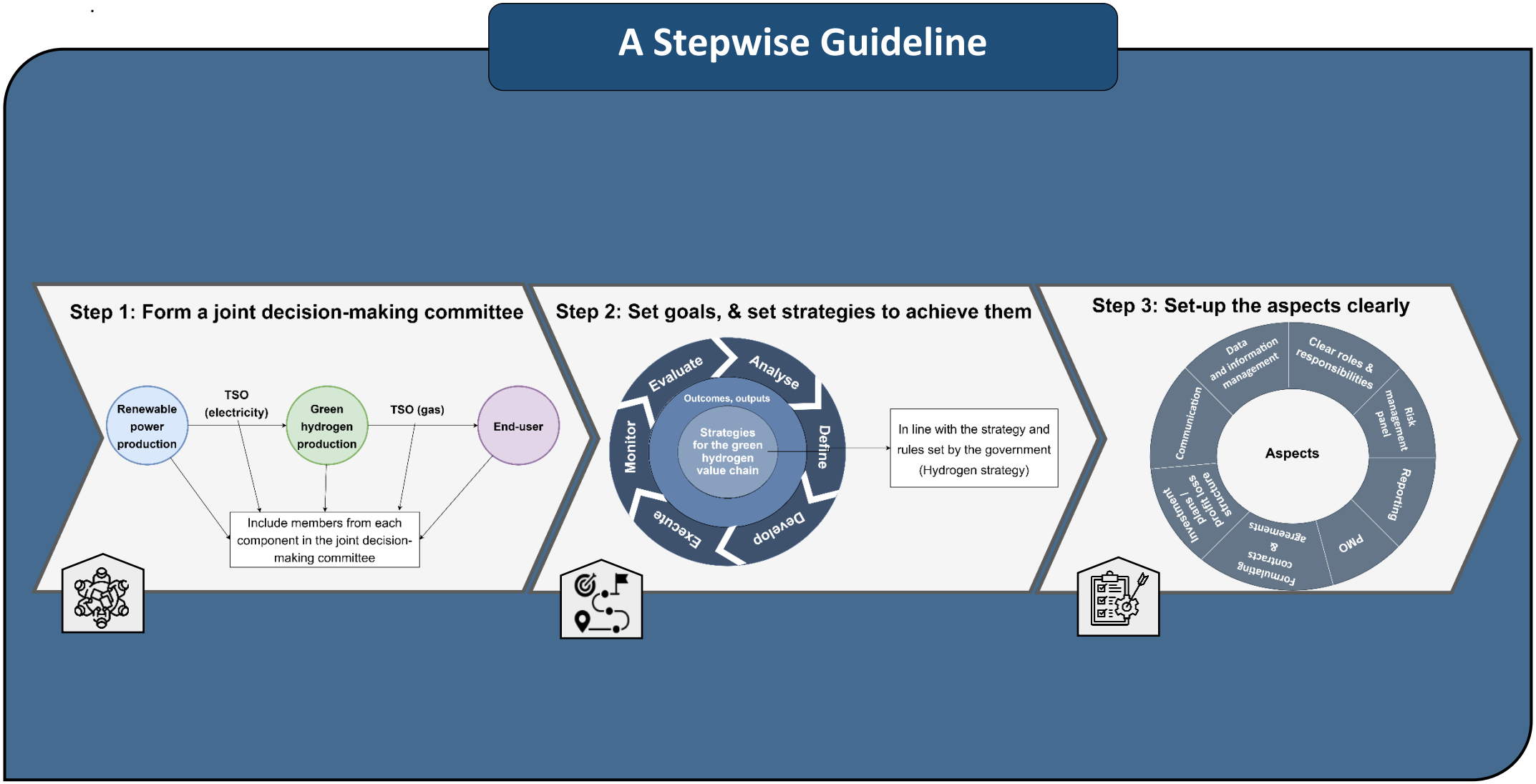

Figure 2: Model

Discussions and conclusions

After conducting the research, the hypothesis was proved to be true. Its application helps to tackle most of the challenges that were occurring. This research not only proves the hypothesis and tackles the challenges but also goes ahead and presents a model on how exactly does the application and set up of programme management work for a green hydrogen value chain. There is significantly less literature available for exploring the challenges in execution of green hydrogen value chains. Also, the application of programme management application on green hydrogen value chains has not been explored. Thus, this makes the research novel and beneficial from the academic and practical perspective. A major contribution to fill the gaps in current literature and industry, was by the use of the methodology of semi-structured interviews. The model helps the actors in the industry to set-up their GH2 value chain giving them a stepwise guideline to incorporate it. Currently, the industry is lagging behind in achieving the goals of the energy transition set in the Netherlands with respect to green hydrogen. This research provides a model for achieving these goals. But there are certain limitations of this study. The value chain is limited to exploring the mentioned components and does not include the supply chain including suppliers and contractors. The model provided does not mention the specifications for construction of the projects and their exact timelines. This research does not mention what subsides need to be given when or what exact policies need to be executed.

Execution of green hydrogen value chain and its projects is the most important factor of getting the GH2 value chain running. This can happen only if the value chain gets connected and running as a whole. Since the energy transition was slowed due to lack of execution of the gh2 value chains, the research provides a holistic view of why it is not happening and how that can be enabled. The research helps in providing a model that can help in accelerating the execution of the gh2 value chains. It is concluded that joining forces and working together in collaboration is essential. Recommendations for practice for the private sector are that: they need to abide by the overarching strategy of the programme, be aware of the new regulations and changes, make clear and flexible contracts, a timeline of actions, conduct workshops and summits. For the public sector it is to introduce taxation and incentivization, tax benefits for taking FID for gh2 value chain, and conduct regular interaction. The semi-public sector needs to provide clarity on infrastructure. Recommendations for the company would be to use the model and grab the opportunity to create value, play a role in this process and provide their expertise. For future it would be interesting to look into the formation of contracts and agreements, apply this model in practice and see its usage in other countries. Also exploring the entire supply chain including contractors and suppliers and researching more on solving the regulation-based challenges on policy level could be done.

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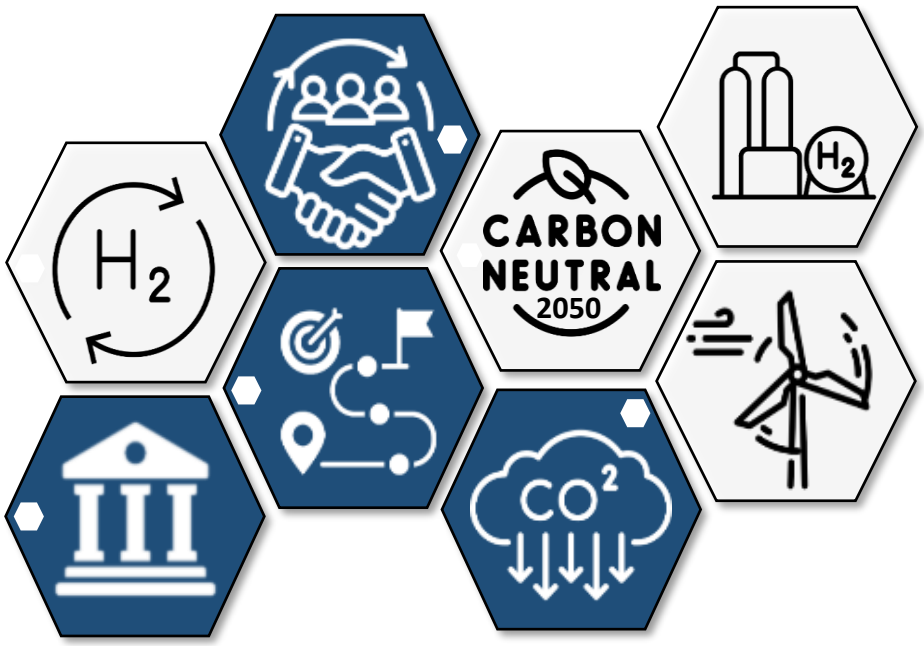
GLOSSARY

GH2	Green Hydrogen
T&T	Turner and Townsend
FID	Financial Investment Decision
TSO	Transmission System Operator



CHAPTER 1: INTRODUCTION

The first chapter introduces the research. First, the current context regarding energy transition and green hydrogen value chain is introduced (1.1). Second, the problem statement is defined (1.2), after which the hypothesis is presented (1.3). Following this, the research objectives (1.4) are given which are translated further into research questions (1.5). Then, the research scope and context (1.6) is defined after which the company description (1.7) is provided. Finally, the methodology (1.8), and the outline of the thesis (1.9) is presented.

1.1. Background

One of the most serious issues the world is facing is climate change which needs urgent attention (Poushte et al., 2022). Carbon dioxide emissions (CO_2 emissions/carbon emissions), i.e. carbon dioxide released into the atmosphere by burning fossil fuels, are the primary driver of global climate change (Ritchie, Roser, & Rosado, 2020). Energy, a basic necessity, is one of the major reasons for this. The energy sector including energy production (e.g. power and heat production, oil and gas extraction and refining, and coal mining) and its use (e.g. transportation, industry, households) is responsible for the highest amount of share of CO_2 emissions in the European Union (EU) (EEA, 2022). Thus, decarbonising the energy sector and exploring alternatives is urgent, and a crucial step to address the climate change (Zachmann et al., 2021). Decarbonisation is a process which contributes to the reduction of CO_2 emissions while simultaneously applying innovative solutions in the energy sectors (e.g. development of energy based on renewable sources) (Bak et al., 2021).

A major step forward in global efforts was marked by The Paris Agreement (Hafner & Tagliapietra, 2020) which aims to avoid climate change by limiting global warming to below 2°C (Paris Agreement, n.d.). Europe is seen at the forefront of the energy transition with the formulation and adoption of the European Green Deal. The most important targets of the deal are a net carbon-neutral European Union by 2050 and a 55% reduction of greenhouse gas emissions compared to 1990 levels by 2030 (Fetting, 2020). According to the European Parliament (2022), carbon neutrality means having a balance between emitting carbon and absorbing carbon from the atmosphere. Fossil fuels are non-renewable resources of energy mainly coal, oil, and natural gas and are the largest source of carbon dioxide. The European Green Deal can be successful when fossil fuel dependency is reduced and eventually phased out but, almost threequarters of the EU's (entire) energy system relies on fossil fuels (Zachmann et al., 2021).

The energy transition concerns the shift from fossil fuels in an effort to reduce CO_2 emissions (IRENA, 2022; Deloitte, 2020). Energy transition is the change in the primary energy supply and the gradual shift from a specific pattern of energy provision to a new state of an energy system (Smil, 2016). The energy transition comes with new approaches to energy production and new alternatives to the current forms of energy used (Apostu, Panait, & Vasile, 2022). The projects that support this transition are called as energy transition projects. As a result of setting the climate goals, various projects and technologies are now coming into existence that focus on reducing carbon emissions. The major types are Renewables (Renewable electricity generation sources such as solar PV, onshore/offshore wind etc.), Hydrogen (Direct use of hydrogen along

with synthetic fuels like ammonia and methanol), Energy conservation and efficiency (increase the energy efficiency of end-use applications), Electrification of end-use sectors, Carbon capture and storage (CCS), etc. (IRENA, 2022). Green Hydrogen (GH2) is one such alternative which will contribute to the reduction of CO_2 emissions to make energy transition happen (Janssen, Jacobs, & Van Oorschot, 2020). Energy transition henceforth in this report is specific to the green hydrogen technology.

The green hydrogen value chain is shown in Figure 3. Green hydrogen is the hydrogen produced by splitting water into hydrogen and oxygen using renewable electricity (Green hydrogen org., n.d.). The Dutch government considers green hydrogen to be essential for achieving the climate goals (Janssen et al., 2020).

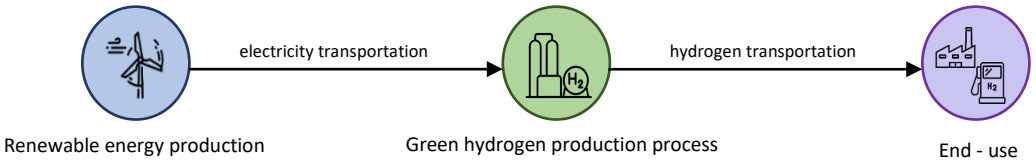


Figure 3: Green hydrogen value chain (own illustration based on Alfa Laval, n.d.)

The Dutch national government focuses on various key aspects in its strategy to realise the opportunities of green hydrogen. The relevant key aspects for this study are (Climate Agreement, 2019):

- to encourage the use of green hydrogen to decarbonise the industry, transportation, and energy sector;
- to regulate the market and increase the demand;
- to establish support schemes and scaling up the project plans;
- reducing current fossil fuel usage;
- and reducing costs (by scaling up the production).

1.2. Problem Description

After the Dutch government set out its hydrogen ambitions in the Dutch Climate Agreement 2019, it released its National Hydrogen Strategy (2020):

- (-2021) Roll out strategy for green hydrogen projects.
- (2022-2025) Develop the demand for green hydrogen and regional infrastructure. Scaling up electrolyser capacity by 2025.
- (2026-2030) Massive scaling up of electrolyser capacity by 2030.

In order to achieve the variety of targets set by the government, the energy transition from conventional fossil fuels into green hydrogen needs to take place and accelerate. Various projects of the components of the value chain are planned and their strategies are laid out.

The execution of some projects in the value chain has started with an ambition to use green hydrogen to decarbonise. However, the energy transition process is seen to be slow (Climatescope, 2022) as not all these projects of the components of green hydrogen value chain are executed. The execution of the green hydrogen value chains is not seen to be happening to keep up with the targets set. In order to scale up and accelerate energy transition to achieve the goals and ambitions mentioned above, the execution of green hydrogen value chains needs to be initiated. This execution needs to speed up (Hazlegreaves, 2021). The problem statement is thus formulated as:

"There is a lack of execution of the projects of the green hydrogen value chains. This is leading to slow energy transition with regards to green hydrogen technology and not meeting the ambitions and goals set."

1.3. Hypothesis

In energy transition, existing structures (regulations, markets etc.) fade away while new ones emerge (Loorbach, 2007). Creating these transitions requires long-term commitment (Atalla, Mills, & McQueen, 2022). This energy transition has led to set long-term ambitious goals of 2030 and 2050 along with formation of strategies for green hydrogen to achieve the goals. An opportunity to help address the problem of execution of green hydrogen value chains, is the use of programme management. Programme management can be defined as the management and coordination of related projects to achieve optimum benefits that cannot be realised if the projects are managed separately (Shehu & Akintoye, 2009; Van Herk et al., 2015). Some literature available have identified relations between transition and programme management. In the Netherlands, the national programme regional energy strategy is being used for energy transition (Nationaal Programma Regionale Energiestrategie, n.d.). Here a programme management was used for aligning policies and for better collaboration between the regional and national government bodies.

The characteristics and theories of programme management can be applied to the energy transition with respect to green hydrogen. This can help in execution of the projects in a green hydrogen value chain. Rijke et al. (2012) has studied the programme management approach for supporting a transition for the flood management in the Netherlands and concluded that programme management can provide a valuable contribution to transitions. However, its use for green hydrogen value chains is not sufficiently explored. Th e hypothesis is formulated as:

"Application of programme management theory to green hydrogen value chains can contribute to the acceleration of their execution."

1.4. Research objectives

In order to trigger the acceleration of energy transition and speed up the execution of the GH2 value chains, it is important to explore the challenges faced in doing so. Literature available on this has barely scratched the surface (Acharya, 2022). The information available through market research, explore the technical aspects, commercial aspects, and roles of public and private sector in the GH2 value chain (IRENA,2022). But a holistic view specific to The Netherlands in terms of the entire green hydrogen value chain is missing. The information available is scattered and the viewpoint of all key actors involved in the value chain is also missing. Moreover, research on how these challenges can be tackled has also been shallow. Also, the application of programme management has been proven useful for transitions, but its use and application for a green hydrogen value chain is missing.

In order to fill the research gaps, the objectives of this research are drafted. To ensure that the green hydrogen value chains are executed, it is important to understand the challenges faced by the key actors in doing so and which potential solutions or opportunities could be used to address the challenges. For this, first the key actors and their roles in The Netherlands need to be identified. Following which the proving of the hypothesis of application of programme management needs to be researched and explored.

The purpose of this research is threefold:

1. To provide insights into the challenges faced in execution of green hydrogen value chain,
2. To explore the application of programme management to a green hydrogen value chain,
3. To develop a model that can incorporate the learnings explored in the research.

1.5. Research questions

To achieve the objectives and address the problem described above, the main research question and sub-research questions are formulated.

Main research question (MRQ):

How can the execution of green hydrogen value chain be accelerated with the use of programme management?

Sub-research questions (SRQ):

SRQ1 What is the green hydrogen value chain and what key actors are involved in it?

SRQ2 What are the challenges faced by the key actors to execute the projects in the green hydrogen value chain and what could be done to potentially overcome them?

SRQ3 What is programme management and its characteristics?

SRQ4 What is the application of programme management for green hydrogen value chains?

SRQ5 How can the learnings be incorporated into a model for accelerating the execution of a green hydrogen value chain?

1.6. Research scope and context

Research scope defines the boundary of the research.

- The energy transition is focused on the green hydrogen technology. (All other alternatives and decarbonising technologies are excluded)
- The research focuses on the green hydrogen value chains in the Netherlands. (International/cross country collaboration and import is excluded)
- The hypothesis focuses on the application programme management. (Other approaches are excluded)
- This research will not look in depth of the technical challenges in the execution of green hydrogen value chains but more towards actor-based challenges.

The context of the research provides a clear idea on the target audience of this research.

- This research and the model are primarily aimed at the key actors involved in a green hydrogen value chain.
- The recommendations provided will be for the private, semi-public, and public sector.
- The company at which the research is conducted (Turner & Townsend), will also be provided with some recommendations.

1.7. Company description

The research is executed in collaboration with Turner & Townsend (T&T). Turner & Townsend is a multinational professional services company specialising in programme management, project management, cost management and consulting across the three main departments - real estate, infrastructure, and natural resources segments (Turner & Townsend, n.d.). This research is conducted within the natural resources department. These purpose, values and services of the company aligned with the research topic. The company has its head office in London, UK. The company specializes in the programme management which provided great support to understand its practical implication. The company provides its services to various of the key actors involved in this research.

1.8. Methodology

A qualitative research approach was used. Qualitative research methods are designed to help researchers understand people, in the contexts of their environment (Palmer & Bolderston, 2006). Qualitative research is an interpretative approach, which attempts to gain insight into the specific meanings and behaviours experienced in a certain situation through the subjective experiences of the participants. The researcher can build concepts, hypotheses, or theories (Palmer & Bolderston, 2006). In order to answer the MRQ, the sub-research questions (SRQs) will be answered with different methodologies. The research began firstly with reading

literature around the topic of interest of energy transition and management theories. Along with literature study, conversations were conducted around this topic with company experts and supervisors. After getting a rough path of the topic and the problem, a more in-depth literature review was conducted (1.8.1). After this, semi-structured interviews (1.8.2) were conducted to obtain information not available through literature. Finally, desk research (1.8.3) is conducted in order to analyse the data and draw solutions. This section provides an overview of the methodologies used in the thesis.

1.8.1. Literature review

The methodology used for exploring the topics theoretically is literature study. For the literature study, focus was given on research available through journals, reports, papers, books, magazines, and other such publications along with websites and articles that provide insights into the topics explored to answer the question. The search engines used for finding the material were Google Scholar, ScienceDirect, Scopus and from general google searches. After identifying the relevant data based on the keywords and their combinations, depending on their availability, the data most relevant to the direction and scope of the study was selected. The literature was organised in Excel in different sheets based on the keywords and the individual sheets included the title of the material, authors, links, main findings, etc. The literature and other material pdfs were also similarly organised in different folders based on the keywords. This helped in systematically reviewing and arranging the articles.

The methodology used for answering the *first sub-research question* is literature study. This question explores the green hydrogen value chains and role of key actors involved. The key words used - energy transition, green hydrogen (value chain), role of different actors in the GH2 value chain, strategies for green hydrogen, GH2 developments/projects in the Netherlands, etc. These keywords formed the bases of the search. For the literature study, focus was given on research available through journals, reports, papers, books, magazines, and other such publications along with websites and articles that provide insights into the topics explored to answer the question. Since the literature available is meagre, grey literature was also considered in addition. Adams et al. (2016) describes grey literature as the diverse and heterogeneous body of material available outside and is not subject to the traditional academic processes. These make positive contributions to the practice. Grey literature provides alternative perspectives and offers new insights. These information pieces are produced from the information pieces produced during actual action (Adams et al., 2016; Oemrawsingh, 2023). The literature chosen was from publishing organisation that were reputed to determine its credibility.

The methodology used for answering the *third sub-research question* is also literature study. Here again the study focuses on the research available from journals, papers, books, etc. This question helps to explore the topic of hypothesis theoretically and to provide the definition, and benefits and characteristics of programme management. The key words used - program(me) management, programme management approach, characteristics, transition, etc. The findings from the literature review provide theoretical insights into the programme management and a theoretical model.

1.8.2. Semi-structured interview

A major part of the data gathering done for this research was done by semi-structured interviews. Semi-structured interviews play an important role in qualitative research to uncover knowledge through interaction, conversations, and subjects from different backgrounds and experiences (Kakilla, 2021). It allows researchers to acquire in-depth information and evidence from the interviewees considering the focus of the research and it also allows flexibility and adaptability for researchers to hold their track (Mashuri et al., 2022). Semi-structured interviews are a popular choice for collecting qualitative data which helps the researcher to cover a set of questions (Magaldi & Berler, 2020). The goal is to gather data as the participant reflects upon his or her own experiences which provides the researcher an in-depth understanding of a particular area of interest. Semi-structured interview provide opportunity to interact and explore through follow-up questions depending on the participant's responses (Magaldi & Berler, 2020). The semi-structured interviews conducted here follow a certain protocol and a set of criteria for selecting the interviewees. A set of questions were formulated to get as much information and practical insights as possible. The interview did not only stick to those questions but had flexibility in the discussion and also ensuring that the interview stays on the main topic. After gathering the data from interviews, it is analysed and presented (later in the report). The interviews were conducted for green hydrogen value chains and for programme management. They are divided and presented depending on the sub-question.

The *second sub-research question* is answered with semi-structured interviews. After gathering the theoretical knowledge available, it is important to understand the challenges faced in execution of the projects. It is important to know the viewpoint and opinions of the key actors playing an important role in the $GH2_{value}$ chain and understand their expectations. The semi-structured interviews were conducted within the company with those with knowledge of green hydrogen value chain, with clients working in the green hydrogen market and with public and semi-public sector. The interviews were conducted to gain additional and empirical data.

The *fourth sub-research question* is answered with semi-structured interviews. In order to get more insights and practical understanding on the application of the programme management (hypothesis), interviews were conducted within the company with the expertise on programme management and also on green hydrogen value chain.

1.8.3. Desk research

After gathering and analysing the data, based on the findings, a model was created. The model links the theoretical findings and the empirical findings. The data analysis and model making is done through desk research. Then the final recommendations are formulated.

The *fifth sub-research question* is answered by conducting a desk study. The inputs from four of the sub-research questions are used and analysed to develop the solution of this research. Here a model is presented.

All of these sub-research questions ultimately answer the main research question.

1.9. Thesis structure

Chapter 2 presents the first part of the research which explores and discusses the findings and results for SRQ 1 and 2. The focus of Chapter 2 is on the green hydrogen value chain and its actors. Chapter 3 focuses on programme management where its theoretical and empirical findings along with results are presented. The chapter presents the findings and results for SRQ 3 and 4. Finally, the solution is developed, and a model is presented in Chapter 4. This is followed by discussion of results in Chapter 5 and finally presenting conclusion along with recommendations in Chapter 6. The structure of the thesis and the methodologies used is shown in Figure 4.

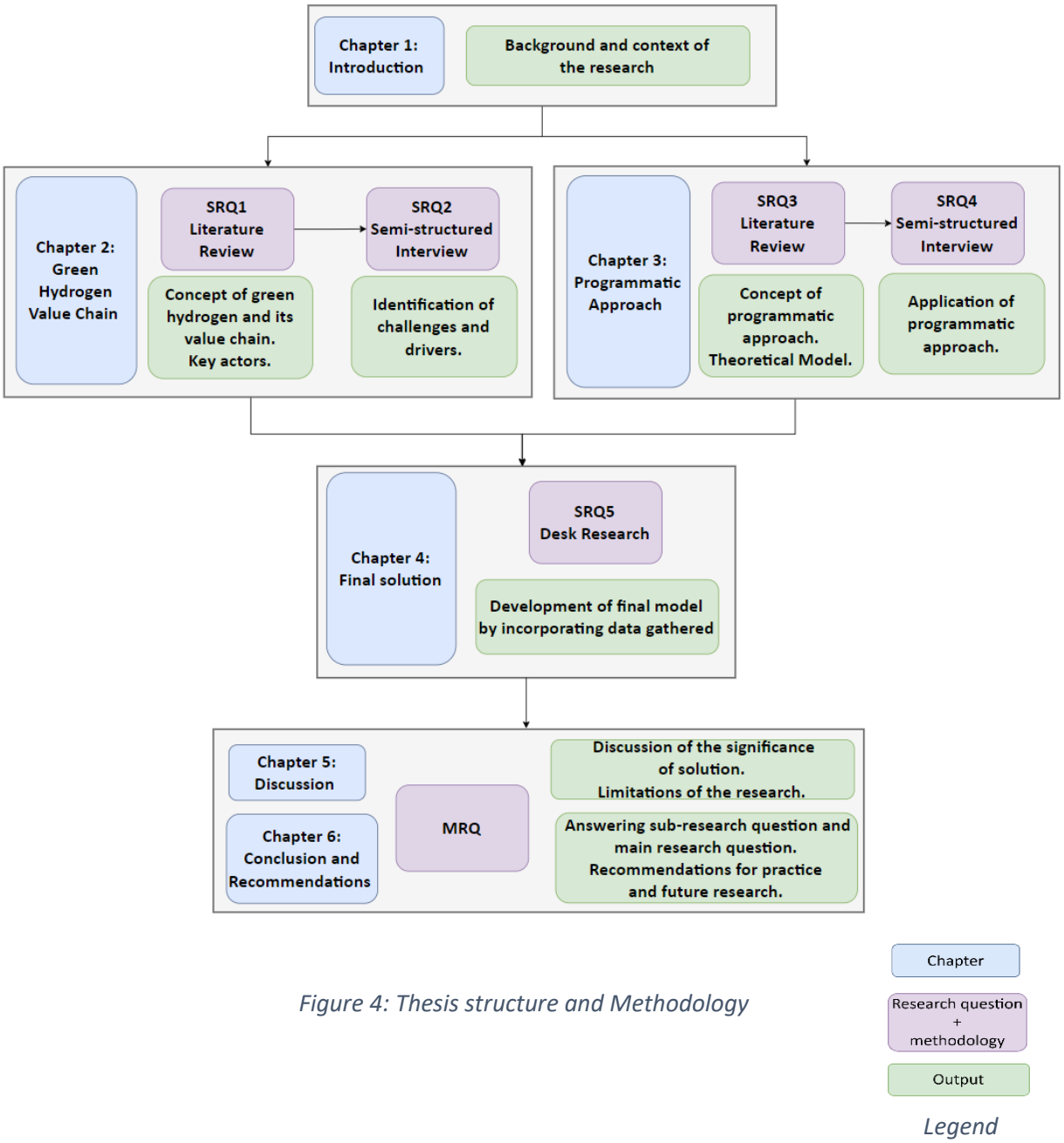
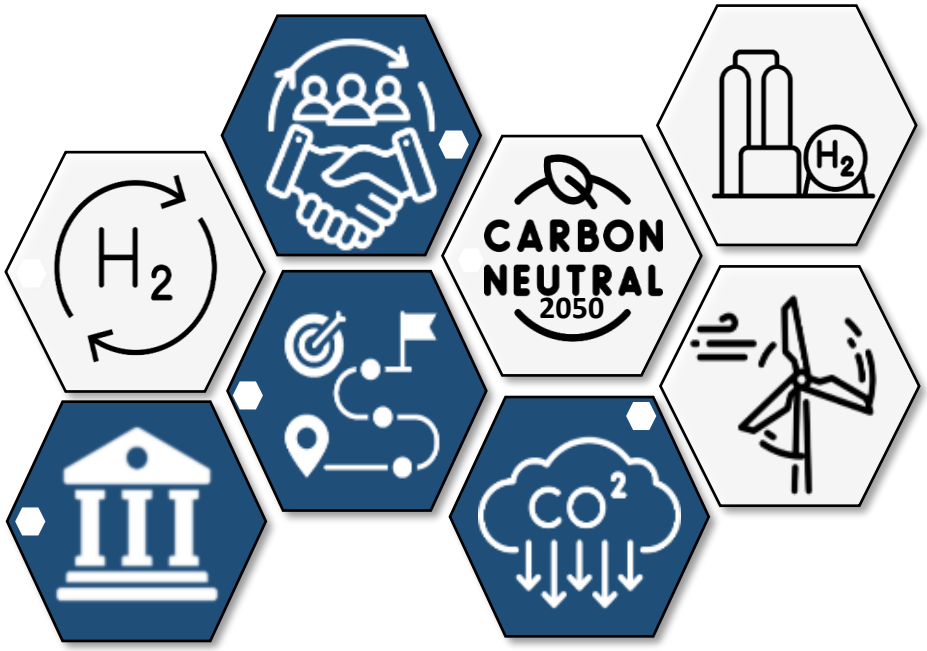


Figure 4: Thesis structure and Methodology



CHAPTER 2: GREEN HYDROGEN VALUE CHAIN

This chapter focuses on exploring the green hydrogen value chain. Here the sub-research questions 1 and 2 will be answered. This chapter first presents the theoretical background (0) followed by the findings and analysis of semi-structured interviews (2.2). Then the chapter summary and next steps are presented (2.3).

2.1. Theoretical Background

This section presents the results of the literature review. The chapter provides an understanding of the green hydrogen (GH2) value chain (2.1.1), where firstly the explanation of the value chain and the current scenario around it is provided. Then the role and importance of the key actors involved in the value chain is discussed (2.1.2). This section answers:

SRQ1 What is the green hydrogen value chain and what key actors are involved in it?

2.1.1. Green hydrogen value chain and the current scenario

Green hydrogen is a term used to describe hydrogen that is produced using renewable energy sources, such as solar, wind, or hydroelectric power. This method of production does not produce carbon dioxide emissions, making it a critical factor to combat climate change (Hydrogen Newsletter, 2023). The hydrogen is produced by splitting water into hydrogen and oxygen using renewable electricity and this process is called electrolysis (World Economic Forum, 2023). A value chain refers to the full cycle of a product or process, including material sourcing, production, and consumption (Walker, 2011). The green hydrogen value chain is composed of multiple components, from its production to its consumption (IRENA, 2021).

Hydrogen can be used in the transportation, industrial and energy sector. Hydrogen is also one of the leading options for storing energy from renewables with hydrogen-based fuels potentially transporting energy from renewables over long distances (World Economic Forum, 2023). For this research, the green hydrogen value chain has been drawn into components (see Figure 3). Storage is also an important aspect of the green hydrogen value chain. This storage can be at the green hydrogen producer's location or the end-user's location or the distributer's location (IRENA, 2021). Since the storage is incorporated by either one of the major components of the chain, it will not be considered a separate component.

As mentioned before, there are various projects of the components of value chain of green hydrogen planned in the Netherlands of offshore wind farms, and various companies), oil and gas companies, transport sector (for fuel), etc with an ambition to use green hydrogen to decarbonise.

For green hydrogen development, the government sets various goals in the Government strategy on Hydrogen in 2020. The ministry responsible for this is the Ministry of Economic Affairs and Climate Policy (Dutch: Ministerie van Economische Zaken en Klimaat). Law states that the central government coordinates large energy projects (of national importance), and these projects fall under the care of the Minister of Economic Affairs and Climate Policy (RVO, n.d.).

The Dutch government has decided to go completely gas-free by 2050, and to halt domestic production by 2030 (RTA, 2021). Coal based power generation is to be phased out around same time. The government has a target to phase out sales of fossil-fuel based vehicles from 2030 (Climate Agreement, 2019). The hydrogen strategy document (2020) states that development of the green hydrogen supply chains is crucial to the Dutch economy for having an affordable, reliable, and sustainable energy which is influenced by government policy.

2.1.2. Key actors involved

After observing the current scenario, it can be seen that the actors TSOs also play a major role. The key actors involved in the GH2 value chain in the Netherlands are: Renewable electricity producers, TSO (electrical), Green hydrogen producers, TSO (gas) and End users/market industry. Transmitting System Operators (TSO) in the Netherlands are semi-public sectors. As stated in the introduction, the Dutch government sets out its ambitions in the Dutch Climate Agreement (2019) and has introduced the Government Strategy on Hydrogen (2020) which sets various aims to be achieved. They are the main policy drafters, and this sets out their major role in this energy transition (MEZK, 2022). All the key actors are influenced by the decisions and policies of the government. In the Netherlands, the polices for green hydrogen are laid out and major responsibility of the Ministry of economic affairs and climate policy. The public sector plays a part in supporting the change in the energy system and must make sure that the energy transition is encouraged (Hazlegreaves, 2021).

The government has started the idea of the GH2 value chain. They are responsible to formulate the regulations (McKinsey, 2023; MEZK, 2022). So, for the private sector to execute the projects, the regulations need to first be in place. Same applies for the semi-public sector to start their projects. Currently, depending on the European frameworks and laws provided, the Dutch government formulates the national regulations and policies (MEZK, 2022). The renewable power production has started building their offshore wind farms. This should be followed by building the electrolysis plants for making the green hydrogen. Parallelly the end-user needs to ensure that provisions are made to incorporate the green hydrogen into their systems (McKinsey, 2023). But all the three components have to be ready around the same time. Not only this, but the TSO also have to finish building their infrastructures and to be able to incorporate the vast number of GH2 value chains that will be coming up. They have already started building their infrastructure, but it has to be completed such that the GH2 value chains can also finish building their chain and get it working (Gasunie & TenneT, 2019). Other chains also need to follow-up this.

Based on Table 1 is formed which shows the roles and responsibilities of each of the key actors.

Table 1: Key actors and their roles

Key actors	Roles
Renewable electricity producer	- Initial part of the chain - They are responsible for producing the power required for electrolysis - Private sector - Here, the renewable electricity produced is from offshore wind farms
TSO (electrical)	- Responsible for transferring electricity from renewable electricity/power producer to green hydrogen producer - Transmission System Operator - Semi-public sector - Power producer and GH2 producer completely dependent on monopoly
Green hydrogen producer	- Main production of GH2 - Perform electrolysis to produce green hydrogen - Run the production plant and responsible for setting it up - Private sector
TSO (Gas)	- Responsible for transferring GH2 produced to end-user - Transmission System Operator - Semi-public sector - GH2 producer and end-user completely dependent – monopoly - Responsible for building the Hydrogen backbone
End users	- End part of the chain - Responsible for using the GH2 produced - Private sector
National Government	- Responsible for drafting policies, rules, regulations, etc - Public sector - All parties mentioned above dependent on the regulations formulated - Not directly a part of the value chain - Influences the value chain externally

The green hydrogen value chain thus formulated for Netherlands is depicted in Figure 5:

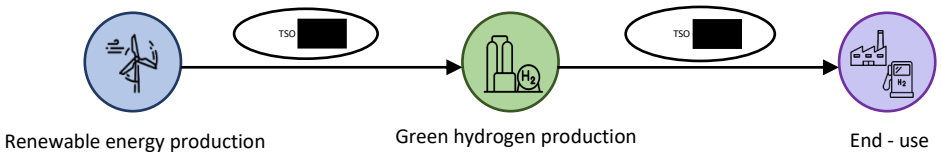


Figure 5: Final Green Hydrogen Value Chain (for Netherlands) (own illustration)

A report by DNV (2022) on Hydrogen Forecast To 2050 gives insights into challenges on global scale. The report mentions that they find that hydrogen is not on track to fulfil its full net zero goal. Their forecast predicts that hydrogen in general will not be able to satisfy the demand. The challenges observed were its availability, cost acceptability, safety, efficiency. The implementation of hydrogen in the energy system needs skills and services all across the whole chain. The report mentions that although there is capital available, it is feared that it still flows towards fossil fuels. Capital will only flow into projects that are profitable. Energy companies and investors need to ensure that projects offer a balance between risk and return. In the early

stages of rolling out technologies, the costs are often high, and actors may not get profits in the short term. But uncertainty in demand and availability exists. Initial investments are indeed high and a big challenge.

Overall,
The literature provides an understanding of the green hydrogen value chain and the roles of key actors involved. It helps to understand what current scenario in the Netherlands is. It was observed that only a few green hydrogen value chains are being executed. Moreover, the components of projects are planned, but individually. The literature available on this topic is scarce. The available literature only mentions the challenges on a global level and in general for hydrogen. There is a need to dive deeper into as to why are the GH2 value chains not executed yet. The information on the challenges specific to the Netherlands and with regards to green hydrogen is not available. The interviews were thus conducted in order to identify the challenges faced and also what their expectations are or what could be done to tackle the challenges.

2.2. Semi-structured interviews

The literature review conducted above provided a theoretical background on the topic of the green hydrogen value chain. But in order to get more insights into the topic and know the perspectives of the key actors, semi-structured interviews were conducted. The goal is to understand what is happening currently in practicality. It is important to know what challenges the key actors are facing in executing their projects and what they want or think will help in overcoming their challenges.

This section presents the selection criteria of the interviewees (2.2.1), and protocol and process of conducting the interviews (2.2.2). After this the data analysis (2.2.3) and findings of challenges (2.2.4) and potential solutions (2.2.5) of them are presented.

This section will answer SRQ2
SRQ2 What are the challenges faced by the key actors to execute the projects in the green hydrogen value chain and what could be done to potentially overcome them?

2.2.1. Interviewee selection and criteria

Based on the theory and literature, the current scenario and key actors were identified. This formed a basis to select the interviewees (see Table 2). Firstly, the experts within Turner & Townsend were contacted. The company has some of the key actors as their clients. The company experts play a role in consulting the key actors by providing their services. They provided a perspective on the GH2 value chain and what they observed and know regarding the challenges and potential solutions. The interviews were done in order to acquire knowledge on the entire value chain. The code letter used to denote the experts within the company is ‘T’. The main criteria were that the interviewees had to be experts in energy transition, possess knowledge on green hydrogen and/or be experts in strategic development plans. The interviews conducted within the company provide a third perspective on the GH2 value chain apart from the private sector’s and government’s perspective.

The next set of interviewees were conducted outside the company. Based on the key actors identified, interviewees working in the green hydrogen business were selected. The code letter used to denote the components outside the company is ‘C’. The criteria for selecting the interviewees were that they should be working in the business development department. This helps understand why the execution of chains is not happening and how this can be done. It provides perspective of each of the components of the green hydrogen value chain.

Apart from the private sector, we have seen that the government and TSOs (semi-public) actors also play a crucial role in the value chain. Hence, they were also interviewed. The code letter used to denote them is ‘G’.

Table 2: Overview of interviewees selected

Interviewee Code	Position
T1	[redacted]
T2	
T3	
T4	
T5	
T6	
T7	
C1	
C2	
C3	
C4	
C5	
C6	
G1	
G2	
G3	
G4	
G5	

2.2.2. Interview protocol

The interviewees T were identified with the help of the company supervisor. They were then contacted through the company email. The interviewees C and G were also identified with the help of the company supervisor. Most of these are clients and some were contacted through LinkedIn and some with help of contacts within the company, whereas some with help of first supervisor. After finalizing the interviewee, the interviewees were contacted and asked for their interest in participating in the interview (by me/company supervisor). If they agreed, they were sent a meeting invite via MS Teams. In some cases, the selected interviewee redirected towards another one as they had more expertise in it. In those cases, as well the criteria mentioned in the above section and the interview protocol was followed.

On the day of the interview, the interviewee was greeted and thanked for their participation after which a small description of the topic and idea of the interview was provided. Then they were asked for their consent to record the meeting and use the material in the thesis. After their consent was provided, the interviews began. To ensure confidentiality, the interviewees will remain anonymous. More details on data handling are mentioned in the DMP (Data Management Plan) and HREC (Human Research Ethics Committee). A set of guiding questions was formulated depending on the interviewee type which were discussed with the first supervisor and company supervisor, and the basis of all of them was revolving around main theme of the thesis. The interviews lasted around 30-40 minutes on an average.

2.2.3. Data analysis

Data analysis is bringing order, structure and meaning to the mass of the data collected (Marshall & Rossman, 1999). After conducting the interviews, the first step was to transcribe the interviews. The transcripts were saved in a systematic manner as 'code letter-number' (e.g., T1). An Excel sheet was created to track the analysis of the interviews. Although MS Teams provided a word document, there were various errors produced as it did not take in the exact words mentioned in the interview. To overcome this problem, increase the accuracy and help in understanding the interview, the interviews were reiterated, and the transcripts were parallelly edited in the word document. After which the texts were shortened to the main content of the interview. After this process, the material was again read and properly analysed. The key findings and important points relevant to the thesis were highlighted in Ms Word. The shortened material again went through an analysis where categories were created by clubbing the common and related challenges. This shows the frequencies of viewpoints of the interviewees based on identification of challenges. Based on the description and meaning/perspective of the interviewees, similar points were combined under one. Example, 'green hydrogen is not cheap' and 'green hydrogen is expensive' were combined under the 'GH2 is expensive'. Similar method was used for potential solutions. Thus overall, the material went through double analysis (see Figure 6) to increase the accuracy of the results.

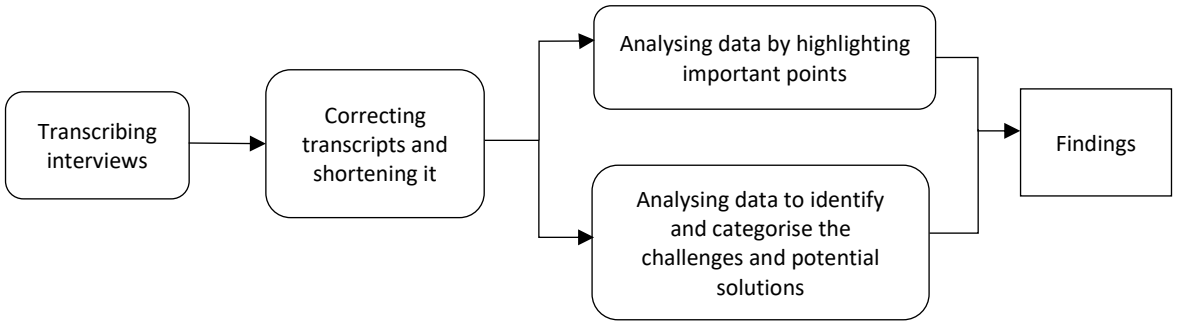


Figure 6: Data analysis (own illustration)

2.2.4. Findings - Challenges

Here the findings from the interviews are presented. The observed findings for challenges following a similar term are categorised below to simplify the understanding, and club the common and related ones. Firstly, the challenges observed were listed down in MS Excel. Later depending on their nature, they were combined under 4 categories: cost, regulation, uncertainties and novelty, and actors. Around 47 challenges were observed from the interviews (Table 3) and their frequency of occurrence (

Figure 7) was checked, depending on which those scoring ≤ 2 are not included in the explanation. The table below presents an overview of the challenges observed and/or faced by the interviewees. The frequency shown in the figure gives an overview of the challenges

which were scored in order to see which challenges are mostly faced in executing the value chains.

Table 3: List of challenges observed from interviews (own illustration)

Category	Challenges	C1	C2	C3	C4	C5	C6	G1	G2	G3	G4	G5	T1	T2	T3	T4	T5	T6	T7
COST	gh2 is expensive	x	x	x	x	x	x	x	x		x	x	x	x		x	x	x	x
	high power price	x	x	x			x	x			x	x					x	x	
	high investment in electrolysers	x	x	x		x		x				x	x				x	x	
	high grid fees				x		x		x								x		
	tariff price					x			x										
	uncertainty and differences in price of gh2			x	x	x	x	x	x		x	x	x	x		x		x	
	efficiency loss							x			x							x	
	h2 from other sources	x	x		x	x		x			x	x	x	x	x			x	x
	fossil fuel usage instead					x		x							x			x	
REGULATION	unclear regulations	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x
	strict regulations	x		x	x	x	x		x										
	funding mechanism	x	x	x		x	x				x	x							
	credibility of gh2	x	x	x	x	x	x	x		x									
	permitting delays	x									x								
UNCERTAINTIES AND NOVELTY	shortage of renewable power	x		x		x									x			x	
	timing issue						x	x	x				x	x				x	
	lack of workforce for infrastructure					x													x
	infrastructure not in place	x				x	x	x	x		x		x	x	x			x	
	first time working with electrolyser	x			x		x				x			x				x	
	running the plant				x		x											x	
	unclear roles				x		x				x								
	technology risk				x	x	x	x				x		x		x	x	x	x
	unknown risks and uncertainties				x	x	x	x	x		x	x	x	x		x	x	x	
	demand supply (market) uncertainty		x	x	x	x	x	x	x		x	x	x	x		x	x	x	x
	surety in price of gh2 / end value of product	x	x	x	x	x	x	x			x	x	x					x	x
	societal acceptance - future risk								x										
	political risk - cabinet resign								x						x				
ACTORS	not taking risks / poor risk allocation							x					x					x	x
	lack of commitment producer	x	x			x	x		x			x	x					x	
	still looking for power supply					x						x							
	reluctant to buy gh2	x					x	x				x		x				x	
	lack of commitment end-user	x	x			x	x	x	x			x	x	x			x	x	
	no connection in the chain	x	x	x	x	x		x	x		x	x		x	x		x		x
	not meeting the ambitions			x	x	x	x	x	x			x	x	x		x	x	x	
	locked in mindset				x													x	
	short term thinking				x	x		x				x	x			x		x	x
	fragmentation	x		x		x	x	x	x	x		x	x		x	x	x	x	
	lack of communication/transparency & understanding						x			x		x		x				x	x
	hesitant to invest and delay in decision making	x		x	x	x	x	x			x	x	x	x		x	x	x	x
	difficult to make profit	x	x		x	x	x	x				x	x			x		x	x
	gh2 price not acceptable	x						x					x						
	just in plans (on paper)	x				x											x		
	individualism			x		x				x		x	x				x	x	
	no surety for producer to sell				x		x		x		x	x	x	x		x	x	x	x
	lacks integration					x	x				x	x	x			x			x
	no clear path/ unstructured				x		x	x	x			x	x	x			x	x	x
	no collaboration				x	x	x											x	x

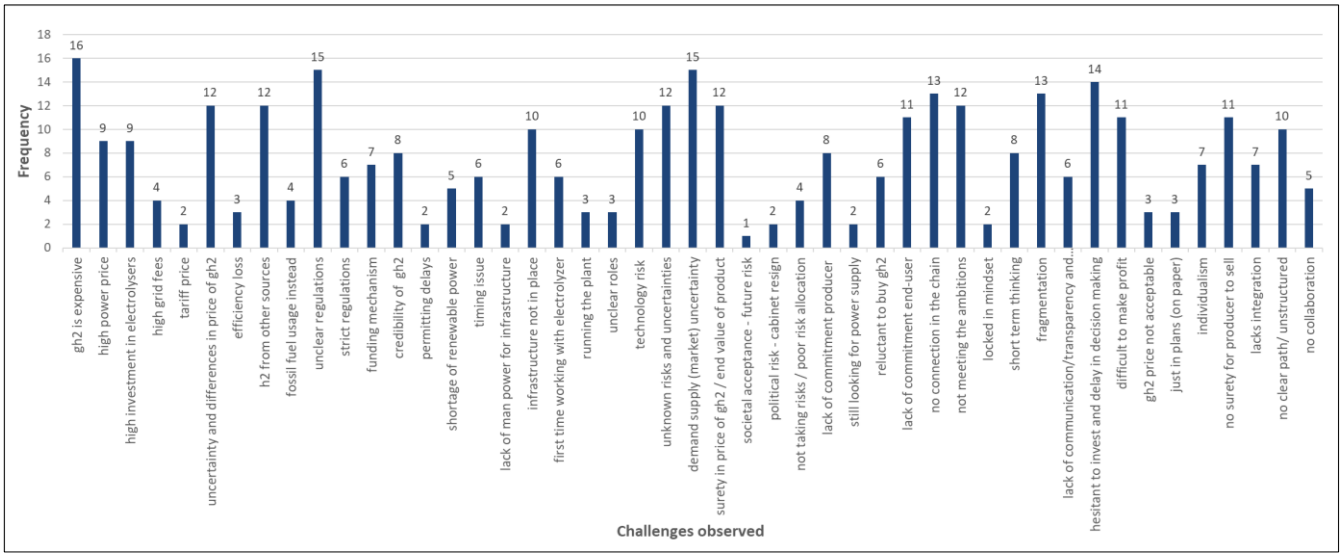


Figure 7: Frequency of challenges observed based on Table 3 (own illustration in MS Excel)

- *Cost*

Almost all interviewees mentioned that high cost of green hydrogen was a challenge. Interviewee C1 says "Green hydrogen is highly priced, and its pricing is non-acceptable by the industry". This is mainly because of high renewable power prices and high investment requirement for electrolysers. The price of renewable power is high because there is a shortage of it. The uncertainty and differences around the prices anticipated of the GH2 creates a risk also for the end-users. Interviewee T1 mentioned "developing the facilities costs a lot of money". Moreover, there is an efficiency loss in transferring of energy and conversion of hydrogen creating a cost gap in the product sent and the product received. Hydrogen obtained from natural gas is cheaper currently than green hydrogen, because of which the producer and end-user favour cheaper options. The end-users are hesitant to buy green hydrogen as they know that its price will drop in the future. Interviewee G1 says that "even though they (end-user) want to use GH2, it's more expensive than gas". This is because there are other (fossil fuel) options still available. Interviewee G4 mentions "a lot of the companies want to keep the natural gas connection, then they can arbitrate between natural gas and hydrogen. So, if price of hydrogen goes too far up, they can go back to natural gas".

- *Regulation and subsidy framework*

Rules and regulations are very strict on the definition of green hydrogen. Interviewee G2 says that "the definition took a long time and is strict". The regulations are complex and puts constraints on GH2 producers. The producers will not move forward until there is complete clarity on regulations. Interviewee C2 mentioned "regulations are still not crystallized making it difficult to commit to something". Regulations are complex and its processes are slow. Interviewee C5 says that "we haven't really landed on the right types of funding /subsidy mechanisms". Also, all the code C interviewees said what is the use or benefit of using green

hydrogen and is there a premium with the sale of the green hydrogen versus a grey or blue hydrogen.

- *Uncertainties and Unfamiliarity/Novelty*

Interviewees mentioned that since green hydrogen is a new technology there is lack of experience leading to lots of unknown risks and uncertainties. Companies have never built electrolysers on this large scale before, and it is challenging to build these. Interviewee C4 mentions that "there is no knowledge about how to exactly run the plant". This is a new market, and don't have a lot of examples and track records. Interviewee C6 mentions that the "hydrogen gas transportation system doesn't exist yet, so there are a lot of unknowns". There is also an uncertainty if the infrastructure by will be ready on time. Also, there is a shortage of renewable power demanding more of it for which plans are laid out. But the major challenge observed is that if all projects would be ready on time. There is market uncertainty as the exact demand is unknown and where is the demand, how much to be produced/supplied is unknown and there is no surety in price of GH2 or end value of product which overall makes it complex for the actors to commit and invest.

- *Actors*

The business case becomes hard because the producers are not sure who wants to buy their hydrogen. The end-users have big plans, but they did not make any firm commitments as they have no view on affordable green hydrogen and the plans just are limited to draft on paper. Thus, it is difficult for producers as well to make firm commitments. Interviewees also mentioned that due to these uncertainties, the actors want to take less risks and tend to put on each-other. Moreover, interviewees mention that currently making profit is also difficult as the costs are high, risks are high, and market is not developed. The producers want to sell GH2 for fixed price and fixed volume for long-term (10-15 years) and although the end-users would like to buy their hydrogen, they don't know how the market will develop. Since the GH2 is expensive, the end-users want to buy only for small volumes and for short term (1-2 years).

Almost all interviewees mentioned that the chains are currently not connected and lacks integration. The collaboration within parties is missing. There is fragmentation not only in projects of the components of the value chain but also in the policies. Interviewee T4 mentions that "Renewable energy has policy and regulation. Water has policy and regulation. Electrolysis has policy and regulation, and so do the end-user." Interviewee G1 mentions "You cannot go in isolation and need to look at all the elements. It has to be at the same time and have to connect". The chain is dependent on each of its component, but another challenge observed was that the actors lack communication and transparency, and also understanding each-others needs and requirements. Due to the fragmentation, the actors work in isolations and execute their own plans and there is a delay in commitments. Interviewee G3 says that "many of these projects executed by the industry are fragmented and each of them makes its own plans with its own timing".

No (or very few) single company can do the whole chain alone. Interviewee G4 says “the parties are hesitant to go ahead and make the FID (financial investment decision)” as it requires really high initial investment. Interviewee C3 mentions that “not everyone can have the whole chain and make the investment decision”. It was also observed that there is no clear path. Interviewee G5 mentions that “without a clear path how will this scale up work and how would that contribute to cost reduction”. Interviewees mention that due to fragmentation and no connection in the chain, achieving the overarching ambitions/goals is difficult. This is also because the actors are focusing on short term gain instead for long term growth. The different actors have their own business models, and this creates more individualism and fragmentation. Interviewee C3 says that “the ambition is set from the governmental level. But if you calculate the ambition and look at the pipeline of projects that are actually in development, it's not going to be realized because all those projects, are deeply underwater”.

2.2.5. Findings – Potential Solutions

Here the findings from the interviews are presented regarding the potential solutions. After gaining insights into the challenges, the interviewees view on potential solutions and expectations to help overcome the challenges was analysed. The observed findings for views on potential solutions following a similar term are categorised below to simplify the understanding, and club the related ones. Firstly, the potential solutions observed were listed down in MS Excel. Based on their nature they were combined under 3 categories: cost & demand, government, and actors & integration. Around 25 were identified from the interviews

Table 4: List of potential solutions observed from interviews (own illustration)

Category	Potential solutions	C1	C2	C3	C4	C5	C6	G1	G2	G3	G4	G5	T1	T2	T3	T4	T5	T6	T7
COST & DEMAND	clear gh2 prices	x			x	x	x		x		x	x				x			
	higher cost of other alternatives	x	x								x	x	x						x
	percent of gh2 to be used	x				x	x		x		x	x							x
	stimulate demand and supply			x	x						x	x	x				x	x	
	scale up	x	x								x	x	x	x				x	
	high demand and its clarity	x			x		x		x		x	x	x			x	x	x	
GOVERNMENT (REGULATION & SUBSIDIES)	clear and eased regulations	x			x	x	x	x	x		x	x	x	x		x	x	x	x
	premium for gh2		x		x		x	x				x	x						
	forced by regulations to go green	x				x													
	subsidies for electrolyser	x		x	x	x	x		x		x	x	x			x	x	x	x
	clear subsidy framework	x			x	x			x		x	x	x	x			x		x
	subsidies for gh2	x	x	x	x	x	x	x			x	x	x			x	x		x
	pay losses in conversion						x	x			x								
	willingness to invest	x		x	x										x				
	reduce permitting time										x								
ACTORS & INTEGRATION	value chain infrastructure in time	x			x	x	x	x	x										
	commitment from all actors		x			x	x					x			x		x	x	x
	integration and connection	x		x	x	x	x	x	x		x	x	x	x	x	x	x	x	x
	learning and knowledge sharing		x	x	x		x	x	x					x			x	x	
	flexibility and being transparent				x		x							x			x		x
	ensure goals are met		x	x					x										
	creative risk sharing			x	x								x					x	x
	communication				x	x	x	x	x	x	x		x					x	x
	trust and confidence					x		x	x				x					x	x
	long term thinking					x		x								x		x	

(see Table 4) and their frequency of occurrence (Figure 8) was checked to understand what actors considered more important. Here as well, those scoring ≤ 2 are not included in the explanation. The table below presents what the interviewees mentioned as potential solutions or expectations to overcome the challenges. The figure following it provides an overview of the potential solutions that were mentioned the most.

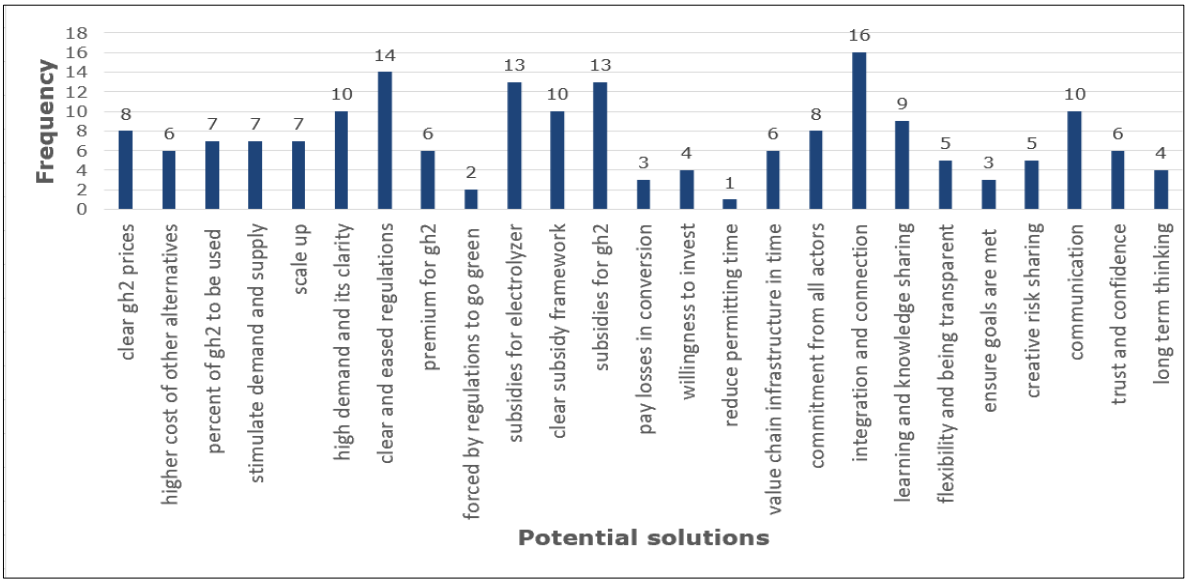


Figure 8: Frequency of potential solutions observed based on Table 4 (own illustration in MS Excel)

- *Cost and demand*

Cost is a major potential solution addressed by the interviewees. Having clarity and surety of the price of GH2 motivates the producers to produce and end-users to buy it. Having certainty reduces the risk. But along with certainty, the prices need to be affordable. For this, overall risks in the chain need to be reduced or distributed. Since, other options like grey hydrogen and fossil fuels are still a viable option, increasing their costs can drive the market to invest more in green hydrogen. The end value of the product for end-user is dependent right from the cost of electricity (renewable power). Hence cost drives the entire chain. Cost and demand are interdependent. The more the demand, the more is the production which plays a major role in bringing down the costs. Interviewee G5 mentioned that “of course the price is important, but also need the quantity and percentage guarantee”.

Demand certainty drives the producers to produce GH2 and that increases the demand of renewable energy. This increases the certainty that there is a demand which motivates the actors to invest. Thus, stimulating the supply and demand is important. This will drive the market towards the execution of the value chains. Interviewee C3 says “there needs to be stimulation on demand and supply side to get the market running”. Scaling up helps the green hydrogen economy grow and contributes to lower the costs. Interviewee T6 mentions that

"the customers will always look for the most cost-effective solution for their energy needs. The cheapest solution in transportation is currently diesel. To change that we need to make hydrogen as cheap, available and flexible as diesel".

- *Government (Regulation and subsidies)*

Government plays a major role in driving the execution of the value chain. Almost all interviewees mentioned their role with regards to regulations and subsidies. Regulation clarity and easing was observed to be a potential solution for all actors across the chain. With more clarity and less strictness, especially around the definition of GH2, reduces the regulatory risks for the actors in the value chain. The clarity and ease motivate them to go ahead and invest. Interviewee T5 says that "need clarity in policy. If the policy is correct, then you attract private investment". Interviewee C4 mentions that "taxation, public infrastructure, things to stimulate it and provide clarity is of course with the government." Government also plays a major role in providing subsidies. Clear subsidy framework/funding mechanisms was also observed to be a potential solution that it can help with the cost uncertainty. Providing subsidies for electrolysers and for cost gap due to losses motivates the private sector to invest in electrolysers (for producers) and to buy GH2 (for end user) as it reduces their uncertainty around the cost investment. Interviewee C5 mentions that "clear subsidy framework really helps for the supply and profits of offshore wind". There should be clear regulations or subsidies for using green hydrogen.

A premium given for GH2 will drive the actors to invest and use hydrogen which is green. Interviewee C6 mentions that "there needs to be clarity whether green hydrogen will receive credits (if they go to a refinery). When do you receive these credits? So, it's a sort of subsidy and another revenue stream". Not only introducing a premium for using GH2 motivates the actors to invest but it also makes the deals look more attractive. Since there is loss in electrons and in transferring and converting the hydrogen, taking away the risk of this loss will also drive the parties to execute their projects. Interviewee T6 mentions, "the industry needs more incentives to motivate customers to switch to hydrogen and needs to bite where companies are procrastinating. Government needs to create an environment where customers are willing to enter into long term offtake agreements". It was observed that most of the actors are willing to support green hydrogen, as long as they see return on their investment which is observed as a potential solution. Interviewees mention that if their loss is compensated with subsidies, they will still be willing. Since consumers cannot afford the GH2 price, here is where subsidies play an important role.

- *Actor and integration*

Commitment is one of the most important aspects observed. Ultimately, committing to the roles, timelines and responsibilities will decide the execution of the value chains. The interviewees mentioned, aligning the timelines is very important i.e., all the components of the chain should be ready at the same time. Even the infrastructure from TSOs needs to be ready on time. This will motivate the actors to start aligning their projects with the

infrastructure. There should be clarity on the infrastructure. The value chain will start running only if the entire chain is completely built. Thus, ensuring that the goals set by the components are met will drive the other actors to invest. Interviewee T5 says that “need certainty that the bit before and the bit after will happen”. Having trust and confidence in the value chain drives the investment decisions. The actors need to provide confidence to each other that they will invest in the chain. Not only is providing confidence enough, but also having confidence and trusting each other is important.

Having a long-term thinking and vision was also noted to be a potential solution. It is not just about the short-term gains, but the long-term benefits to achieve. The actors want a long-term surety and commitment from each-other. Interviewee C5 mentioned that “You have to build a network, industry, and infrastructure. There's a long-term stability, a long-term promise needed”.

Interviewees mentioned that flexibility and being transparent is important as this technology is new, the risks involved are high. Flexibility is needed around the definition of green hydrogen from the government to the private sector. Interviewee T5 mentions that “the flexibility has to be there. The governments have to provide support and is actually only way you're going to get flexibility, especially for the first movers”. This becomes an important potential solution in motivating the actors (private) to be less hesitant to invest. Sharing and distributing risks also drives the investment towards the execution of the value chains. Interviewee C4 mentions that “I think you just need to be very creative in your risk sharing”. Sharing or reducing or properly distributing risks helps the actors to gain clarity on their costs and investments to some degree.

Communication was observed to be an important aspect needed as a potential solution. It was seen to be essential between actors in a chain and, between government and the private parties. Communicating the needs and interests, even risk bearing capacities, helps provide clarity. Sharing knowledge and learning from experiences also serves as a potential solution for actors to learn from each other. Interviewee G1 mentions that “You make optimal use of the knowledge”. Interviewee C2 says that “we can make it cheaper by learning from things that are still coming”.

All interviewees mentioned that the chain needs to be connected and integrated. Collaboration between actors is very important while doing so. Interviewee C1 mentioned that “Outsourcing the electricity from 3rd party will not always give the best deal. To provide power not only to the grid when prices are high, but there are of course times that power prices are low because there's an excess of power. Commercially it is very attractive to be able to utilize your own power because you have control over the pricing based on price of renewable power. More the integration stronger is the business case”.

2.3. Chapter Summary and Next Steps

The aim of this chapter was to provide insights into the topic of green hydrogen value chain. This was done by conducting literature review and semi-structured interviews to address sub-research questions 1 and 2 respectively.

First the concept of green hydrogen value chain is explored. Green hydrogen is a term used to describe hydrogen that is produced using renewable energy sources, such as solar, wind, or hydroelectric power. The green hydrogen value chain is composed of multiple components, from its production to its consumption. This hydrogen produced with 100% use of renewable energy is green hydrogen. It was observed that there are various projects of the components of value chain of green hydrogen planned in the Netherlands. This literature provides insights into the planned projects in the Netherlands. Through literature it was observed that the TSOs play an important role in the Netherlands. The document of Hydrogen strategy was drafted by the government which mentions the goals to achieve in order to have the energy transition from fossil fuels to green hydrogen. The Dutch government has decided to go completely gas-free by 2050, and to halt domestic production by 2030. The ministry responsible for this was observed to be the Ministry of Economic Affairs and Climate Policy. Figure 3 shows the final GH2 value chain. The key actors involved in the GH2 value chain in the Netherlands were found as: Renewable electricity producers, Green hydrogen producers, TSOs (electrical and gas) and End users/market industry. And Dutch government played and external role by drafting the policies. All the key actors are influenced by the decisions and policies of the government. The private sectors responsibility is to make the investment and execute the projects in the GH2 value chain. The semi-public sector i.e., the TSOs are responsible for providing and building the electricity and gas infrastructure. The literature provides an understanding of the green hydrogen value chain and the roles of key actors involved. It helps to understand what current scenario in the Netherlands is. The available literature only mentions the challenges on a global level and in general for hydrogen. But the literature available challenges in executing GH2 value chains in the Netherlands is scarce.

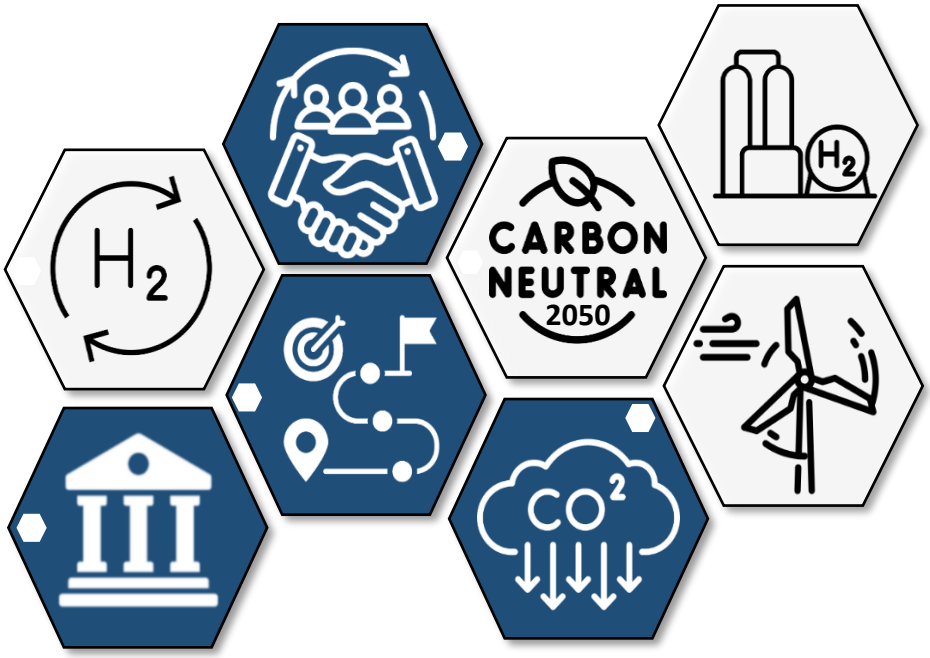
In order to explore the challenges faced in execution of the GH2 value chain, semi-structured interviews were conducted. The goal was to gain insights from the key actors about their challenges and also their view on potential solutions or their expectations. Apart from gaining the insights from the private sector and the (semi-)public sector, the experts from the company were also interviewed. The challenges observed were categorised based on the relativeness and similarity. The first category is cost. The high cost of green hydrogen poses a significant challenge, with issues related to expensive GH2, high power prices, and a high investment in electrolysers. Other cost-related challenges include high grid fees, uncertainties in GH2 pricing, and efficiency losses during energy transfer and conversion. The second one is regulation. Challenges related to unclear regulations, strict regulatory frameworks, and uncertainties surrounding funding mechanisms and the credibility of GH2 create hinderance in the execution of projects. The third category is uncertainties and novelty. Challenges from uncertainties and novelty include a shortage of renewable power, timing issues, lack of workforce for infrastructure development, and infrastructure not being in place. The fourth and final

category is actors. Challenges here involve a lack of commitment, fragmentation, communication/transparency issues, and hesitation in investment and decision-making. There is a lack of firm commitments, and the actors want less risks. There is no long-term vision. The biggest hurdle is that the projects in the value chain are not connected and are isolated. The collaboration within parties is also missing.

After exploring the challenges, the interviewees also mentioned their view on potential solutions and their expectations. These were also categorised similarly. The first category is cost and demand. Clarity in GH2 prices and higher costs for alternative options can address challenges. Stimulating demand and supply, scaling up operations, and creating high demand with clarity are essential for overcoming cost-related issues. The government (regulation and subsidies is the second category. Clear and eased regulations, introducing a premium for GH2, and providing subsidies for electrolysers and GH2 can incentivize private sector involvement. Reducing permitting time and creating a willingness to invest are crucial for overcoming regulatory challenges. The last category actors and integration. Achieving commitment from all actors, ensuring integration and connection of the value chain, finishing the infrastructure on time, and promoting learning and knowledge sharing are essential. Flexibility, transparency, and creative risk-sharing mechanisms can help address the uncertainties. Trust, confidence, and long-term thinking are also important factors required.

To conclude this chapter, we have first studied the green hydrogen value chain, its key actors and current scenario around it. It was observed that the entire value chain depends on one another. But the projects in this value chain are not getting executed. Then the challenges as to why these projects in the value chain are not getting executed are explored along with insights on the potential solutions to tackle them.

In the next chapter, the hypothesis will be addressed. The topic of programme management is explored through literature study and semi-structured interviews. The aim of the next chapter is to understand the programme management in theory and then explore its application on GH2 value chain.



CHAPTER 3: PROGRAMME MANAGEMENT

This chapter focuses on programme management. Here sub-research questions 3 and 4 will be answered. This chapter first presents a theoretical background (3.1) on the topic and then provides insights into the empirical findings obtained through semi-structured interviews (3.2). At the end, chapter summary and next steps is presented (**Error! Reference source not found.**).

3.1. Theoretical Background

This section focuses on exploring the theoretical understanding of the hypothesis proposed for this thesis. In order to do so, programme management theories were studied after which its characteristics and benefits were identified. Firstly, defining the concept in context of this research is important (3.1.1). The topic is then explored in detail (3.1.2). After analysing the theory of the topic, the characteristics and benefits are organised and presented (3.1.3). The list of characteristics and benefits of this approach were used to make a theoretical model.

SRQ3 What is programme management and its characteristics?

3.1.1. Definition

Programme management can be defined as the management and coordination of related projects to achieve optimum benefits that cannot be realised if the projects are managed separately (Shehu & Akintoye, 2009; Van Herk et al., 2015). It is a mechanism to coordinate a group of related projects (Rijke et al., 2012). A newly developed view stems from strategic planning and attributes a broader role to programme management in terms of value creation for the organisations involved beyond the performance of projects. Overall, programme management is used to create group of projects, implement strategies, and generate change (Rijke et al., 2014).

3.1.2. Exploring the programme management in theory

Pellegrinelli (2002) mentions that programmes, by grouping, directing, and initiating new projects, set the context for projects. Programmes can help translate them into concrete objectives for projects. Programme management has been used as a way of creating the necessary structure within which projects can operate to achieve the set objectives (Pellegrinelli, 1997). Programme management provides the alignment, coordination, execution, and overall management of a number of related construction projects to provide benefits that would not have been available if they were to be managed individually (Shehu & Akintoye, 2008). Vosman (2020) considers programme management to be an approach to overcome fragmentation and can be adopted as a mean in order to manage, align and coordinate projects to achieve the strategic goals more efficiently and effectively. It is an integrated approach that can facilitate effective delivery of projects (Shehu & Akintoye 2009).

The complex and no-one-knows-what-happens-next state requires more effective and integrated management of projects (Shehu & Akintoye 2009). Programmes have become a preferred vehicle for making required complex changes (Pellegrinelli, 2002). Programme management acts as a tool to coordinate, plan, and accomplish complex changes and it serves as a potential way forward. Management of a group of related and dependent projects tends to be less risky than that of individual projects (Shehu & Akintoye, 2008). The need for programme management has increased where issues and problems arise which multiple projects face, e.g., the lack of coordination and overall control (Shehu & Akintoye 2009). The paper also states that a programme has the characteristic of central control of projects. Programme management operates for strategies to create synergies between projects and deliver set of benefits through coordination of a series of interconnected projects. The approach takes a broader organisational scope and considers the interactions between projects (Rijke et al., 2014).

Programme management is one of the main tools for achieving project integration (Lutt, 2021) and helps ensure strategic alignment (Thiry, 2004). The approach helps in gathering/arranging of projects and resources to achieve the desired strategic benefits (Pellegrinelli, 2002). Programme management is an integrated approach that co-ordinates, aligns, allocates the resources. It also plans, executes, and manages related projects to achieve benefits (Shehu & Akintoye, 2008). Programme management provides an overarching organizing framework for delivering specific objectives/goals, and usually spans over longer duration. It consists of the management of multiple and related deliveries. The focus here lies on achieving the strategic objectives (Lutt, 2021). Programmes help in establishing a bridge between projects and the strategic goals of an organisation. A number of authors have pointed out that organisational leaders have used programmes to implement or support the realisation of the organisational strategy (Pellegrinelli, 2002). Programme management helps in the application of knowledge, skills, and principles to a programme to achieve the overarching objectives, obtain benefits and control which is not available when managing projects individually (Vosman, 2020). It is basically the coordinated management of a group of related projects to achieve the programme's strategic benefits and objectives. The integration and management of a group of related projects is done with the intention of achieving the organisational strategic benefits that would not be realised if the projects were managed independently (Shehu & Akintoye 2009).

As per Van Buuren, Buijs, & Teisman (2010), every project of public interest delivers a specific objective of development. The high-quality development does not result from a single project or even from a multitude of isolated projects. It depends on the aggregated effects of a set of projects and on the mutual impact of these projects. In this approach, the processes of project development as well as the potential interrelatedness between projects and actions are managed with the goal of accomplishing integral development and convert separate procedures into more joint decision-making processes. Programme management promotes collaborative way of working, supports long-term collaboration, and helps build stronger relations (De Groot et al., 2022). Programmes enable effective and integrated learning along with knowledge transfer between project teams and the parent organisation (De Groot et al.,

2022). They have also become common vehicles for innovation (Lehtonen & Martinsuo, 2008; De Groot et al., 2022).

Pellegrinelli (1997) mentions that the approach helps in management of projects in isolation, where project integration in terms of both development and deliverables is crucial. The author has described the advantages of programme management, which include - greater visibility of projects to senior management; programme reporting can better address strategic performance by tracking progress relative to competitors; resources can be more easily reallocated to critical projects even after funds have been assigned to individual projects; and it helps in better planning and coordination of projects.

As mentioned before, the application of programme management on green hydrogen value chain available in literature is scarce. But a paper by Rijke et al. (2012) mentions the application for a transition. The approach was proved to be useful for the transition. In their paper, Rijke et al. (2012) have explored the relativeness of programme management and transition. The paper further states that use of programme management contributed to the success of the transition of 'Room for River'. The top aspects observed in application and contribution of programme management to transition are:

- Programme office was created to monitor the project teams and the performance
- Creating a front office for engagement of project teams and the monitors (i.e., those monitoring the programme)
- The programme office assisted project teams in discussions with decision makers at national, regional, and local levels and in bringing together various stakeholders
- It created network of actor to communicate informally and learn collaboratively
- 6-month update reports on progress were prepared
- An independent panel of risk management experts was created
- Programme management helped confirm decisions and adjust the formed arrangements

3.1.3. Identification of characteristics and benefits

After reading the literature, the data was analysed to identify the various characteristics and benefits observed. The literature study conducted above (3.1.2) is presented in

Table 5 in order to get an organised view.

Process of identification:

First a list of the characteristics and benefits was created and then the connected and similar ones were translated and compiled into 8 key elements. The 8 key elements form the Theoretical model shown in Figure 9.

Table 5: Characteristics and benefits of programme management developed based on literature review (own illustration)

Characteristics and benefits	Key elements
grouping, directing, and initiating new projects set the context for projects	Grouping / integrating, directing, and initiating projects
tools for achieving project integration	
creating necessary framework within which projects can operate to achieve the set objectives	
provides the alignment, coordination, execution, and overall management	
overcome fragmentation	
integrated approach can streamline the effective delivery of projects	
helps ensure strategic alignment	Creating and aligning objectives with the strategic and long-term goals and achieving them
to manage, align and coordinate projects to achieve the strategic and long-term goals more efficiently and effectively	
central control of projects	
provides an overarching organizing framework for delivering specific objectives/goals	
spans over longer duration	
management of multiple, related deliveries and the focus lies on achieving strategic objectives	
coordinated management of a group of related projects to achieve programme's strategic benefits	
achieving the organisational strategic goals and benefits	
bridge between projects and the strategic goals of an organisation	
implement or support the realisation of the organisational strategy	
promotes collaborative way of working	Long-term collaboration
supports long-term collaboration	
helps build stronger relations	
interrelatedness between projects and actions are managed with the goal of accomplishing integral development	Coordination and interaction between projects
create synergies between projects and deliver set of benefits through coordination of a series of interconnected projects	
helps in better planning and coordination of projects	
considers the interactions between projects	
greater visibility of projects to senior management	
reporting can better address strategic performance by tracking progress relatively	
promotes collaborative way of working and helps build stronger relations	Allocating and sharing of resources
helps in the application of knowledge, and principles to a programme to achieve the overarching objectives, obtain benefits and control	
helps to convert separate procedures into more joint decision-making processes	Joint decision-making process
enable effective and integrated learning and knowledge transfer	

integrated, structured framework that co-ordinates, aligns, allocates the resources, plans, executes and manages related project	Cross-project learning and knowledge sharing
gathering/arranging of projects and resources to achieve the desired strategic benefits	
resources easily reallocated to critical projects	
preferred vehicle for making the complex changes required and for innovation	Make and achieve complex changes
tool to coordinate, plan and accomplish complex changes	

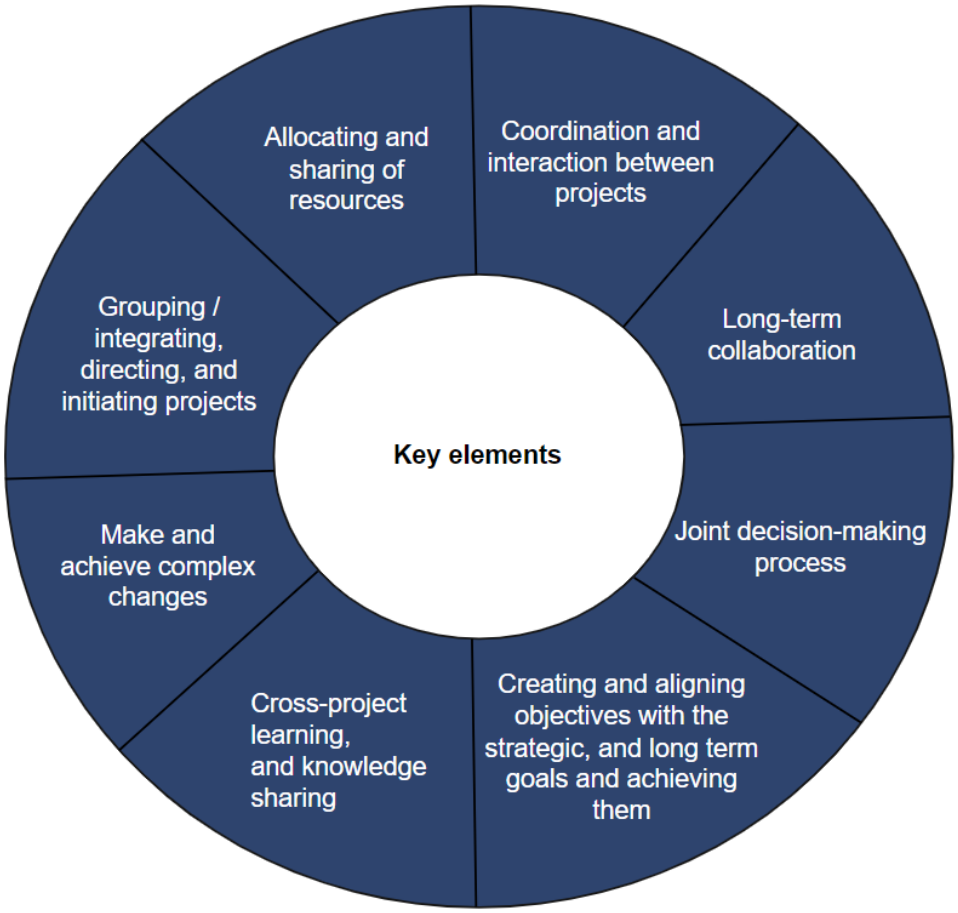


Figure 9: Theoretical model – programme management (own illustration derived from Table 5)

Overall,
The literature provides an understanding on the topic of programme management. It provides the definition in context of this research. Then the characteristics and benefits in the literature were identified. These were further turned into key elements which could possibly be used to tackle and address the challenges with respect to the potential solutions. The literature also suggests that programme management was useful for a successful transition. But the literature has not provided its application to the green hydrogen value and its energy transition. The interviews are thus conducted to explore the missing.

3.2. Semi-structured Interviews

The literature review conducted provided a theoretical background on the topic of programme management. But the literature does not provide information of the application of the programme management on green hydrogen value chain (because of which it is a hypothesis). In order to get more insights into the topic and explore it empirically, interviews were conducted. The goal is to understand what is currently happening in practicality and what learnings could be understood to further use them to apply to green hydrogen value chain.

This section presents the selection criteria of the interviewees (3.2.1), protocol and process of conducting the interviews (3.2.2). After this the data analysis (3.2.3) and the findings around the benefits (3.2.4), application and set-up (3.2.5) are presented. This section answers SRQ4.

SRQ4 What is the application of programme management for green hydrogen value chains?

3.2.1. Interviewee selection and criteria

The experts within the company were contacted. This was done in order to acquire knowledge on programme management. The main criteria were that the interviewees had to be experts in programme management and energy transition field, and also possess knowledge on green hydrogen. The code letter used to denote programme management experts within company is 'P' (see Table 6).

Table 6: Overview of interviewees selected

Interviewee Code	Position	Company
P1	Director, Programme Advisory	Turner & Townsend
P2	Director, Programme Advisory	Turner & Townsend
P3	Director, Head of Programme Advisory	Turner & Townsend
P4	Senior sustainability consultant	Turner & Townsend
P5	Global Programme Advisory Lead, Clean Energy & Decarbonisation	Turner & Townsend

3.2.2. Interview protocol

The interviewees were identified with the help of the company supervisor. They were then contacted through the company email. After finalizing the interviewees, they were contacted and asked for their interest in participating in the interview (by me/company supervisor). If they agreed, they were sent a meeting invite via MS Teams. Similar protocol as mentioned in sub-section 2.2.2 was followed. The interviews also lasted around 30 - 40 minutes on an average.

3.2.3. Data analysis

After conducting the interviews, the first step was to transcribe the interviews. The transcripts were saved in a systematic manner as 'code letter-number' (e.g., P1). Here as well a similar process as mentioned in sub-section 2.2.3. The analysis done here is shown below in Figure 10.

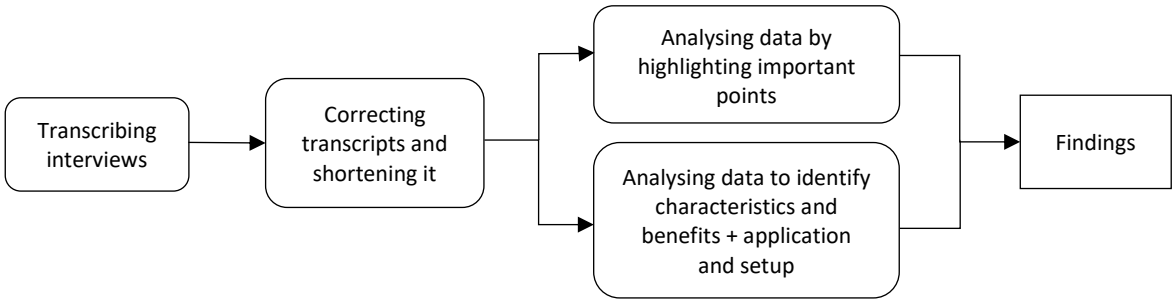


Figure 10: Data analysis (own illustration)

3.2.4. Findings – Characteristics and Benefits

In this section, the findings from the interviews regarding the characteristics and benefits are presented. Here, the theoretical model (see Figure 9) was compared with the empirical findings of the interviews. First the interviewees were asked for their definition and understanding of programme management. The definitions observed were similar to that used and defined in this research. Then throughout the interview, characteristics and benefits of programme management were observed. All of the 8 key elements were mentioned by all the interviewees. In addition to those 8, 3 more were identified, which are explained below:

- Giving / having joint feedbacks for all projects in programme

In a programme when all projects are integrated, providing feedback and recommendations is possible. Interviewee P3 says that "usually what tends to happen is that you will uncover some strengths, you uncover challenges, etc. What we tend to do is give recommendations for how they can change the challenge to a positive outcome".

- Programme management helps bring different skill sets required together

A programme not only brings parties and projects under one roof, but also brings different skills and capabilities together. Interviewee P2 mentions that "the challenges (of the new technologies like green hydrogen) that we face in are more are of increasing complexity and require a broader suite of skills and capabilities to be able to overcome those challenges. You need all the engineers, designers, chemists, financers, etc. You need all of these people to come together and to be able to work the challenge".

- The approach helps judge investment plans across the programme

Depending on the different situations (e.g. change in policies) occurring in a programme, the parties in a programme can judge their investment plans and plan accordingly. Interviewee P3

mentions that “the other companies can create their strategies and develop their approaches (in a programme). From that point onwards also judge their investment planning accordingly”.

Based on the above identified elements, the theoretical model is updated (in yellow). Two of them were merged with existing 8 elements giving total of 9 elements (Figure 11).

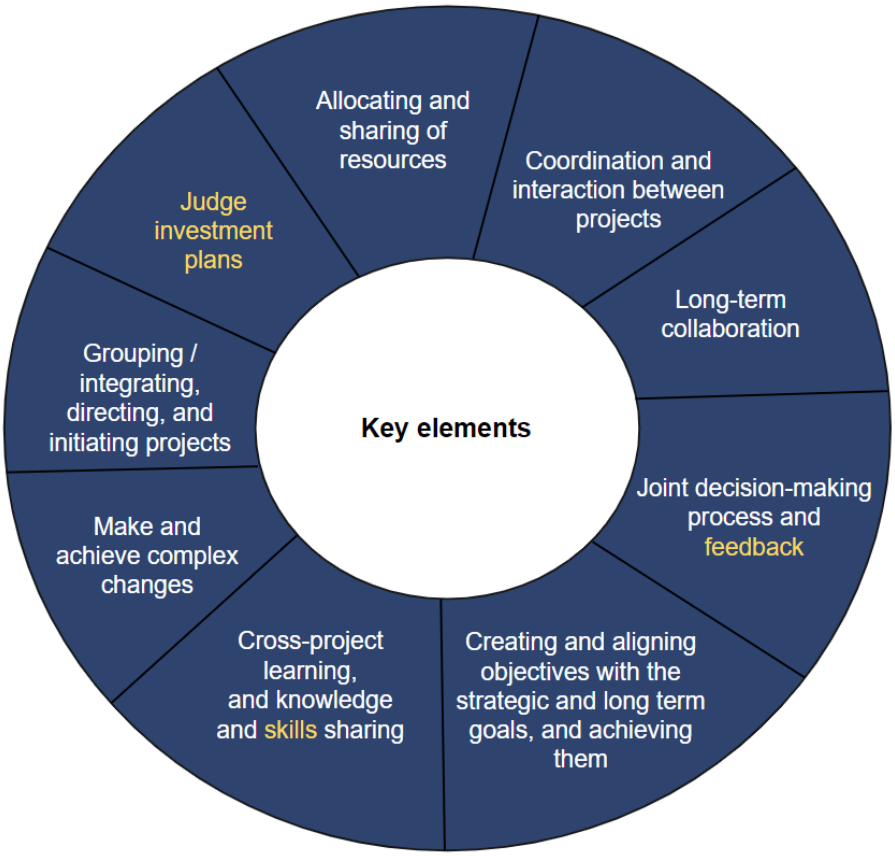


Figure 11: Updated theoretical model – programme management (own illustration)

3.2.5. Findings – Programme management and Green hydrogen value chain

Here the findings regarding the application of programme management to green hydrogen value chain is presented. The interviewees had knowledge on both programme management and green hydrogen value chain which provided insights into the two topics. The interviews aimed at understanding and exploring- how the interviewees viewed the application of programme management on the GH2 value chain, and how the programmes were generally set-up.

All interviewees mentioned that integration in the GH2 value chain was important. There needs to be investment and it needs to happen all across the value chain. It was observed that almost all interviewees emphasised that confidence in the value chain was very important. Since the technology needs high investments, enabling this investment is essential. It is important to have certainty on where the renewable power is coming from, where it is going and similarly for green hydrogen.

Programme management helps the actors develop the commercial models which then drives the behaviour of the investment. Interviewee P1 mentions that “Programme is a mixture of projects, so programme management is effectively taking an approach across it rather than just executing project by project”. The interviewees mentioned that it provides a longer term and more strategic view across a number of projects, instead of each actor developing strategies for execution in isolation. Interviewee P1 mentions “If you have a long-term certainty of pipeline of investment in a programme rather than project by project and a member of chain can have more confidence to invest”. A programme can help provide better coordination to the value chain. Integration was emphasised to be essential in executing the projects in the green hydrogen value chain Interviewee P5 mentions “Integrated full value chain is absolutely essential and a full value chain for green hydrogen is quite complex and fragmented. One doesn't function without the other. The whole value chain must be viable technically, economically, commercially, for the full”.

At the moment costs for hydrogen is very high and implementation of projects is very uncertain. The end-user needs certainty as to when could they start receiving the green hydrogen. Interviewee P2 mentions that “Programme management helps to structure priorities. How do we deal with the things which are first the most important, and then step that down and depending on your lens on what's most important. Anything that's complex being structured and organized helps.” Programme management provides a structure about how to go about it. Interviewee P4 mentions “Programme management will help coordinate the chain and the demand all together”. There is no guarantee around the availability of GH2 and there is uncertainty around what the final price could be. With a programme management there is a clear understanding of what the outcome is for e.g., a clear understanding of the price for GH2 could be the outcome. After knowing what the outcome is, focusing on the executing the actions to achieve the outcome needs to follow Interviewee P4 mentions that “programme is a group of projects which are similar in nature or are trying to achieve a similar outcome. You have a greater understanding of the benefits, and you have a great understanding of the problems you need to solve”.

Programme management would take account of complexity and seek to reduce it as far as possible, and this will improve the deliverability of the projects in the value chain. Complexities are of policy and regulation, technology, legal, economics and commercial. When situations change or policies change, in a programme, it is easier to adopt and absorb it and manage the complexity. The industry needs clear policy and regulation with appropriate market signals for long term investments to help proceed with the value chain. These can help reduce the risk and complexity/uncertainties which will give confidence to the stakeholders. Interviewee P3 mentions that “it is a very structured approach, and also for increasing your efficiency and vision. It is important to know what the programme's vision is”. The approach can help in

providing alignment on what you want to achieve as a programme and then how each individual component will contribute to that. The interviewees mention that strategy alignment at the beginning is very important because it sets the tone of what needs to be achieved as a whole. It also gives direction on how each component would support that. Interviewee P3 further mentions, “What about the cost? What about the risks that you want to manage? What about the changes that might occur? So, for that you need integration and that means all of those different components that schedule, the cost of risk would need to come together”. Considering the integration of cost management and risk management is needed to support the value chain moving forward. The interviewees mentioned that unless there is an integrated view on what has to be achieved from a vision perspective, it's difficult to ensure that the outcomes will be successful. Interviewee T2 mentioned that “in a programme having an overarching goal is required”.

The tracking of the milestones is also essential. Understanding the risks, and how big of a risk is it in comparison with the other is essential. Along with this acknowledging and recognizing that and being able to put resources towards that is required. The expectations need to be set out very clearly at the start, along with a very strong vision. Throughout the programme there should be consistent updating about risks. All of which is possible within a program. Interviewee T3 mentions that “running it as a programme means that you can assess all of the individual components that will make up the challenge and do so in a way where you have one method of reporting, the progress of each area and also know the interdependencies and how any limitation, faults, hold ups, any problems or benefits can impact each one and having that high level view in a programme management means you’re able to spot problems and have a more coherent and consistent approach. For a programme, you have to have something you're working towards”. Interviewee T4 says “programme management is a set of projects or initiatives which have a shared strategic goal”.

There is a need of a programme management because moving green hydrogen forward is not straightforward. There are policy and regulatory issues. Programme management is important because if you think about it, you have to get policy regulation, funding, and a business model. There needs to be supply and demand, and infrastructure. Everything has to come together; hence you need a programme management as they all need to be aligned”. Programme management works where managing the interfaces and interactions between the projects, along with the complex set of relationships, is essential. While working on separate projects in a programme where the components need to communicate what they need from each other, and they are interested in knowing what they need from each other. If one of the projects falls behind it is possible to see what the impact would be on the other projects. A wider view of the overall chain helps walk to the set strategic goal. Programme management should focus on the strategies and benefits to take level cost and ensure that the inputs and outputs from each project come together. Better communication is needed to convey certain aspects to each component in order to maintain the configuration of the strategic objective. Programme management best way of letting the (people in the) GH2 value chain know if something has changed and able to evaluate it. So having a platform is important. It helps in observing and analysing the economics across each project of the programme. Programme management becomes valuable for new energy as the policy and regulation is very immature, look across all

of them and go well. Delivering the chain as a programme by grouping the components will ensure to get it running.

Set-up

Once the expected outcomes and outputs are known, then there is a need to ensure that a common mission, vision, and commitment is demonstrated across the whole programme and that all are heading in the same direction. Then it is managing the interfaces between different projects and ensuring their alignment. Interviewee P5 says, “understand the scope of your overall programme, what are its components, what is the ultimate objective of your programme and what are the outputs and outcomes. What are the outputs you expect from each project and what are the outcomes you expect for the whole programme”. The components need to contribute to the common outcome(s), and that has to be managed. Firstly, define at programme level what the objectives and outcomes are, along with the scope of the programme. Once it is done on a programme level then that has to be done at each project level and then consistently manage how all are performing in relation to the defined programme. The success of the value chain depends on the all the components and thus need to collaborate well. The approach also helps with long-term collaboration. Having a clear long-term vision and mission is needed. Then monitoring the long-term realization of that mission and vision needs to happen.

In the programme management it is possible to also discover where the entire GH2 value chain is, and where the projects are at and how everything is progressing. Interviewee P3 says, “First there needs to be a vision which focuses on what the chain wants for e.g., the net-zero aims”. Current status revolves around three things the people side, which usually covers people, culture, and behaviours. The second one is processes and their ways of working i.e., how is it internally set up from a procedural standpoint. Then it is the digital, data and systems. Interviewee P3 mentions the importance of the above. The organizational scanning through the whole business, can have levels that can focus on a single project or the programme. Then it is possible to identify what is working well and what’s not. If there are challenges uncovered, then assessing and working on solving them is possible. While setting the programme, having a roadmap/timeline of actions is needed as it gives everyone grounding on what needs to be achieved and which steps need to be taken to achieve it.

3.3. Chapter Summary and Next Steps

This chapter discusses the programme management, addressing sub-research questions 3 and 4. It begins by providing a theoretical background on programme management and programme management theories. The programme management is defined as the management and coordination of related projects to achieve optimum benefits that cannot be realized if managed separately. It creates a structure within which projects operate to achieve objectives, facilitating effective delivery of projects and strategic goals. The chapter presents characteristics and benefits of the programme management, such as steering of projects, strategic alignment, collaboration, and integration.

Programme management involves managing a group of related projects to achieve strategic benefits. It provides an overarching framework, aligns objectives, and ensures strategic benefits are realized. Programme management facilitates project integration, and allocation of resources. It overcomes fragmentation, ensures strategic alignment, and promotes collaborative working. The chapter organizes characteristics and benefits into 8 key elements, forming a theoretical model. These elements include integrating, directing, and initiating projects; strategic alignment; joint decision-making processes; cross-project learning and knowledge sharing; allocating and sharing resources; making and achieving complex changes; creating and aligning objectives; and long-term collaboration.

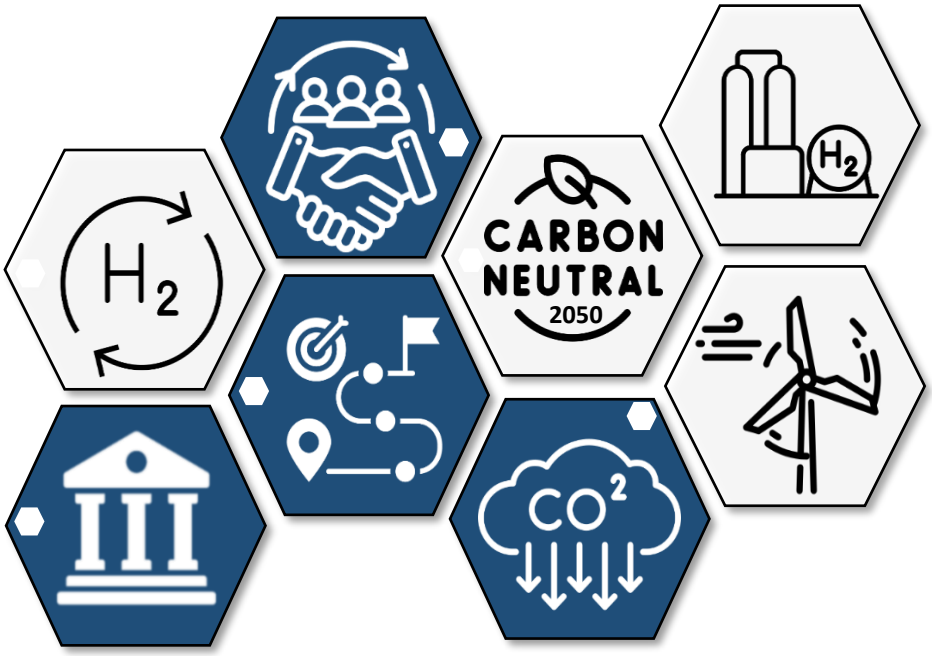
Interviews were conducted with experts in programme management and energy transition, specifically focusing on green hydrogen value chains. Semi-structured interviews were conducted with selected experts. The interviews, lasting 30-40 minutes, covered topics related to programme management and its application in the green hydrogen value chain. Interview data was transcribed, analysed, and organized systematically. The analysis involved comparing theoretical models with empirical findings, identifying characteristics, benefits, and application in the green hydrogen value chain.

The interviews confirmed the 8 key elements identified in the theoretical model. Additionally, three more elements were identified: joint feedback for all projects, bringing different skill sets together, and judging investment plans across the programme. These elements were integrated into an updated theoretical model consisting of 9 key elements. Programme management is vital for the green hydrogen value chain due to its complexity. Integration, coordination, and strategic alignment across projects are crucial. The approach helps structure priorities, manage complexities, and align investments. Clear communication, monitoring of milestones, and consistent risk assessment are essential. Setting up the program requires defining objectives, ensuring alignment, managing interfaces, and maintaining a long-term vision. Moreover, most importantly collaborating and forming a joint committee is important.

Apart from gaining insights on the relation and application of programme management on green hydrogen value chains, insights on setting-up of the programme were also obtained. The interviewees mentioned the importance of considering the goals, outcomes and outputs formulated in the programme. It is important to align the strategies in a programme. Organizational scanning through the whole value chain is enabled with the use of programme management.

To conclude, we have first studied the concept of programme management in theory. This provided with the definition used for this research. Then the benefits and characteristics found in literature were clubbed to form the theoretical model. This theoretical model was then compared with the interviews where additional 3 inputs were added. This model provides benefits which when realized could help in tackling the challenges and address the potential solution. Then further in the interviews, the application and set-up of programme with relation to green hydrogen was analysed and presented.

In the next chapter, the theoretical model will be used in order to see how the challenges can be tackled and address the potential solutions. Then a stepwise guideline is presented in a form of model. All the findings until now are collectively taken as inputs while entering into the next chapter. The next chapter presents the development of final solution.



CHAPTER 4: FINAL SOLUTION

Based on the theoretical and empirical data gathered, analysed, and observed, a model is presented. This chapter focuses on developing the solution by first locating the challenges faced in the green hydrogen value chain. After addressing the challenges, the application of programme management addressing the potential solution and thereby tackling challenges is shown (4.1). Based on the data gathered, and available within the company, a stepwise guideline/roadmap is presented to setup the programme for the value chain (4.2). After this the chapter summary and next steps are presented (4.3). This chapter answers SRQ5.

SRQ5 How can the learnings be incorporated into a model for accelerating the execution of a green hydrogen value chain?

4.1. Locating and tackling challenges

The main problem is that the execution of the GH2 value chain is not taking place and firstly that needs to happen in order to accelerate the energy transition to achieve the goals (of 2030 and 2050) set by the Dutch government. Figure 12 shows who exactly is facing the challenges. After that with the use of potential solution and key elements of programme management the challenges will be tackled. The challenges are located based on the findings obtained through interviews.

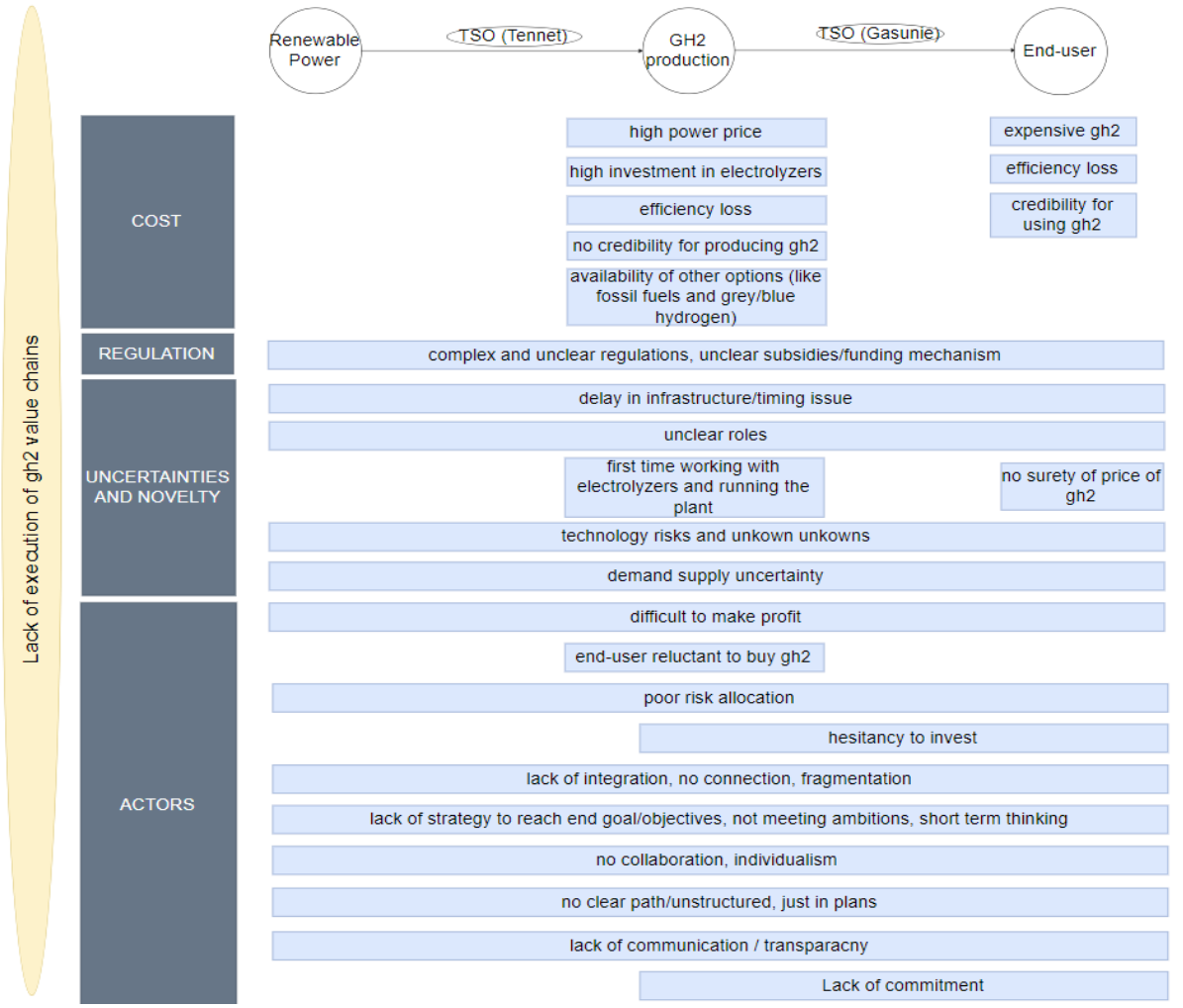


Figure 12: Locating the challenges in GH2 value chain based on sub-section 2.2.4 (own illustration)

Green hydrogen is highly expensive, especially for the end-users. Because of which the end-user is reluctant to buy green hydrogen and instead prefers buying other cheap options like fossil fuels. The reason for high cost of green hydrogen is high renewable power prices and high investment needed for electrolysers. These challenges are mainly faces by the green hydrogen producer. The price for the product they produce thus goes high making green hydrogen expensive. This creates uncertainty around price of green hydrogen creating a risk. There is an efficiency loss in transferring of energy/electricity and conversion of hydrogen. This creates a gap in the product sent and received. These are majorly seen as problems faced by the green hydrogen producer and the end user. Hydrogen obtained from natural gas is cheaper than green hydrogen, because of which the producer and end-user tend prefer other options over green hydrogen. The end-users are afraid to commit to green hydrogen as they know that its price will drop in the future. The availability of other options creates a challenge for the green hydrogen producer, as they do not know if someone will buy their product and how much amount should they produce. Thus, having a clarity and surety on the cost of the green hydrogen and renewable power can increase the certainty of the production and purchase of the product helping in reducing the risks around it. The best way to tackle the challenge around the availability of other options is to increase the demand of green hydrogen and by increasing the prices of fossil fuels by the government. As an when the demand increases, actors will be motivated to execute their chain leading to scale up in production. This can in future, reduce the costs significantly. Having a view of the entire and being able to discuss the challenges can provide more certainty to all the actors in the value chain. Programme management provides key element of long-term collaboration. This gives the actors in the value a long-term assurance and certainty. Given the possibility of high risks and fluctuations in costs, the key element of sharing knowledge can provide the actors with information and help address their hesitancy.

Rules and regulations being strict is challenge for all actors in the value chain. The strictness in as to when the hydrogen is considered green makes it difficult for the producer to sell it as green ad for the end user to buy it at high price and still not get considered at green. Unclear regulations hold back the all the actors as they do not know what their next step should be. Without clear regulations it is not possible for the value chain to invest and execute projects. Regulations are complex and its processes are slow. Also, if the end users use green hydrogen, there is no advantage for them or premium for it when used. These challenges can mainly be addressed by the government. When the actors have a clear idea on the regulations and subsidy framework, the actors will have more surety in taking action. A possibility could be providing subsidies for electrolysers and for cost gap due to losses, this provides more confidence to both green hydrogen producer and end-user. A premium given for GH2 could possibly also motivate the actors to use and develop this technology. It is important for the actors to have advantage of using green hydrogen over other alternatives available. Programme management provides the opportunity for the value chain. When the actors come together under a programme, possibly influencing the government decisions could be possible.

A new technology has many high uncertainties and unknown risks in the start. The green hydrogen producers have not used electrolysers before and nor have many vendors build it in large quantity before. The experience for using this technology is less. Since all actors depend

on each other, there is uncertainty for the all the actors if the other one has its infrastructure ready on time or not. The producers do not have a clarity on the demand. And the buyers do not have certainty if there will be enough supply. This overall creates a lot of uncertainties and risks. With the help of programme management, these challenges can be addressed. When the actors come together and work, uncertainties surrounding each other reduces. The key element of coordination and interaction between projects can improve the collaboration between actors. They can interact on the risks and challenges each actor is facing. Sharing and better allocation of risks can provide more surety and confidence to the actors. With high risks and high uncertainness there is a need to make and adapt complex changes which is also helped by with a key element in the programme management. The key element of sharing information and knowledge with each other can also help the actors.

Given the uncertainties, the actors are hesitant to commit to their roles and make the investment. Thus, it is difficult for producers as well to make firm commitments. The actors are hesitant to take the risks. The green hydrogen producers want to sell GH2 for fixed price and fixed volume for long-term, but the end-user is not willing to commit for long term given the risks and uncertainties. There is fragmentation observed throughout the value chain and the collaboration is seen to be missing. All the actors face the challenges of lack of clear path to achieve the goals they have set. To tackle these challenges, commitment from all actors is required. When the actors show their commitments, this motives the and provides assurance to the others. Alignment on strategies, gaols and completion timeline can help reduce the uncertainties around the infrastructure readiness. Since all components are dependant on each other, finishing the projects almost at the same time is required. Hence alignment can help with that. Programme management has key element like creating and aligning objectives with the strategic and long-term goals along with long-term collaboration that help with setting long term plans. Providing long term vision and alignment is essential to gate the value chain running. Sharing or reducing or properly distributing risks helps the actors to gain clarity on their costs and investments to some degree. Communication can solve challenges where the interaction between the value chain is needed. There is one value chain in execution currently. The insights obtained from them were that since the chain is connected, most of the challenges face by isolated actors like price surety are not face by them. Programme management key elements of grouping / integrating, directing, and initiating projects provides an opportunity to connect the components of the GH2 value chain. The key elements provide helps in jointly making decisions and providing feedback to one another in a joint value chain. The mentioned connected chain in execution has an overview of the entire chain it possible to judge the investment plans and the flow of the capital. Programme management with the benefit of it key element helps in applying this.

But the first step to enable all of the solutions and key elements is integrating and connecting the value chain. All actors need to collaborate and work together as value chain as a whole. Setting up of this programme is required to realize the benefits of the programme management mentioned as key elements. The set-up of the programme for the green hydrogen value chain will be presented in the next section.

4.2. Final model development

After observing the challenges mentioned under actors and the potential solution under actors and integration the hypothesis was proved to be useful. Since the chain was not observed to be connected and integrated, an approach to help that was required. Programme management provides that. Under a programme, having an overview of the entire chain is possible. After conducting the interviews, the application of it on the green hydrogen value was presented in section 3.2.5. The section also presented on how the set-up of programme should be done. The findings from those interviews provided insights on important points to be considered while applying the approach to the chain and the benefits to be realized while doing so.

Keeping in mind the findings from all interviews conducted during the research and the theories observed, a stepwise guideline to set-up the programme for a green hydrogen value chain is modelled (see Figure 16).

i. The first step is setting up a joint decision-making committee (see Figure 13). In this committee, members from each of the three component of the green hydrogen value chain needs to be included. This committee will be responsible for taking the decisions of the entire value chain. The committee will be responsible for monitoring the entire value chain. This will help with steering of the programme. It includes 1 member from each of the component of the GH2 value chain. Roles: responsible for monitoring the entire chain, staying updated with the rules and regulations set by government, ensuring their application in the chain, staying in contact with the TSOs. In order to form this collaboration, the parties could form a joint venture. Most of the interviewees mentioned that collaboration is essential in the green hydrogen value chain. The interviewees mentioned that the chain connection/integration along with collaboration helps the actors in networking together, sharing information, work together and put together resources. Interviewee T1 and T6 mention the use of JV (joint venture) in a hydrogen value chain project and a tool for collaboration respectively. Another suggestion to enable collaboration could be tendering of projects together. Interviewee G5 mentioned that a combination of tendering windfarm and hydrogen together by actors (components) in the chain can bring the actors together. Through interviews, another help in this programme was identified which was project 13 approach. Project 13 approach supports integration. The interviewee mentioned that this approach can be used to support a programme. The Project 13 model takes an enterprise approach in that it brings together owners, design firms, contractors, advisors, and suppliers. This group is placed into a governance model that provides an environment where they can work in a more integrated approach and more collaboratively (Project13, n.d.).

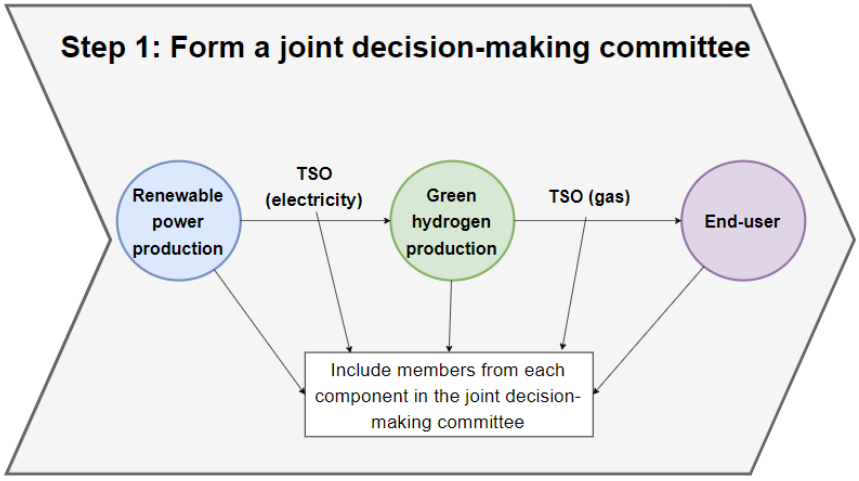


Figure 13: Model - Step 1

ii. The next step is to set the goals, outcomes, outputs, and the strategies to achieve them (see Figure 14). These will be set-up for what needs to be done to get the chain execution running. To set these a process is formulated:

- Evaluate: Initially understanding and evaluating the requirements of the components of the GH2 value chain needs to take place. The current principles, values and aims need to be assessed, laid out and discussed in terms of the people and the processes. It is also important here to discuss what parties need from each other.

- Analyse: After evaluating the current requirements individually, the next point is to analyse what is needed for the GH2 value chain as a whole. Here the understanding the business case as a whole need to be done. All actors here need to be clear and transparent about their opinions and challenges while this process for whole chain is conducted.

- Define: After evaluating and analysing the current requirements, the next step is to formulate the outputs and outcomes of the programme. Outputs are for each component of the project and outcome is for the programme. Depending on that the vision and mission of the programme can be set. Defining these in alignment with the programme is important. These should be set by ensuring that it aligns with the Hydrogen strategies and aims set by the government.

- Develop: After setting the targets, the next step is to develop strategies to achieve them. The programme will have its own strategy, and the individual components need to align their strategies with that of the programme.

- Execute: The next step is actually executing and implementing the strategies by taking the actions required to achieve the goals and ultimately getting the value chain running.

- Monitor: Throughout the programme it is important to monitor the processes taking place. Tracking if the GH2 value chain is achieving its milestones and if all components are performing and are on track.

The inner core (as shown in the core of Figure 14) is for specifying the outcomes and outputs along with the strategies of the overarching programme.

Figure 14: Model - Step 2

iii. After setting up the base of the programme, the next steps are to consider the following aspects (see Figure 15):

- Clear roles and responsibilities: The roles and responsibilities throughout the GH2 value chain have to be clearly put out. It is not only for the private sector but also the TSOs. All roles and responsibilities have to be clearly discussed and well formulated. There can be instances where the role of a certain situation is not predetermined in case of unexpected events. In this case as well, the situation must be discussed, and the role should be then provided. The risks occurring due to that should be divided transparently and fairly.

- Risk management panel: There should be a panel setup specifically for risk management. Here risk management experts need to appoint that will be a one stop for all the members in the value chain. This can be done by members of the organisations involved in the GH2 value chain or a third party can be hired to do so.

- Reporting: Depending on the progress and requirement of the GH2 value chain a reporting frequency should be determined. This has to happen to discuss the performance and progress of each of the components and the value chain as a whole. For example, it can start with reporting every 6 months or what the joint decision-

making committee agrees upon. Being transparent and truthful here is very important as progress and changes need to be made to improve it can be done.

- Communication: Clear communication needs to be ensured in the value chain. This aspect is important to be followed throughout the programme.

- PMO: Creating a PMO i.e., a programme management office. This will help facilitate the communication. It will provide engagement between the decision makers and the managers of individual components, the risk management panels, etc.

- Formulating contracts and agreements: As seen before, the risks and uncertainties are high. This affects the cost and execution of the value chain. Even if the actors come together, contracts need to be formulated between the key actors. These contracts need to ensure that there is proper division of risks or a collaborative approach to sharing risks. The contracts need to be transparent. This provides more confidence and trust within the actors in the value chain.

- Investment plans: As we have seen previously that use of programme management can help in judging the investment. This is the next aspect to consider. It is important to see the investment plans as to where does the money get invested in a value chain.

- Data and information management: Another aspect observed through the interviews was an effective digital platform. It is important to have this in place where the actors can share their information with confidence to the value chain. This has to be updated. All changes and current statuses need to put up here. This can also serve as a great platform for facilitating communication.

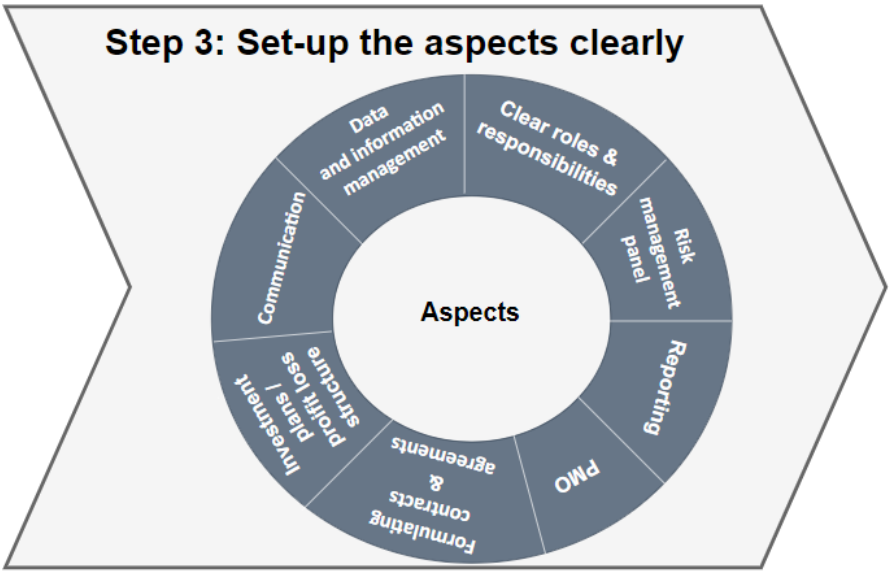


Figure 15: Model - Step 3

Combing these 3 steps makes the final model which is shown below in Figure 16.

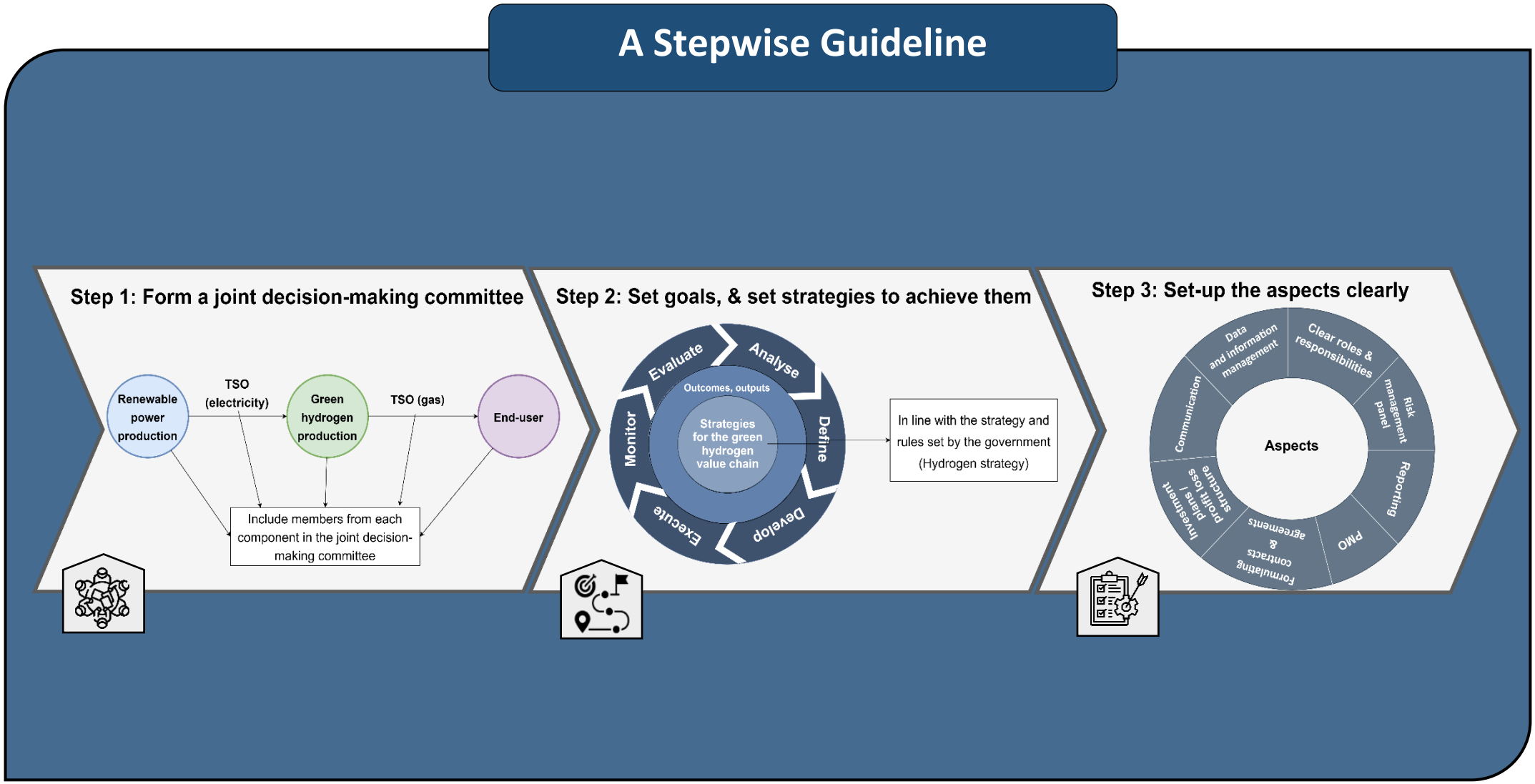


Figure 16: Model

Benefits of using the model

Using this model provides various benefits. By using this model, the actors in the value chain have a better view of risk allocation. When the actors in the value chain, join forces and work together, they have an overview of the entire value chain. This helps them decide and discuss with each other on how the risks can be divided. Moreover, it also provides an opportunity to the value chain for risk and pain-gain sharing. With the use of this model, the actors in the value get an opportunity to create a business model. The programme enables all the components to be grouped together. By joining forces, instead on working in isolation, the actors can integrate their projects to form a connected value chain. This enables to see how the investment can be done across the value chain. When actors come together, the confidence increases helping them to commit to their roles. The model helps in designing goals and strategies. This helps the value chain as a whole to form a business model.

As mentioned in the model, formulating the outcome of the programme is important. When the actors are joint as one (i.e., the projects in the value chain are joint as one), the control over price is more. Since the actors are working together, the advantage it provides is that there is a better view of the price structure throughout the value chain. For e.g., in case there is more wind and extra electricity is generated, the price of green hydrogen will go down. If the chain was not integrated, a fixed price agreement would be needed. But with help of integrating the value chain, there is better understanding of the price structure of the products produced in the value chain (e.g., electricity, green hydrogen). The model helps the actors in collaborating. It supports the being clear and transparent while working together. We know that the entire value chain is dependent on each other, effects of one the components affect the entire chain. While working together, it is important to be transparent to one another and while making decisions jointly. For this the model has provided an opportunity to evaluate the expectations of all actors and analyse the requirements of the value chain as a whole, even before the strategies and other aspects are aid out. It prioritizes the opinions of all actors before making decisions. This overall provides confidence for the actors to make the investments.

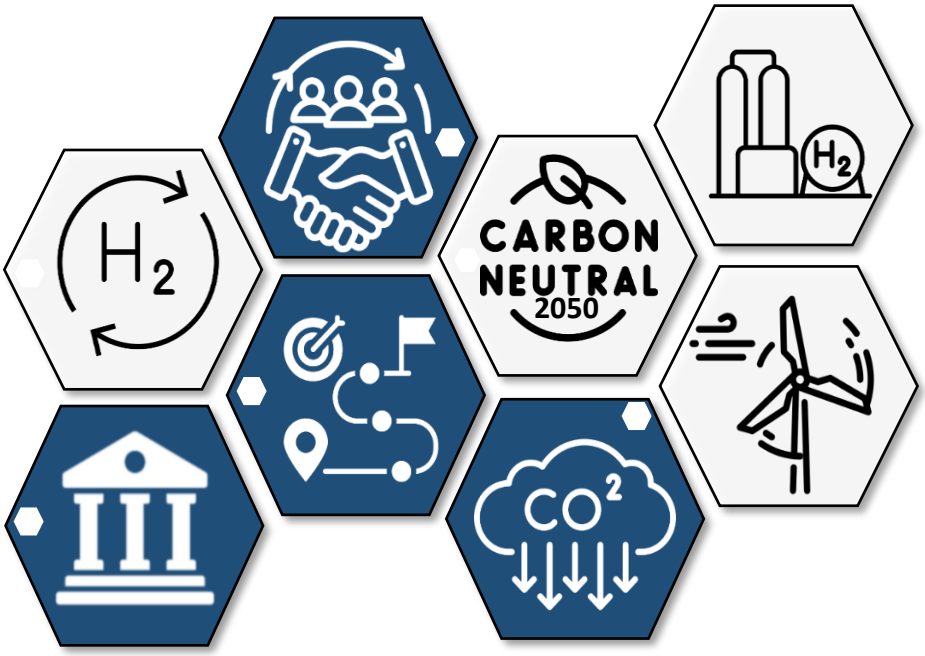
4.3. Chapter Summary and Next Steps

This chapter is aimed at addressing sub-research question 5. This chapter takes in all findings until now in the report as an input.

The chapter first delves into the challenges faced by the actors in the chain. The challenges faced are located in the value chain. It shows which actor is facing which challenge. Then potential solution and key elements of programme management are applied to these challenges in order to tackle them.

After addressing the challenges, a stepwise guideline is presented. The first step is setting up a joint decision-making committee where members from each component of the green hydrogen value chain need to be included. This committee will be responsible for taking the decisions and monitoring the entire value chain. The next step is to set the goals, outcomes, outputs, and the strategies to achieve them. To set these, a process is formulated: Evaluate the current status and needs; Analyse what needs to be done for the value chain as a whole; Define output, outcomes, goals, etc based on that; Develop strategies to achieve them; Execute the strategies and actions developed; and Monitor the programme to ensure if the milestones are achieved. The core of this programme lies by the goals and strategy set for the programme. All members need to abide by those. After this step the third step is to set up the aspects which are: Clear roles and responsibilities; Risk management panel; Reporting; Communication; PMO; Formulating contracts and agreements; Investment plans; and Data and information management. Using the model provides better risk allocation, an opportunity to create a business model, sharing risks, more certainty and control on the price of the end product, transparency by all actors and this overall provides confidence to the actors to make the investments.

After developing and presenting the final solution of this research study, the next steps are to discuss the results and present the academic and practical contribution of this research. Then the conclusion of this research is drawn where the sub and main research question are addressed. Finally, recommendations are provided



CHAPTER 5: DISCUSSION

This chapter discusses the research findings (5.1) and the relevance of the research (5.2). Then the limitations of this research (5.3).

Execution of green hydrogen value chain is the most important aspect of getting the GH2 value chain running. This can happen only if the value chain gets connected and starts running as a whole. In this research, a study has been conducted to explore the reasons or the challenges as to why the green hydrogen value chains are not being executed specifically for the Netherlands. The study also explores possible solutions executing the GH2 value chain are. This all was done with respect to the key actors involved. In this research, a hypothesis was proposed that programme management if used could help with the execution of the GH2 value chain and ultimately accelerating the energy transition with regards to green hydrogen. After conducting the research, the hypothesis was proved to be true. Its application helps to tackle most of the challenges that were occurring. This research not only proves the hypothesis but also goes ahead and presents a model on how exactly does the application and set up of programme management work for the GH2 value chain.

5.1. Discussion of Results

The research provides the key actors in the GH2 value chain specific to the Netherlands. The literature available provides an idea of the value chain and after identifying the key actors the chain was updated specific to the Netherlands. Moreover, the literature mentions their responsibilities, which were observed similar to the interviews. But there was a difference observed compared to the literature when an interviewee mentioned that building a substation was not previously the responsibility of the private sector. This was expected to be done by the semi-public sector. The technical definition of green hydrogen observed in theory is quite simple. But in interviews it was observed that the definition set in use was complex and strict. The interviewees mentioned that for hydrogen to be considered “green” there are certain criteria to be followed which are strict. The interviewees mention that the produced hydrogen has to come from a wind farm that is built within six months of the startup of the electrolyser plant. All the interviewees were in support of the green hydrogen value chain. But it was observed that one of the interviewees was sceptical of the technology. Although the interviewee provided insights into the challenges and potential solutions, they were few.

For programme management the definitions obtained from literature and interviews were very similar to each other. Although the literature does not detail the relation between green hydrogen value chain and programme management, the interviewees provided detailed insights into their relation. The key elements observed in literature were all observed in the interviews of programme management. But apart from that more additional benefits were obtained from the interviews.

This research provides a list of challenges and potential solution. But not all the challenges get tackled as it focuses on the GH2 value chain. The challenges of the regulations were not entirely addressed in this study. The research points out those challenges, giving insights into what is wrong and what could be done. Although it does not dive deep into solving it, based on the findings and observations, certain suggestions will be mentioned later in this chapter.

5.2. Academic and Practical Contribution of the Study

There is significantly less literature available for exploring the challenges in execution of green hydrogen value chains. Also, the application of programme management for transitions is explored but its application on GH2 value chains to accelerate energy transition has not been explored. Thus, this makes the research novel and beneficial from the academic and practical perspective. A major contribution to fill the gaps in current literature and industry, was by the use of the methodology of semi-structured interviews.

Considering the *academic* point of view, this study adds to theoretical knowledge. Currently, there is little research on the topic of green hydrogen value chain with regards to the challenges occurring in execution of projects. Most of the literature studied and reviewed in this research, explores global challenges to execution of the GH2 value chain. This available, specific to the Netherlands is quite limited. Research available does not focus much on how to tackle the challenges and application of management theory to it. In addition, there is little research on perspectives of all key actors on this in one set to help accelerate energy transition with regards to green hydrogen. This lack necessitates the need to understand what challenges the actors are involved facing. Not only this, but the research also focuses on understanding what the key actors expect from each other and what could potentially drive them to execute the chains. Thus, this research is addressed qualitatively. Using a qualitative approach provides a base as it first explores the topic at the starting stage of the energy transition. Additionally, the research provides the challenges and potential solution from perspective of different actors, and which challenges and potential solutions were commonly considered by a majority. The research therefore adds to current literature by providing a holistic view of the entire GH2 value chain in the Netherlands helping to understand what could be done to tackle the challenges. It provides a one stop point to learn about the challenges and potential solutions. Moreover, the research studies and presents the most recent findings which is scarcely available and thus contributes to the literature. The findings/data were gathered from the 18 semi-structured interviews conducted with actors involved in the GH2 value chain and actors with a connected chain whose chain is in execution. It is not limited to this, but also involves the semi-public and public actors. To get a third perspective for the GH2 value chain, the interviews were also conducted with experts in the company to additionally get insights. The interviewees emphasised on the importance of the connection and integration of the chain. Here is where a management approach to help solve certain challenges was required. The interviewees supported the use of programme management.

The study of this research not just limited to that. It further goes ahead and explores the hypothesis as seen earlier. Use of programme management could be useful to help with the execution of the GH2 value chain. But the application of programme management to the GH2 value chain is not available in the academic literature. The current studies focus on providing its use for transitions. The approach was seen to be successful to help with these transitions. The application of the programme management specific to a GH2 value chain is not available yet. Moreover, there is vast literature available on its characteristics and benefits to prove its advantage to the challenges seen but, the set up and views of actors on it from an energy transition perspective for a GH2 value chain execution is not seen. Thus, this research adds to

the literature available not only for programme management for energy transition but also for GH2 value chain. After studying and proving its use, the research goes another step ahead by providing a model to set up the programme for the GH2 value chain. To understand the concept in practicality and understanding its application and relation for a GH2 value chain, additional 5 interviews were conducted. Also, in the 18 interviews conducted before, some interviewees provided more insights into programme management. A roadmap/guideline is provided as a model to set-up the programme for a GH2 value chain. While researching and gathering data, some great insights were observed and some of those insights/findings were not used directly until now. But the points need to be addressed and mentioned as it provides an idea to explore in future research. This will be discussed in upcoming sections. A set of recommendations and suggestions are also presented for the key actors involved. Overall, this distinguishes the research from the current literature available.

From a *practical* perspective, the study provides a complied view of the challenges faced throughout the GH2 value chain. This provides the actors insights with what challenges other actors are facing and expecting. The model helps the actors in the industry to set-up their GH2 value chain giving them a stepwise guideline to incorporate it. Currently, the industry is lacking behind in achieving the goals of the energy transition set in the Netherlands with respect to green hydrogen. The execution needs to happen and needs to speed up to ultimately accelerate the energy transition. This research provides a model for achieving this. The model provided will help guide them to set up their aims and goals in line with those set in the hydrogen strategy by the Dutch government. It promotes a collaborative way of working and also elaborates on how that can be done. Currently, programme management is used in different sectors and transitions, but its use for energy transition is still blooming and there is none for a green value chain. The industry is willing to invest and has plans on the paper. This model will help bring that to practise. The model will help them bring together the aims and goals along with strategies and formulate a single one based on that or even formulate new ones altogether.

Thus, this research adds to existing knowledge both academically and practically and also provides insight into views of various key actors to execute the GH2 value chains along with the application of programme management on it.

5.3. Limitations of Research

- The value chain is limited to exploring the three components and does not include the supply chain including suppliers and contractors. Hence the challenges occurring due to them is not included in the research. Nor the challenges they are facing with regards to the green hydrogen energy transition are included.

- Although a wide number of literatures were read, there is a limited amount of literature available on the topic, hence the topic had limited actor-based literature for green hydrogen value chain.

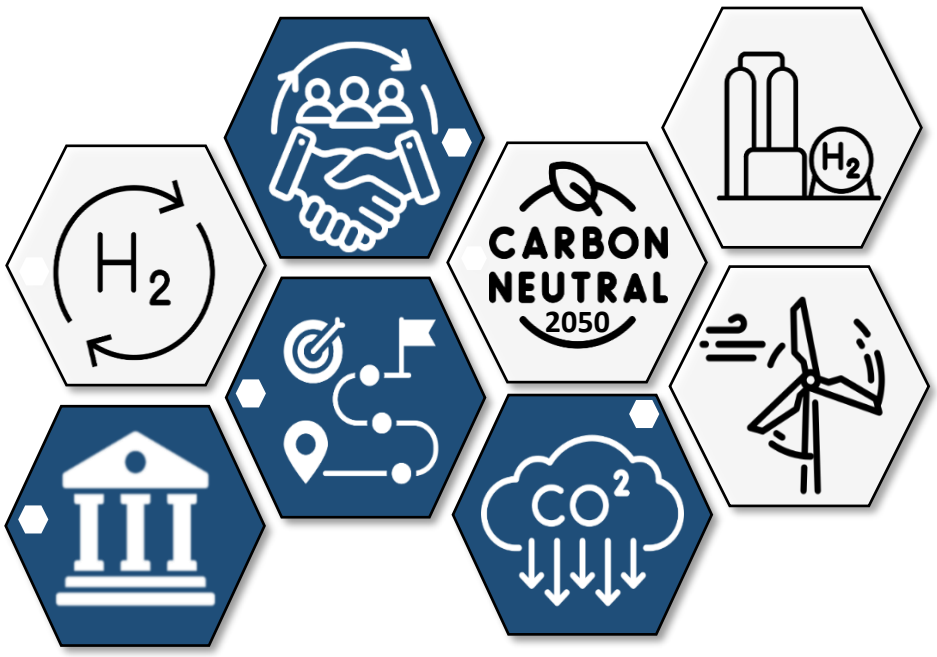
- The renewable power production is explored limited to offshore wind farms

- The chain does not explore storage and distribution of GH2 in detail. Since the GH2 value chains have not started running yet, the challenges experienced in that domain could not be explored.

- Since this is a new topic, the new additions to the information keep coming up. Certain updates in the process were observed and were included in the research. But any new information after presenting the model was not included.

- The model presented is for setting up the programme for GH2 value chain and explores the initial stage this transition. But it does not focus on the entire life cycle. The model supports the analysis procedure for identifying the challenges and working on them along with communication and collaboration which can be used throughout the programme lifecycle. But it does not mention the specifications for construction of the projects and their exact timelines. Although it does mention its importance and it can be done with the use of the model.

- The model is limited to a green hydrogen value chain where its components are mentioned. Government, an important actor, yet is an external influence. The model does focus on being adaptable to the changes in regulations, but it does not solve those external challenges in this study. This research does not mention what subsides need to be given when or what exact polies need to be executed when.



CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

The main objectives of this research study were to provide insights into the challenges faced in execution of green hydrogen value chain, explore the application of programme management approach to green hydrogen value chain, and finally develop a model that can incorporate the learnings explored in the research. To achieve these, main research question and sub-research questions were formulated. This chapter presents the conclusion of the research by answering the sub-research questions (6.1) and following with answering the main research question (6.2). This is followed by recommendations for practice (6.3) and for future research (6.4).

6.1. Answering the Sub-Research Questions

SRQ1 What is the green hydrogen value chain and what key actors are involved in it?

This question was answered with literature study. From the literature reviewed, the definition and concept of the green hydrogen value chain was derived. Green hydrogen is the hydrogen produced using renewable energy for electrolysis that does not emit carbon dioxide. This process right from renewable power production until end-use consumption is the green hydrogen value chain. It was found that there are various projects of the components of the GH2 value chain in the Netherlands, but their execution is lacking. The green hydrogen value chain has components that make it a chain. Here the key actors play an important role. The key actors found in the Netherlands are renewable energy producer, green hydrogen producer, end-user, TSOs (electrical and gas), and the government. It was observed that the entire value chain is dependent on each other, and one cannot work without the other. The government plays an important role externally by drafting of the policies. They set out the major aims that need to be achieved for energy transition (with regards to GH2) to take place. An important document drafted was the Government strategy on Hydrogen based on the Climate agreement in 2019 which was the responsibility of the Ministry of Economic Affairs and Climate Policy. These documents mention various aims and objectives like, to halt domestic production of fossil fuel by 2030 and ultimately achieving net-zero by 2050. The hydrogen strategy mentions various production aims to be achieved for which the execution of the green hydrogen value chains is important. The semi-public sector also plays an important role as they are the only TSOs (electricity and gas). They are responsible for providing the infrastructure and transportation. The other three important components of the value chain are the renewable electricity producer, green hydrogen electrolysis producer and the end user. Here the private sector plays an important role and need to make the investments. They are responsible to execute the projects.

SRQ2 What are the challenges faced by the key actors to execute the projects in the green hydrogen value chain and what could be done to potentially overcome them?

Since not all GH2 value chains are getting executed, the challenges were important to be explored. Since the literature does not provide the challenges, semi-structed interviews were conducted. This was done with an aim to identify the challenges faced in the execution of green

hydrogen value chain and the potential solutions in the view of the actors in the value chain. Around 47 challenges were identified through the interviews conducted, these were combined into 4 categories depending on their nature and similarity. The categories are regulations, cost, uncertainness and novelty, and actors. The challenges observed most were that the cost of GH2 is high, regulations are strict and unclear and that the demand and supply is uncertain. There is lack of commitment from the actors along with fragmentation. The private sector is hesitant to invest and there is lack of structed path and collaboration. This overall makes it difficult to execute the GH2 value chains and achieve the goals set. Then, the potential solutions identified were also categorized. The 25 potential solutions were also categorised in to 3 namely, cost and demand, government, and actors and integration. They could help in tackling the challenges observed. The potential solutions observed were clear and low cost of GH2, clear and eased regulations along with clarity in demand. Commitment from the actors, investment and better communication are important to get the GH2 value chain rolling. Lastly, an important finding was that integration and connection in the GH2 value is essential.

SRQ3 What is programme management and its characteristics?

In order to answer this question, first the concept of programme management was explored through literature study. The question addresses the hypothesis. It was hypothesized that the use of programme management can contribute to help with the execution of the GH2 value chain. The definition derived for this research is that programme management is the management and coordination of related projects to achieve optimum benefits that cannot be realised if the projects are managed separately. It is a mechanism to coordinate a group of related projects and is used to create group of projects, implement strategies, and generate change. Then after conducting the review, a list of characteristics and benefits was made. The extensive list was compiled into 8 key elements which are grouping / integrating, directing, and initiating projects; creating and aligning objectives with the strategic and long goals and achieving them; long-term collaboration; coordination and interaction between projects; allocating and sharing of resource; make and achieve complex changes; cross-project learning and knowledge sharing; and joint decision-making process. These 8 key elements form the theoretical model. This theoretical model provides the characteristics and benefits of the programme management which when used could help tackle the challenges. The literature mentions that programme management has proven to be useful for transitions, however its application to a GH2 value chain is not available.

SRQ4 What is the application of programme management for green hydrogen value chains?

This question was answered with semi-structured interviews in order to explore how programme management is applicable to the GH2 value hydrogen and how it could be setup. The theoretical model with 8 key elements were compared to the interview findings and additional 3 points were added. Two of those were merged with the existing ones and one was added making a total of 9 key elements. The additional ones are judge investment plans along joint decision-making process and feedback; and skill sharing. With the help of the programme management the investment throughout the GH2 value chain can be seen. It was found that

when the value chain will be integrated and connected in a programme, there will be certainty as to where the produced products will be going and coming from. The GH2 value chain will have a more strategic view across its component projects. For this, the actors need to come together as one. Since it was observed that GH2 value chain faces uncertainties making it complex. Programme management helps to bear these complexities and provides more structure on facing the challenges and achieve the goals set. Within this programme setting out the outcomes and outputs is possible. The integration also helps in having an integration on the risks, costs, infrastructure structure, etc. The overarching view of the entire GH2 value chain is possible which needs to be monitored and tracked. The success of the value chain depends on the all the components and thus need to collaborate well. These aspects need to be considered while setting up the programme. The overarching view enabled due to the programme management provides an opportunity of scanning the entire GH2 value chain.

SRQ5 How can the learnings be incorporated into a model for accelerating the execution of a green hydrogen value chain?

This question was answered by developing a model through desk research. The findings obtained throughout the research were used as an input. Firstly, it addresses the challenges observed in the GH2 value chain by using the theoretical model and the potential solutions. Then a guideline model is constructed by incorporating all the learnings observed. This model provides a stepwise process. Initially forming a joint decision-making committee is required followed by setting goals and strategies. This is the most important step. Then a risk management panel needs to be set up and finally there needs to be a digital platform available for interaction and information sharing when the actors come together. The process for setting goals and strategies starts with evaluating the requirements and the current situation, followed by analysing the chain requirements. Then defining the output and outcome of the programme needs to take place which is followed by developing strategies to achieve the set goals. Then executing the strategies and taking action is important along with monitoring the programme and tracking the milestones is important. The next part of the model shows the aspects to be considered which are clear roles and responsibilities, formulating contracts and agreements, investment plans and as mentioned before the risk management panel, reporting, and joint decision-making committee. The model has an inner core where the outputs and outcomes along with the strategies need to put and the entire chain needs to abide by those. All the components of the value chain need to align their strategies with the overarching ones. This means that the GH2 value chain needs to work together as a whole and not in isolation. Thus, this model is designed by incorporating the learnings of green hydrogen value chain and programme management. It helps with setting up the programme for green hydrogen value chain.

6.2. Answering the Main Research Question

The answers to the sub-research questions contribute to answering the main research question of this research.

How can the execution of green hydrogen value chain be accelerated with the use of programme management?

The main goal of the research was to accelerate the execution of the green hydrogen value chain for energy transition with respect to green hydrogen in the Netherlands. It was observed that although there are various aims and goals set by the Dutch government, there are very few value chains being executed to achieve that. There are various projects of the components of the GH2 value chain planned, but it all is just seen on paper. It was hypothesized that the use of programme management can help with the execution of the GH2 value chain. The study proved that the hypothesis was true. Green hydrogen value chain involves components and each of the actors involved in the value chain plays an important role. The key actors face challenges in the execution of the GH2 value chain. Not only were these challenges found, potential solutions and expectations of these actors were also identified. The projects in the GH2 value chain depend on each other, but they are fragmentated and isolated. There is not enough information and certainty around the technology especially around costs, demand, and supply, as so on. Thus, there are many risks making it difficult for actors to make investments and commit to it. In order to tackle the challenges, it was observed that the integration and connection in the GH2 value chain needs to happen first for the chain to run. The theoretical model made of the key elements of programme management was used to address potentials solution and thereby tackling most of the challenges. Once the challenges are tackled and addressed, then is when the path to execution of the GH2 value chain opens up. It was found through literature and semi-structured interviews that programme management would play an important role in addressing the challenges.

A model was prepared to address the challenges and potential solutions and provide a guideline to apply programme management to the GH2 value chain. With the use of this model, the connection and integration of the GH2 value chain is enabled. For this the actors need to form a join decision making committee and work together to get the value chain running. The model provides the actors in the value chain with an opportunity to collaborate and integrate their strategies by coming together as one. This will ultimately help in enabling the investment and communication, and thereby providing confidence in the GH2 value chain. The model also helps in setting strategies to achieve the goals set for the value chain as a whole. The model helps the actors in taking decisions together regarding the sharing and/or distribution of risks involved. The costs and demand will be better regulated after the connection of the chain as it provides surety to the actors. This overall will help in the execution of the GH2 value chain after which the aims and goals set for the Netherlands with regards to green hydrogen can be achieved. The research provides a holistic view of why executions are not happening and how that can be done. The research helps in providing a model that can help in the accelerating the execution of the GH2 value chains, there by addressing the gaps in academia and practise.

6.3. Recommendations

The objectives of this research were to provide insights into the challenges, exploring application of programme management and making a model of the learnings to overall help the execution of the green hydrogen value chain. This was achieved by answering the main and sub-research questions. This section presents the recommendations for practice to the private sector, public and semi-public sector, and the company (T&T).

6.3.1. Private sector

- Abide by the overarching strategy of the programme: Even though the programme will help set a strategy, all individual components will have to set their own strategies for their own organisations. But it is important to ensure that the strategies are aligning with the overarching strategy that was set for the programme.
- Being aware of the new regulations and changes: External factors like changes in regulation can occur at any point. It is important that the responsible committee is keeping up with it. Thus, the joint decision-making committee needs to stay updated and aware of the changes occurring. This also further needs to be effectively communicated to the entire chain. Here is where the digital platform needs to be used.
- Clear and flexible contracts: Having clear contracts is important. The contracts should clearly define the risk and opportunities sharing terms. Since there is lack of experience with the technology, having flexibility is important. It was observed that old contracts cannot be bluntly applied for the new energy transition. Hence, new contracting forms should be introduced providing clarity and flexibility. This should be discussed fairly and transparently within the GH2 value chain.
- Set a timeline of actions: The entire construction timeline and a proper roadmap needs to be set. This will provide a clear path of the actions. This has to be embedded in strategies or in the outcomes.
- Workshops and summits: Have a digital platform to communicate is provided through the model. Apart from that having more panel discussions, workshops, summits/ conferences also to spread awareness. This will bring many companies and actors together. This will help in engaging with parties that are similar, e.g., green hydrogen producers. Sharing insights within similar projects can help to gain more insights from each other.

6.3.2. Public and semi-public sector

- Taxation and incentivization: Since other alternatives like fossil fuels are still an option, increasing taxes on them could enable the private sector to move more towards green technologies. Whereas taxes for using green hydrogen should be reduced. Also, incentives or tax benefits need to be introduced for those producing and using green hydrogen over not only fossil fuels but also grey or blue hydrogens.

- Tax benefits: Interviewee T1 mentions working on a hydrogen value chain project (outside Netherlands) and says that “projects which took FID (financial investment decision) before the end of 2022 got major tax advantages. And it has driven a huge number of projects to take off”. Hence, introducing such benefits could enable the investments from the private sector and motivate them.
- Influence the transition: The government plays a crucial role in this energy transition. They influence the execution of GH2 value chain through rule and regulation. Although they will not be directly involved in the programme or form it, it is the role of the private sector to do so. But they need to motivate and help in enabling this connection and collaboration.
- Regular interaction: There needs to be regular interaction with the private sector to understand their needs and opinions, while formulating policies and regulations.

6.3.3. Company

The company can play a significant role in providing consultancy to the industry with the use of this model.

- Opportunity to create value: With the help of advisors from the consultancy, there is an opportunity to create value for the clients and develop new ways of working. The expertise can contribute to the energy transition with regards to green hydrogen.
- Role in process: Either the value chain does the setting up on its own, or they might get the consultancy to support them. Here the company needs to be engaging and supporting them with the whole process of setting up and could continue for the monitoring as well.
- The company could also play a role in identification of the challenges and helping in developing solutions.

6.4. Future research

After providing recommendations for practise, this section presents recommendations for scientific research in future.

- The model provides various aspects. One such aspect is formulating contracts and agreements. In future, a study can be conducted on the different forms of contracts available that need to be modified for considering the new energy transition. Also, new contracting or governance forms can be explored.
- The GH2 value chain studied is specific to the Netherlands, further research can be conducted on exploring what challenges exist in other countries and how the programme management could be applied there.
- Further research can be conducted by applying model in practise and observing what additions can be made to it.

- The GH2 value chain presented is the core of the chain. The stakeholders are limited to this core. Indeed, there are suppliers and contractors attached to these components. Their viewpoints and challenges experienced by them can be explored.
- Regulation based challenges were not provided with a concrete solution. More in-depth study can be conducted considering the policy analysis for green hydrogen.
- In the chapter where solution is developed, other suggestions like project 13 approach is provided. But the research does not go in detail of their application. For future research, this could also be investigated.

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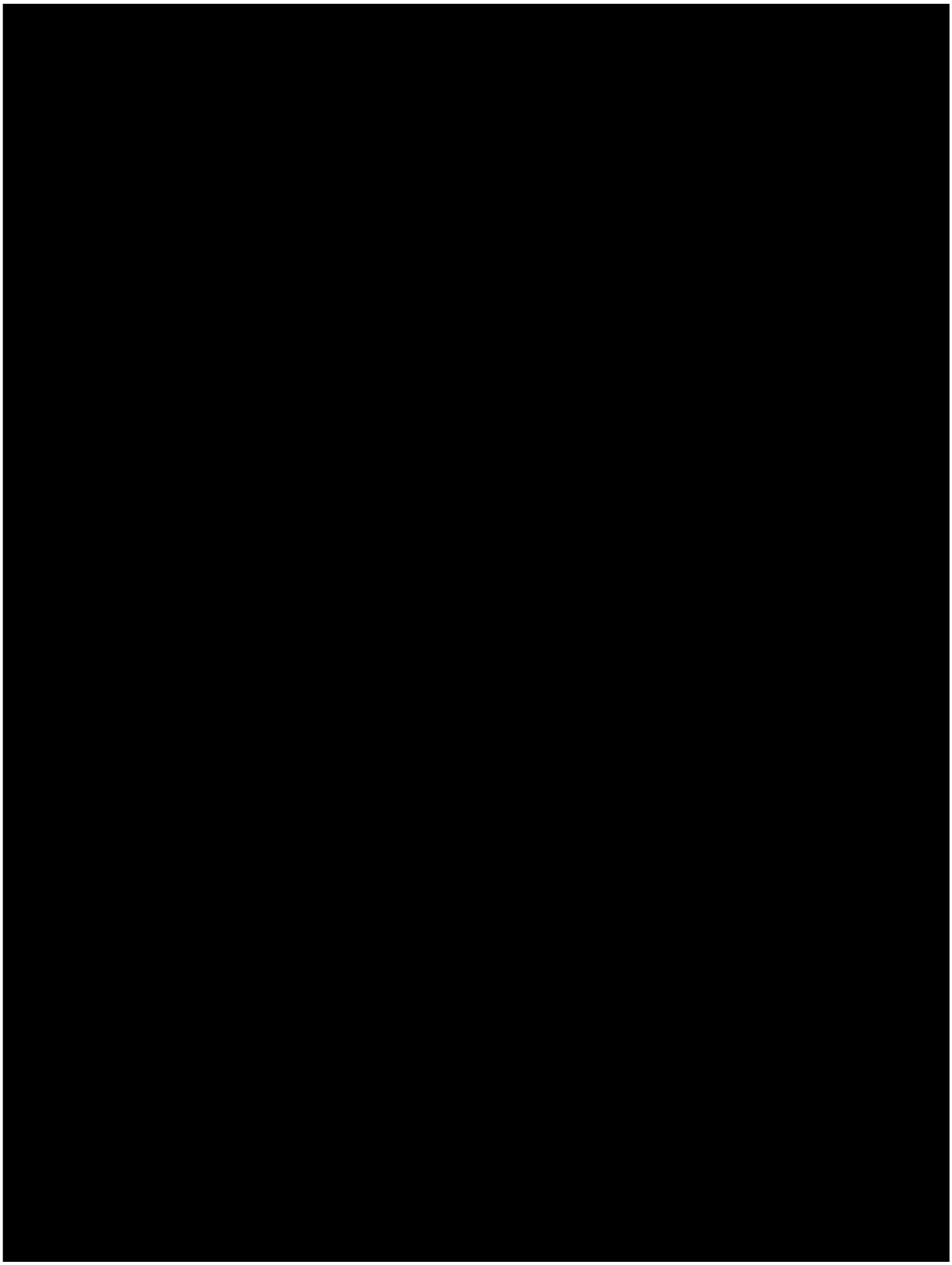
APPENDIX

Interview questions



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