TACKLING DELAY DURING THE PLANNING PROCESS OF HYDROGEN PIPELINE INFRASTRUCTURE

- The Case of Groningen Seaports -

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Abstract

In the fight against global climate change, hydrogen is considered to be a promising source of renewable energy. Seaports play an important role in providing the necessary space to construct the required infrastructure for the production, storage and transportation of hydrogen. However, the planning of hydrogen infrastructure is often delayed by lengthy decision-making processes. This delay can be attributed to technological issues, conflicting interests leading to prolonged public engagement processes, and/or missing or unclear laws and regulations. Focusing on the case of a new hydrogen pipeline between the Eemshaven and the seaport of Delfzijl in the northern Netherlands, this research studies the nature of delay in the planning process, and will focus on reforms of institutions and regulations that could help to responsibly minimize delay in planning for this critical infrastructure. Focusing on interviews with sixteen key stakeholders, the results of this study provide a clear overview of the perception of delay, its causes, and possible solutions to speed up the planning process for hydrogen pipeline infrastructure in seaport areas.

Key words: hydrogen infrastructure, pipeline planning, delay, externalities, critical infrastructure

Explanation of used abbreviations

Bevb: Besluit externe veiligheid buisleidingen

Bevi: Besluit externe veiligheid inrichtingen

BRZO: Besluit risico's zware ongevallen

CES: Cluster Energie Strategie

CO2: Carbon Dioxide

DSO: Distribution System Operator

ETS: Emission Trade System

GR: Groepsrisico

GSP: Groningen Seaports

H2: Hydrogen

HEAVENN: Hydrogen Energy Applications for Valley Environments in the Northern Netherlands

IFV: Instituut Fysieke Veiligheid

ILT: Inspectie Leefomgeving en Transport

LSNED: Leidingenstraat Nederland

MER: Milieu Effect Rapportage

MIEK: Meerjarenprogramma Infrastructuur en Klimaat

Ministerie BZK: Ministerie van Binnenlandse Zaken

Ministerie EZK: Ministerie van Economische Zaken en Klimaat

Ministerie I&W: Ministerie van Infrastructuur en Waterstaat

NAM: Nederlandse Aardolie Maatschappij

NEN: Nederlandse Norm

NIMBY: Not In My BackYard

NMF: Natuur en Milieufederatie

NOM: Investerings- en Ontwikkelingsmaatschappij voor Noord-Nederland

O2: Oxygen

ODG: Omgevingsdienst Groningen

PEH: Programma Energie Hoofdstructuur

PR: Plaatsgebonden Risico

RED: Renewable Energy Directive

RES: Regionale Energie Strategie

Revb: Regeling externe veiligheid buisleidingen

RIVM: Rijksinstituut voor Volksgezondheid en Milieu

SDE: Stimuleringsregeling Duurzame Energieproductie

SMR: Steam-Methane Reforming

SVB: Structuurvisie Buisleidingen

TSO: Transport System Operator

VELIN: Vereniging van Leidingeigenaren in Nederland

Wabo: Wet algemene bepalingen omgevingsrecht

QRA: Quantitative Risk Assessment

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1] Introduction and problem statement

Facing the consequences of global climate change, governments and companies all over the world are looking for new ways to cut greenhouse gas emissions and develop zero- or low-carbon alternatives to replace current technologies that heavily rely on fossil fuels. At the 2015 United Nations Paris Agreement, 196 countries pledged to limit global warming by placing a greater emphasis on renewable energy sources to limit emissions (UNFCCC, 2015).

One example of a promising renewable energy technology is hydrogen (H_2). Hydrogen can be produced through a process called Steam Methane Reforming or through Electrolysis. Hydrogen is used as a raw material for manufactured goods, such as fertilizer, but it can also be used as an energy source to power, for example, factories or modes of transport. The production, storage and transportation of hydrogen requires extensive industrial infrastructure. Even though the large-scale application of hydrogen in economies is still in its infancy, hydrogen is seen as an important technology in the future energy transition. A clear benefit of hydrogen is that the only rest product of its use is water (H_2O), which does not harm the environment (TNO, n.d.).

Initiatives for the planning of new hydrogen infrastructure can be found in seaports all over the world (e.g. the seaports of Rotterdam, Hamburg, Antwerp, Shanghai, Hong Kong, et cetera). The production of green hydrogen requires an adequate source of clean energy; an electrolyser to produce the hydrogen; buffer space; and an extensive network of pipelines to distribute the produced hydrogen to off-takers (TNO, n.d.). Seaports regard the development of hydrogen infrastructure as a boundary condition to make their operations more sustainable, and they might provide the necessary space to house the installations and infrastructure for the future hydrogen economy. However, the construction of hydrogen infrastructure is often delayed in the planning decision-making phase due to factors such as strong public opposition or objection to the plans (Cowell & Devine-Wright, 2018), missing or unclear legislation or permits (Lindholm, 2010), or technological issues (Patil, et al., 2013). This all leads to hydrogen projects being faced with months or even years of delay. This raises the financial costs for both public and private parties, but also leads to social costs, because climate goals will not be met in time.

The issue of delay in infrastructure planning is not new to the field of spatial planning. To tackle delays, governments could impose institutional changes in order to try and streamline procedures, for example, by implementing fixed times schedules, easing regulations, or lowering the number of opportunities for public engagement (Marshall & Cowell, 2016). For example, Moroni and Buitelaar (2020) focus on the importance of 'simple rules' to speed up planning processes. Besides such 'change of the rules', adjustments in institutional arrangements will also be necessary to minimize delays. Involved parties could strive towards a better coordination of agencies and actors through horizontal, vertical or territorial interaction (Huck, et al., 2021). This all leads to a change in seaport governance processes, a topic which has been studied by Witte, et al. (2012; 2016; 2020), Bergek, et al. (2008), and Nouzari, et al. (2019).

Studies into the causes of infrastructure planning delay can be found in abundance, mostly focusing on delays in infrastructure projects (e.g. in Qatar: Emam, et al., 2015; and in Jordan: Al-Hazim, 2017) and factors of delay have been studied comprehensively by Keogh & Evans (1992) and Marshall & Cowell (2016). However, these studies often focus on infrastructure like highways or electricity grids, and not on hydrogen infrastructure. A unique trait of hydrogen infrastructure is that it is considered to be ‘critical infrastructure’ that could pose high risks to the environment. This means that no unnecessary or irresponsible risks should be taken while trying to tackle delay in hydrogen planning. Literature focused purely on hydrogen infrastructure in seaport areas is scarce and there is a need for new literature on this matter that explores the multiple factors responsible for delays and pathways towards a more efficient planning of the infrastructure through institutional and regulatory changes. This could help seaports to more quickly plan their hydrogen infrastructure and reach their sustainability goals in time.

This study focuses on the case of a new hydrogen pipeline between the Eemshaven and Delfzijl in Groningen, the Netherlands. Convinced by the opportunities of hydrogen in the northern Netherlands, private and public parties in this region have drawn up the ‘Northern Netherlands Hydrogen Investment Plan’ (2020) to guide the development of hydrogen technologies in this part of the country. The plan aims to transform this area (the Dutch provinces of Drenthe, Friesland and Groningen) into the ‘Hydrogen Valley’ of Europe, a fully-fledged ecosystem focused on the production, distribution and use of green hydrogen (The Northern Netherlands Hydrogen Investment Plan, 2020). HEAVENN, a consortium of 31 public and private parties from six European countries, will now work on a wide range of different projects in this Hydrogen Valley. The European Commission has selected the projects in the Hydrogen Valley for European subsidies as well (Rijksoverheid, 2019).

The seaports of Delfzijl and Eemshaven play a central role in the realization of the Hydrogen Valley. The seaports will house the necessary infrastructure to produce, import, store and export the hydrogen. The ports will need to give space to the necessary electrolysers to produce the green hydrogen and the infrastructure that is needed to connect the electrolysers to the renewable energy sources (for example, wind parks at sea). Furthermore, a hydrogen pipeline backbone is essential for the transportation of the produced hydrogen to off-takers through a network of pipelines.

The seaports of Groningen are managed by Groningen Seaports, the commercial operator and port authority of the ports of Delfzijl and Eemshaven. Groningen Seaports wants to speed up the process of planning the hydrogen infrastructure in order to meet the climate ambitions of the Dutch government and of the company itself (Groningen Seaports, 2021). However, the port authority is faced with lengthy planning decision-making processes for this critical infrastructure. Planning processes for pipelines are often delayed by years, due to factors such as a lack of legislation, experience or knowledge for planning and providing the permits for the infrastructure. It is to be expected that such delay will occur during the planning of hydrogen infrastructure in the Groningen Seaports as well. Besides, the hydrogen pipeline infrastructure poses risks to the environment and often conflicts with other uses in the port area (New Energy Coalition, 2021), leading to technological issues or lengthy public engagement processes.

In creating future hydrogen infrastructure, Groningen Seaports wants to speed up the planning process and create a system in which it can more quickly and easier be tested whether proposed hydrogen infrastructure projects will be approved in the planning process. To reach this goal, it will first be necessary to make a thorough exploration of the nature of the delay, and the possible solutions via reforms of the current institutional and regulatory system. However, due to the risks surrounding this critical infrastructure, it will be important to strive towards a faster planning of the infrastructure, while keeping the risks into account.

The focus of this study is to identify the perception of different involved actors in the Groningen Seaports case about delay during the planning of hydrogen pipeline infrastructure, and the experienced causes of delay. Furthermore, this study will look for solutions that will help to responsibly shorten the time necessary to plan this critical infrastructure through institutional or regulatory changes. The research question of this study is stated as follows: "*What are the causes of delay in the planning of hydrogen pipeline infrastructure and how could institutional and regulatory change provide solutions to more quickly plan this critical infrastructure?".* To answer the research question, three sub-questions have been designed:

1] What can be considered to be delay in planning decision-making processes for new infrastructure?

First, it is important to understand what exactly can be considered to be delay in planning decision-making processes and what factors contribute to the presence of delay. This first sub-question will be answered through a literature review of existing studies on delays in infrastructure projects.

2] What are the causes of delay in hydrogen pipeline planning processes in seaport areas, focusing on the case of Groningen Seaports?

Focusing on the case of the construction of a hydrogen pipeline in Groningen Seaports, the factors responsible for the delays in the planning of the hydrogen infrastructure will be identified, based on interviews with involved stakeholders. It will foremost be important to investigate the perception of the different stakeholders about (the presence of) delay. Further questions in the interviews will focus on *what* exactly constitutes the experienced delay, *when* it happens and *who* is responsible.

3] What are possible institutional and regulatory reforms to responsibly provide solutions to speed up the planning of this critical infrastructure?

Lastly, based on the interviews with involved stakeholders, possible solutions will be mentioned in order to speed up the hydrogen planning decision-making processes and make those more efficient. It will also be investigated whether respondents think it is responsible to shorten the planning period for this critical infrastructure, taking into account the related risks. Stated solutions will concern changes of regulations and institutional changes that could help to speed up the planning process.

The case of Groningen Seaports does not stand alone: worldwide, the planning and construction of hydrogen infrastructure is often faced by barriers and challenges that cause delay (McDowall & Eames, 2006), perhaps due to similar reasons as in the case of Groningen Seaports. A clear overview of the nature of the delay in the planning decision-making process for hydrogen, and possible solutions in the Groningen Seaports case could help planners all over the world to more quickly plan this infrastructure that will play an essential role in combating the effects of global climate change.

Hydrogen is a relatively new source of energy, and the construction of critical hydrogen infrastructure on such a large scale is still in its infancy. Existing delay studies mostly focus on 'old' infrastructure like highways or electricity nets. Those studies mostly take a quantitative or mathematical approach to calculate the optimal planning of hydrogen (supply chain) infrastructure. However, multiple quantitative studies (e.g. Yang, et al., 2020; McDowall & Eames, 2006) note that more in-depth, qualitative data is necessary about the factors that (might) delay the planning of the hydrogen infrastructure and how to tackle these. As an answer to this current demand for new knowledge, this study takes an inductive approach by adding the necessary qualitative knowledge to literature about how to reduce delay when planning new, critical hydrogen infrastructure.

The remainder of this thesis is structured as follows. Section 2 provides a literature review into delay studies in relation to the planning of critical infrastructure. Section 3 then describes the methodology for this research. Results of this study are presented in section 4, followed by a conclusion in section 5 and a discussion in section 6. References are provided in section 7 and the appendices can be found in section 8.

2] Literature review

2.1] The production of hydrogen

Hydrogen will play an important role in the future sustainable energy supply. Hydrogen can be used as a clean energy source for heavy industrial processes, but also as a feedstock for the production of chemicals, fertilizer and fuels (Abdalla, et al., 2018). There are two processes to make hydrogen: Steam-Methane Reforming (resulting in the production of grey or blue hydrogen) and Electrolysis (resulting in the production of green hydrogen whenever a sustainable energy source is used).

Firstly, there is the process of Steam-Methane Reforming (SMR). Nowadays, most hydrogen is created through an SMR process. There are two important factors that make the SMR method unsustainable. Firstly, methane sources like natural gas or gasoline are necessary as raw materials to create the hydrogen. The provision of these fossil fuels is finite, thus unsustainable. Secondly, in this process, carbon dioxide is produced as a side product, which contributes to the global greenhouse effect (U.S. Office of Energy Efficiency and Renewable Energy, n.d.). Hydrogen produced through this 'normal' SMR method is known as 'grey hydrogen'. However, the carbon dioxide that is produced during the production of the hydrogen could be captured and stored, for example in underground caverns. This helps limit carbon emissions. Hydrogen produced through a method where produced carbon dioxide is captured and stored is called 'blue hydrogen' (TNO, n.d.).

A second method to produce hydrogen is called electrolysis. In this process, electricity is used to decompose water into oxygen and hydrogen gas. Hydrogen that is produced through electrolysis where a renewable source of energy is used, is known as 'green hydrogen' (TNO, n.d.). The advantage of this method is that (almost) no greenhouse gases are emitted in the process. The full process of creating green hydrogen is shown in **figure 1.**

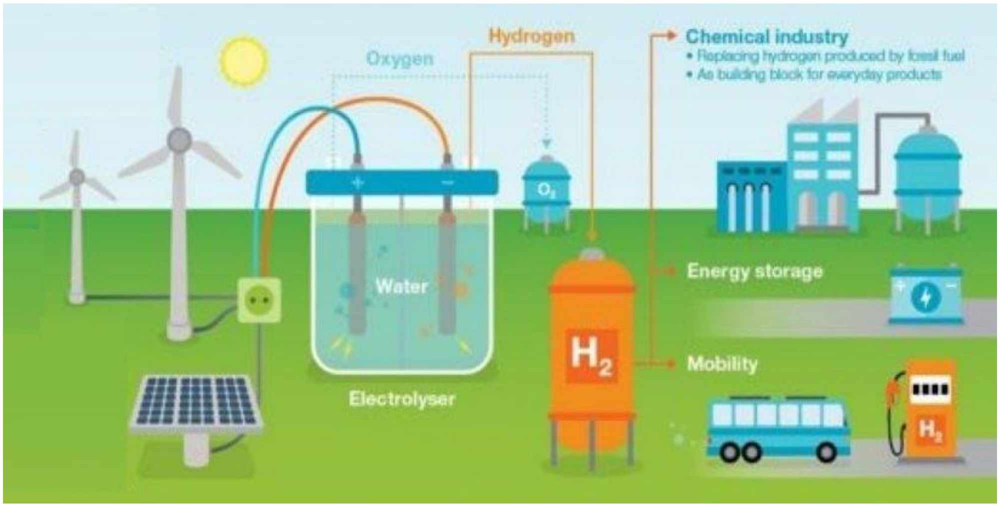

Figure 1: Production of green hydrogen. *Source: Chemiepark Delfzijl*

The road towards a green hydrogen system will probably go in steps with an initial focus on grey and blue hydrogen. The total future energy system will remain hybrid and will probably never 100% consist of green hydrogen. The International Energy Agency has, however, calculated that in the long term, green hydrogen will probably have lower costs than blue hydrogen, which means that on the long run, green hydrogen is expected to outplay blue hydrogen (Körner, et al., 2015).

A benefit of hydrogen over electricity is that the transportation of gas through a system of pipelines is cheaper than the transportation of electrons through cables. Hydrogen can easily be transported through a network of pipes to off-takers, or it could be buffered, for example in underground caverns, for later use. The fact that hydrogen can be stored for long periods of time is another advantage of this renewable energy source, compared to other energy sources. In times of a surplus production of hydrogen, the hydrogen can be stored to be used in times of energy shortage (TNO, n.d.). Hydrogen can thus be seen as an essential part of the future CO2-free Dutch energy transition and will provide new jobs in the country as well: *"An appropriate hydrogen infrastructure that is also available on time is a necessary condition for achieving the climate goals, preserving existing industry, and attracting new companies to the Netherlands"* (Wiebes, 2020).

Creating this hydrogen economy requires new infrastructure. The electrolyser installations where the hydrogen is created need to be connected to an adequate source of renewable energy, like solar power plants or wind parks (Van der Leun, et al., 2020). This requires an extensive electricity infrastructure. Produced hydrogen that is not used immediately needs a place to be stored as well. To transport the produced hydrogen to off-takers, a network of pipelines is necessary. For the long distance high-pressure transportation of hydrogen, usually steel pipelines are used, although for the low-pressure distribution of hydrogen in the industry, other pipeline materials, like thermoplastics, are in use as well. This study will mainly focus on the required pipeline infrastructure for the hydrogen economy. Planning this new hydrogen pipeline infrastructure takes time. McDowall & Eames (2006, p.1236) stated that there is *"a broad consensus that the hydrogen economy emerges only slowly, if at all, under 'Business as Usual' scenarios"*. That is why there is a need to speed up the planning of the required (pipeline) infrastructure for the hydrogen economy. Sections 2.2, 2.3 and 2.4 will now first provide an overview of the scientific debate on delay during the planning of (hydrogen) infrastructure.

2.2] Delay in planning decision-making

It is now first of importance to develop a good understanding of what exactly 'delay' in the planning decision-making process is. Based on Keogh & Evans (1992), we can come to the following definition of delay (Keogh & Evans, 1992, p.689): *"Delay becomes any period over and above what is necessary or, perhaps, what is reasonable to determine an application".* Quantitatively stating what exactly is delay in a process is a very subjective task: planning is a complex matter, with many different steps taken at the same time and different involved stakeholders might have different views on when delay occurs in the process. However, in short, one can broadly speak of delay when the main path between initiation and completion of development is significantly extended.

Delay in planning processes is one of the biggest pain points that involved parties experience in spatial developments. Delay can be considered to be undesirable for a number of reasons. Firstly, delay poses serious extra costs and uncertainty to all participants in the planning process. There has been a growing role of the private sector in the provision of infrastructure, and delay could seriously harm the business interests of these private parties (Marshall & Cowell, 2016). Due to the privatization and financialization of infrastructure (O'Neill, 2013), there is a growing focus on the effects of infrastructure planning delay on the economy. Delay in projects often brings about extra costs for the commercial parties involved, negatively affecting their business case.

Besides such private costs, there are also wider social costs for society that can be attributed to delay. New infrastructure is often essential in society, and if the construction of the infrastructure is delayed during the planning process, there is a loss of external benefits for society during the period of delay (Keogh & Evans, 1992). Furthermore, crises, like global climate change, are often used by governments to press for an acceleration of planning processes. There is an urgent need in societies to meet climate goals, and governments may want to speed up planning processes of 'green' projects to meet the stated sustainability goals in time (MacKerron, 2009).

In planning literature, there has been a considerable amount of work on the causes of delay in spatial planning processes. The reasons for delay in infrastructure projects and possible interventions have been the key focus of numerous case studies (e.g. in Qatar: Emam, et al., 2015; and in Jordan: Al-Hazim, 2017). Based on these case studies, various reasons for delay can be grouped into three classes. It is important to note that this study focuses only on delay occurring during the planning phase of hydrogen pipeline infrastructure, and not during the construction or usage stage (Delphine, et al., 2019). Delays during the construction phase could, for example, occur due to bad weather during construction of a pipeline. Such factors of delay are out of the scope of this research. It is, however, possible that factors of delay apparent in the planning phase still remain an important factor of delay during the construction and usage stage of the infrastructure. While focusing only on the planning phase, three groups of delay factors can be distinguished. An overview of these three types of delays can be found in **table 1**.

Firstly, delay can be caused by technological factors. For example, there could be unexpected physical barriers requiring a change in the design of the infrastructure or a change in the material used for the pipeline (e.g. for infrastructural projects in India, see: Patil, et al., 2013). Secondly, there can be delays related to the planning and regulation of the process. For example, authorities can be slow in issuing the required permits, or authorities lack the skills, knowledge or feeling of urgency to check infrastructure with the regulations. There can also be missing or unclear legislation or guidelines for pipeline construction (Lindholm, 2010). Thirdly, delays could be caused by lengthy public engagement processes. These could be caused by strong public opposition or objection procedures to the plans (Cowell & Devine-Wright, 2018). Opposition to infrastructure plans could arise due to conflicting interests or fears about negative externalities. A lack of adequate participation or late participation might exacerbate this type of delay, because stakeholders' knowledge and experiences are not, or too late, integrated into the process (Wilker, et al., 2016).

Table 1: Three types of delays during the planning decision-making process for infrastructure

Type of delay	Examples from literature	Literature
1] Technological	● Problems considering layout, material or (barriers on) pathway of the pipeline ● Change in the design of the pipeline	Emam, et al. (2015); Patil, et al. (2013) Al-Hazim, et al. (2017)
2] Planning & Regulations	● Slow response from regulators and/or permit issuers; ● Authorities lack skills, expertise, knowledge or sense of urgency to assess the (impact of) the project; ● Unclear or missing (safety) regulations or guidelines; ● Poor coordination between stakeholders and/or authorities;	Emam, et al. (2015) Delphine, et al. (2019) Lindholm (2010) Huck, et al. (2019)
3] Public participation	● Lengthy objection procedures to the plans; ● Opposition from action groups; ● Opposition from land owners ● Inadequate or too late participation procedures	Ellis (2004) Cowell & Devine-Wright (2018) Lindenbergh, et al. (2018). Wilker, et al. (2016)

2.3] Tackling delays through institutional and regulatory change

To tackle occuring delays, governments could impose institutional changes in order to try and streamline procedures, for example by implementing fixed times schedules, easing regulations, or lowering the number of opportunities for public engagement. This will always be a question of a trade-off. Sometimes, lengthy decision-making procedures are necessary to come to better-informed actions (Marshall & Cowell, 2016). A reduction in the time spent in the planning decision-making phase will only be desirable if it does not harm the quality of the planning decision, or when the cost savings by the saved time are bigger than any loss in economic growth, safety, environmental benefits or democracy.

The trade-off that is visible here can be associated with the triangle of sustainable development of Campbell (1996). Spatial planners have to delicately balance three conflicting goals for planning. Firstly, there is environmental protection, which encompasses a sustainable use of natural resources, and attention to safety risks of the infrastructure. Secondly, there is overall economic growth and efficiency, with a focus on (economic) prosperity, profits and the distribution of goods. Lastly, there is social justice, which entails a focus on people's health, welfare, opportunities and equality. In between these three corners of the triangle, multiple conflicts exist. Planners who aim to tackle delays must seek creative solutions that lead to a (non-static) balance between the three corners of the triangle. This leads to infrastructure development that is green, profitable and fair.

To find a balance between these many overlapping interests that are present in seaports, governance strategies are needed for planning the infrastructure. Governance could be described as *"the exercise of political authority and the use of institutional resources to manage society's problems and affairs"* (Witte, et al., 2012, p.59). Governance includes formal aspects, like the ruling laws and regulations, and informal aspects, like traditions and customs (Witte, et al., 2016). One of the main issues in seaports is a lack of land for expansion of necessary infrastructure. Planning of the available space in port areas is complex, due to a large variety of actors, each with different interests (Witte, et al., 2012). These different interests can become increasingly intertwined and spatial conflicts between different uses in the seaports arise. To solve these conflicts, port governance strategies are essential.

In order to understand the governance of a seaport, it is necessary to take a look at the dynamics between the actors, formal and informal institutions ('rules of the game') and the technology itself (Bergek, et al., 2008). Nouzari, et al. (2019) state that a process of interactive governance is an effective method to reach stakeholder satisfaction and reach effective ways to plan underground space in urban areas. To understand the governance structure, it is essential to take a look at the use of institutions, regulations and politics to plan the infrastructure in seaports. How the institutional structure is used plays an important role as well, for delays in planning can appear due to fragmented, overlapping, conflicting or missing rules and legal systems (Witte, et al., 2012).

Huck, et al. (2020) underlined this complex governance situation in urban areas. Fragmented and complex governance structures hinder an efficient solution to planning issues and are partly responsible for the occurrence of delays. Therefore, there should be better coordination between actors in different organisations and areas. The concept of institutional connectivity (Huck, et al., 2019) could be a solution to the inert situation. The aim is to improve the interconnectedness of governance systems to better react to chances in the planning context. Connectivity can be improved by three factors:

1. *Horizontal connectivity:* Improving the institutional connectivity between different sectors.
2. *Vertical connectivity:* Improving institutional connectivity between different policy levels. This is also known as multi-level governance. Romein, et al. (2003) already noted that the

complex planning situation in port areas requires governance at multiple scales and with multiple involved actors.

3. *Territorial connectivity:* Improving institutional connectivity beyond administrative jurisdictions.

However, not only the institutions should be subject to change in order to decrease delays. The formal 'rules of the game' should be simplified as well. Moroni and Buitelaar (2020) note that legal rules should be simple rather than complex in order to effectively respond to the planning context. The current complex rules for planning and land use lead to lengthy processes of approval of plans. Simple rules are accessible, binary, general and lead to a significant reduction in time spent in the planning phase of a project.

It is now necessary to identify the actors and the informal and formal frameworks through which they act to plan the land use of seaport areas and see how changes in institutions and a simplification of rules could help to reduce delays in the planning of hydrogen infrastructure. Because of the critical nature of the hydrogen infrastructure, actors must find a balance between reducing delay, while at the same time guaranteeing that the time savings do not in a too large degree negatively impact the economic, social and environmental prosperity of the parties involved. The critical nature of the infrastructure is discussed in the following section.

2.4] The nature of the infrastructure: critical infrastructure

Lastly, what makes the matter even more complex is that the hydrogen infrastructure that needs to be planned can be considered to be critical infrastructure. This infrastructure is critical for modern society, but is also vulnerable to various risks. Hydrogen infrastructure poses certain risks to the environment, like explosion risks, that should be taken into account during the planning phase. Such risks are an example of negative external effects. Laffont (1989) describes externalities as *"the indirect effect of a consumption activity or production activity on the consumption set of a consumer, the utility function of a consumer or the production function of a producer"* (Laffont, 1989, p. 112). Certain functions in an area might be (in)directly impacted by the (negative) effects of another proximate use. This may concern external effects like air or noise pollution that cause a welfare loss to other uses in the area.

Large parts of the rules and regulations for critical infrastructure are enshrined in rigid laws. In the Netherlands, a probabilistic approach to land use planning in hazardous situations is applied, in which identified hazards are calculated and compared to acceptance criteria. The acceptance criteria are based on a quantitative risk assessment (QRA). Legally binding maximum acceptable risk quantities are defined by law. Subsequently, risk maps with risk contours are created to inform the planners and other stakeholders (Basta, et al., 2006).

In land use planning for hydrogen infrastructure, the risks of the hazardous installations need to be taken into account. This may include explosion or fire risks related to the infrastructure. The hazardous nature of hydrogen infrastructure makes it very important to make a well-considered decision on the planning of the infrastructure. It will be irresponsible to speed up the planning process, while compromising on safety measures. That makes the case of reducing delay in the planning of hydrogen a very delicate one, since the hazardous nature of the infrastructure sets high demands on planning: land use planning of critical infrastructure should be consistent, in proportion to the level of expected risk, and the planning decision-making process should be transparent (Christou, et al., 2011).

3] Methodology

3.1] Research design

Based on the research question for this research and the previous literature review, the research design for this thesis is provided in **figure 2**. The figure explains how the main question of this research is answered in this study. Formal and informal institutions and rules currently shape the way actors jointly plan the necessary critical hydrogen infrastructure. Actors try to balance the prevailing environmental, social and economic interests while planning the hydrogen infrastructure. However, actors are frustrated by delays during the planning phase of the infrastructure.

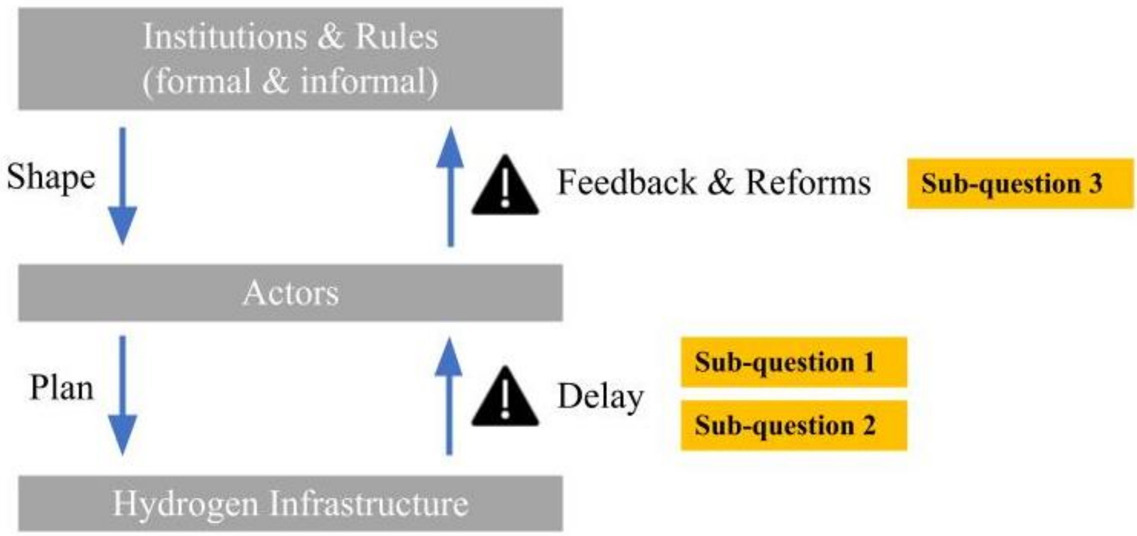

Figure 2: The research design for this research. Source: own work.

Firstly, it is important to get a clear understanding of the nature of the experienced delays. Sub-question one explores what exactly can be considered to be delay during planning. In the literature review, this first sub-question has already been discussed. In short, delay is *"any period over and above what is necessary or, perhaps, what is reasonable to determine an application".* Secondly, by focussing on the case of Groningen Seaports, the causes of delay in hydrogen planning processes are explored. This will aid to answer the second sub-question of this thesis. It will be important to investigate what exactly is considered to be delay during the planning phase, who is involved and when this delay happens. Found causes of delay will be categorized into one of the three groups distinguished in the literature review of this study: (I) technological issues; (II) spatial planning issues; or (III) public engagement issues.

When the nature of the delay is clear, actors can use this information to give feedback and aim for reforms that change institutions and rules in order to shorten the delay in the planning decision-making process. This will aid to answer the third sub-question and find out what are possible institutional and regulatory reforms to provide solutions to the current sluggish situation. Results will focus on how to simplify rules for planning the critical infrastructure (Moroni & Buitelaar, 2020), without taking any irresponsible risks for the critical infrastructure, and how the three types of improved connectivity for the institutions (Huck, et al., 2019) could speed up planning.

3.2] Qualitative Approach

To answer the questions of this research, a qualitative approach has been applied, focusing on in-depth interviews with key stakeholders. It is chosen to use a qualitative approach in order to receive rich in-depth information about the opinions of many different involved stakeholders about their perception of the delay, causes of delay, and possible solutions for the delay. Such rich in-depth qualitative insight will help planners in similar situations to look for comparable solutions to tackle delay.

The interviews have been carried out with involved stakeholders in the Groningen Seaports case. In total, sixteen interviews with different actors have been carried out for this study. These sixteen respondents have been selected, because they play a key role in the planning of hydrogen infrastructure in Groningen, or the Netherlands. A brainstorm session has taken place with colleagues at Groningen Seaports in order to identify these key actors, and to check whether these are the most important actors to interview. Furthermore, at the end of each interview, the respondents were asked whether they had contacts that should be interviewed for this study as well. Some of the respondents in this study were found through such "snowball"-technique. The sixteen respondents can be divided into five different groups of actors that are all involved in a different way in the planning of the hydrogen pipeline infrastructure. All parties that have been interviewed can be found in **table 2**.

Table 2: List of interviews for this study.

Number	Date of interview	Interviewed party	Description of party	Type of actor in this study	Respondent's occupation
1	20 April 2021	ILT	Inspector	III] Inspector	Inspector
2	21 April 2021	LSNED	Manager of the pipeline corridor between Rotterdam and Antwerp	V] External expert	Programme Manager Infrastructure
3	22 April 2021	RIVM	Inspector	III] Inspector	Researcher
4	23 April 2021	Provincie Groningen	Province of Groningen	II] Public authority	Project leader hydrogen
5	23 April 2021	NAM	Natural gas exploiter in the northern Netherlands	I] (Semi-)commercial party	Advisor permits and land issues
6	26 April 2021	Omgevingsdienst Groningen	Inspector	III] Inspector	Researcher
7	26 april 2021	Gasunie (I)	Pipeline operator	I] (Semi-)commercial party	Asset manager & environmental jurist
8	3 May 2021	RWE	Energy company	I] (Semi-)commercial party	Project leader hydrogen
9	3 May 2021	Port of Rotterdam	Port authority of the Port of Rotterdam	V] External expert	Programme manager pipelines
10	4 May 2021	Ministerie van Infrastructuur en Waterstaat	Ministry of Infrastructure and Water Management	II] Public authority	Policy officer
11	5 May 2021	Gasunie (II)	Pipeline operator	I] (Semi-)commercial party	Project leader hydrogen
12	6 May 2021	VELIN	Association of pipeline owners in the Netherlands	V] External expert	Director
13	6 May 2021	Gemeente Het Hogeland	Municipality Het Hogeland	II] Public authority	Policy advisor economy
14	19 May 2021	Ministerie van Economische Zaken en Klimaat	Ministry of Economic Affairs and Climate Policy	II] Public authority	Policy advisor hydrogen
15	26 May 2021	Natuur- en Milieufederatie	Environmental action group	IV] Civil society	Director
16	31 May 2021	Groningen Seaports	Port authority & commercial operator of the seaports of Eemshaven and Delfzijl	I] (Semi-)commercial party	Pipeline specialist; Programme manager hydrogen; Manager Strategy & Business Development; Project director hydrogen

Firstly, there is a group of (semi-)commercial regional parties who are directly responsible for the development of the hydrogen infrastructure in Groningen. This concerns pipeline operators, energy companies and Groningen Seaports itself. Secondly, there is a group of public authorities. They are responsible for providing the regulatory framework for the private parties to act, and issuing the required permits. Thirdly, there is a group of inspectors who need to make sure that the planned infrastructure meets safety and environmental criteria. Fourthly, there is civil society, giving a voice to environmental and neighbour interests in Groningen. Lastly, a group of external pipeline experts have been interviewed to provide more information about the technical and the organizational aspects of planning the hydrogen infrastructure. Some of the actors in this final group, like LSNED and the Port of Rotterdam have no direct business in Groningen, but they are external experts that could still provide valuable information about delay in planning hydrogen infrastructure in the Netherlands and possible solutions that are applicable to Groningen Seaports as well.

Interviewees have been asked about their perception of delay during the planning decision-making process, what factors they think contribute to delay in the process and what interventions might help to make the process more efficient and quicker. The interviews are semi-structured (Galletta, 2013), which means that the interviews were based on a pre-set list of topics and questions that are derived from the literature, but there is enough freedom for new questions and discussion during the interview as well.

An entire topic-list with the questions for the interviews is available in **Appendix 8.1** of this document. The topic list starts with some introductory questions about the role and tasks of the interviewed party during the planning of hydrogen infrastructure. Then, the topic list focuses on the perception of the interviewee towards delay: does the actor experience delay, and if so: is there a felt need for reducing the delay? Because many different types of actors are involved in this study, it is important to get a clear idea of the perceptions about delay that are present. After this, the topic list focuses on answering the second sub-question of this study by focusing on the causes of delay. This part of the topic list is divided into three sections, corresponding with the three types of delay observed in the literature part: technological delay, delay due to public participation and delay due to the planning and regulation process. Lastly, the topic list focuses on institutional and regulatory solutions for the experienced delay, in order to answer sub-question 3.

Questions about solutions are already posed in the topic-list at the end of the questions about each of the three types of delay, but there is also a separate part in the topic list that more generally focuses on overarching solutions. This final part puts more emphasis on possible changes in institutions to tackle delay, and on the horizontal, vertical and territorial interventions that could be implemented for this aim. The topic-list in the appendix can be considered to be a ‘general’ topic-list. In each of the sixteen interviews, this topic-list was used as a basis for the conversation, but usually some extra questions have been asked that applied only to that certain respondent.

Interviews have been carried out online via Microsoft Teams in April and May 2021. Enough interviews have been carried out until the ‘point of saturation’ (Saunders, et al., 2018) was reached and no new information emerged from the interviews. Interviews have been fully transcribed and coded in NVIVO for analysis. A full topic list is available in **Appendix 8.1**. The coding tree can be found in **Appendix 8.2**. Full transcripts of all interviews have been put in a separate Transcript Appendix, which can be requested from the author. Quotes from the various interviews have been included in the text of the results chapter of this thesis. These quotes have been translated into English from Dutch. The original, Dutch quotes can be found in **Appendix 8.3**.

Some ethical issues have been discovered in this methodology (Allmark, et al., 2009). First, the construction of hydrogen infrastructure might be a sensible topic, because of the many conflicting (commercial) interests. Will all the respondents be open to share their knowledge about this topic? This problem might be exacerbated, because this thesis is written as part of an internship at Groningen Seaports, a party that is directly involved in the creation of hydrogen infrastructure. To take any possible conflicts of interest into account as best as possible, some actions have been taken. Upon interviewing, the procedures of the interviews have been made clear to the interviewees, and permission has been asked for recording. Confidentiality has been ensured by making the interviews anonymous and it was checked whether the interviewee felt comfortable with the online nature of the interview. A full written transcript of each interview was sent to each interviewee after the interview had taken place, so that the interviewee had the opportunity to respond to the transcript. All of the respondents agreed with carrying out the interviews. Transcripts were sent to the respondents and all of the respondents have agreed with the contents of the transcripts as well.

3.3] The case: Groningen Seaports

This research focuses on hydrogen pipeline infrastructure in the ports of Groningen Seaports. Groningen Seaports is the port authority and commercial operator of the ports of Delfzijl, Eemshaven and adjoining industrial sites. In total, Groningen Seaports manages an area of approximately 2600 hectares. Both ports are equipped for the storage and transhipment of a wide range of goods. In the port of Delfzijl, mostly chemical and circular industries are located. The Eemshaven is mostly specialised in offshore wind and data centres (Groningen Seaports, 2020). A map of both ports can be found in **figure 3.**

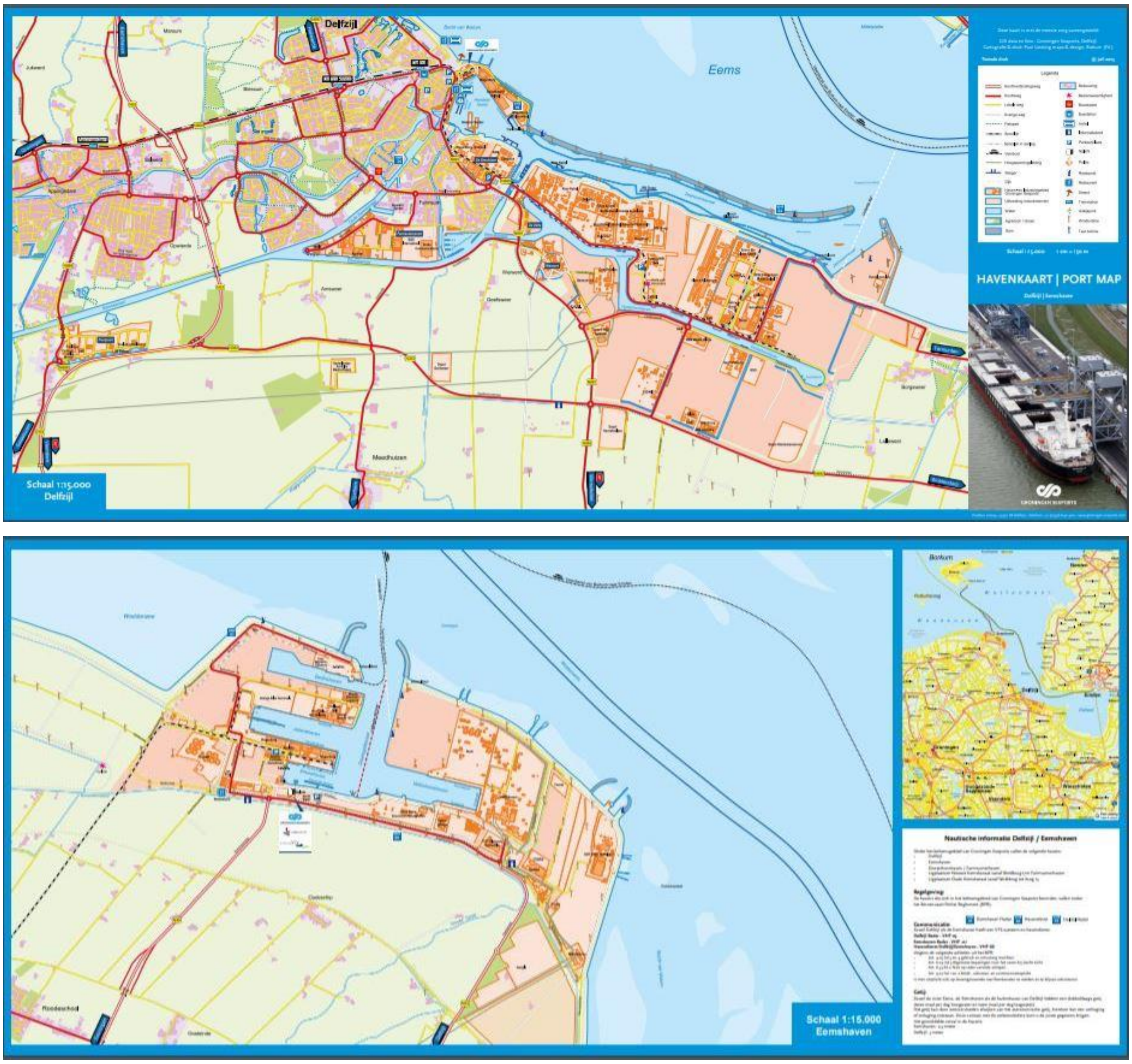

Figure 3: Maps of the port of Delfzijl (above) and Eemshaven (below). *Source: Groningen Seaports.*

In their Business Plan 2021-2025 ('Bedrijfsplan 2021-2025', Groningen Seaports, 2021), Groningen Seaports expresses its aim to invest in the development of hydrogen infrastructure in their ports. They understand the potential of (green) hydrogen in their ports, and invest and/or take part in multiple hydrogen projects (Groningen Seaports, 2020). Groningen Seaports is part of HEAVENN, a cooperation of 31 public and private parties from six European countries. Together, they work on a wide array of projects in the northern Netherlands to create the biggest hydrogen hub of Europe: the Hydrogen Valley. For the future of this Hydrogen Valley, an Investment Plan Hydrogen (Investeringsplan Waterstof Noord-Nederland, 2020) has been drawn up, in which big investments are pledged for hydrogen infrastructure in the northern Netherlands. Investments aim at the production of blue and green hydrogen, building the necessary infrastructure, and the transformation of existing industries to be able to use hydrogen. There is a great potential for hydrogen in the northern Netherlands, since there is enough space for wind parks at sea and for the production of hydrogen on the land; the existing gas infrastructure can be used to transport the hydrogen; and there is existing expertise in the region about the trade in gases.

There are multiple key projects that are going on in Hydrogen Valley. Firstly, in the project NorthH_2, a consortium of Groningen Seaports, Shell, Gasunie, RWE and Equinor is working on creating a wind park at sea that will deliver electricity to produce 800,000 tons of hydrogen per year in 2040. In 2027, the first wind turbines will be erected in the North Sea. Furthermore, a new 50 MW electrolyser of the energy company RWE in Eemshaven will use energy from wind to create green hydrogen. This is part of the Eemshydrogen project, as projected in **figure 4**. In the Eemshydrogen project, a hydrogen pipeline network will transport produced hydrogen from Eemshaven to all kinds of off-takers in Delfzijl. For example, the Delfzijl-based company BioMCN could use hydrogen to make biofuel (Hammer, 2020).

Figure 4: Project Eemshydrogen. *Source: RWE*

Groningen Seaports could be responsible for developing this pipeline to transport the hydrogen between the two seaports. Groningen Seaports is currently looking at creating a new, direct hydrogen pipeline between the Eemshaven and Delfzijl. Such a direct pipeline to transport hydrogen does not exist at the moment between the two seaports. Groningen Seaports is aiming to construct a pipeline made of thermoplastic composite to transport the hydrogen between the two ports. The benefits of a thermoplastic pipeline, compared to a steel pipeline, is that it can be constructed more quickly and that the costs of construction are lower. However, the planning process is still facing delays, which will be explored in this thesis.

Currently, Gasunie is also working on creating a national hydrogen backbone that will also connect the Eemshaven and Delfzijl. However, it will not be until at least 2026 before this backbone will be completed. That is why there is a current need to swiftly construct a new pipeline between the two seaports. Furthermore, a new, direct pipeline between the two ports could transport hydrogen at higher purity than the hydrogen backbone of Gasunie (>98%), which could be a benefit for some of the off-takers of the hydrogen, who require hydrogen of high purity. The new pipeline will be an open access system, which means that multiple parties will be able to make use of the pipeline to transport hydrogen. However, the first concrete project for which the pipeline will be constructed is to transport hydrogen from the 50 MW electrolyser of RWE in Eemshaven to off-takers in Delfzijl. In the future, more hydrogen projects, like the ones indicated in the "Investeringsagenda Waterstof", might make use of this pipeline to transport hydrogen as well (Avebe, et al., 2021).

This thesis will take this planned thermoplastic composite pipeline between Delfzijl and Eemshaven as a case study to see what causes of delay exist in the current planning process and what might be solutions to speed up the planning of this hydrogen infrastructure. The next chapter will discuss the results of the study.

4] Results

The aim of this study is to investigate the multiple factors causing delay during the planning phase of hydrogen pipeline projects in Groningen, while taking the planned pipeline between the Eemshaven and Delfzijl as a case. In the upcoming sections, the found reasons for delay will be explored. The found reasons for delay will be classified according to the three groups distinguished in the literature review (in **table 1)**, firstly focusing on technical causes of delay (section 4.2), secondly on delay due to planning and regulations (section 4.3), and thirdly on delay due to public participation (section 4.4). Any bottlenecks that cause delays will be presented and discussed in these sections, and stated solutions will be named. At the end of this chapter, overarching institutional changes to reduce delay during the planning phase will be presented in section 4.5, as proposed by the respondents. A synthesis of all found causes of delay and possible solutions will be provided in **table 3** in section 4.6. First, however, it is of importance to get a clear view of the perception of delay in the Groningen Seaports case. This will be discussed in the upcoming section 4.1.

4.1] Perception of delay

In the literature review of this study, delay is portrayed as an important factor of nuisance in (hydrogen) infrastructure planning. As a first step in this study, it is important to check the perception of delay that is present among the respondents of this research to see whether there are different perceptions about the presence of delay and whether there is indeed a felt necessity to address the delay and speed up planning.

Following from the sixteen interviews that have been carried out for this research, it can be concluded that there is wide agreement among the respondents that delay during the planning of hydrogen infrastructure in Groningen is an issue which is present and should be addressed. Indisputably, the respondents in this study voiced the univocal need to speed up the planning process and address the issues that stand in the way of a rapid rollout of the hydrogen infrastructure in the Netherlands (interview 1-16). The main reason for wanting to speed up the planning process of hydrogen infrastructure is because hydrogen is part of the ambitions to work towards an energy neutral system in the Netherlands, which will help to achieve the climate goals of the Paris Climate Agreement of 2015, the Dutch Klimaatakkoord and European climate ambitions (interview 6, 14, 16):

"Green hydrogen helps us to achieve the goals of the Paris Agreement faster than we thought and it creates new, sustainable jobs in the northern Netherlands. We need to speed up now" (interview 14).

Hydrogen will in the future be a reliable and clean source of energy in the Netherlands, and will create jobs as well. Specifically for (sea)ports, a focus on hydrogen can help to play a role as an important hub in international energy flows, where hydrogen will be transported via pipelines to all kinds of off-takers all over Europe (Wiebes, 2020). Since it is expected that (green) hydrogen will play this vital role in the future Dutch carbon-free energy economy, it is important to address the factors of delay during the planning of the necessary hydrogen infrastructure for this energy transition, and make sure that a fast roll-out of this critical infrastructure is possible (interview 14).

Some of the respondents, however, did provide the disclaimer that no unnecessary or irresponsible risks for the environment should be taken in reducing this delay. A balance is necessary between speeding up the planning process of hydrogen infrastructure, while keeping into account the risks and effects of this critical infrastructure on the environment (interview 1, 3, 9, 15). This issue will be discussed more extensively in chapter 4.3.

Delay is often a result of the many interdependencies that exist between multiple regional infrastructure projects. In Groningen, various parties work simultaneously on different projects concerning the production, buffering, and transportation of hydrogen. Many of these projects are dependent on the progress of other projects in the region for their own progression: any delay in other projects affects their own time planning as well (interview 16):

"You should take a look at all the interactions that exist during the planning process, and how those relate to delays. All involved parties have their own time schedule. However, one party's time schedule can only be followed if a 'check mark' appears in the time schedule of another party. So it is not like you make your own time schedule and you can go all the way down that route by yourself. To achieve progress, you regularly depend on a 'green tick' in one of the parallel time schedules. And if there is a delay in one of the many time schedules, the whole process actually collapses." (interview 16)

Since it is clear that delay *is* apparent in the planning process of hydrogen pipeline infrastructure, the found reasons for delay will be explored and classified in the upcoming sections 4.2, 4.3, and 4.4.

4.2] Delay due to technical aspects

The planning of new hydrogen pipeline infrastructure could be delayed due to uncertainties about the techniques that must be used for the planned infrastructure. Although some technical bottlenecks do still exist, respondents noted that most of the technical problems around high-pressure hydrogen pipeline infrastructure will be resolvable in the future, and will thus not be the main cause of most of the delays (interview 1, 4, 5, 6, 7, 9, 11, 12, 16). There is already years of experience with using hydrogen and constructing hydrogen infrastructure in the industry. The biggest difference with current use is that hydrogen will be applied on a larger scale in the future. Multiple pilots in the province of Groningen will try and look for missing information about the techniques that are necessary for the safe production, transport and buffering of hydrogen (interview 4). VELIN, the association of pipeline owners in the

Netherlands, is actively stimulating these pilots and tries to enthuse (private) parties to test new hydrogen innovations (interview 12).

No great technical issues are to be expected when constructing new hydrogen pipelines made of steel. There is years of experience with constructing these kinds of pipelines and the regulations and guidelines for constructing these pipelines are clear. There is a distinction, however, between using hydrogen as an industrial gas or as an energy source. The first purpose will mostly require pipelines with smaller diameters, and lower pressures (<16 bar) for the distribution of hydrogen in the industry. The second purpose will mostly require pipelines with bigger diameters, and under higher pressure (>16 bar) for the large-scale transportation of hydrogen (interview 9). However, in both cases, when steel is used as a material for the pipelines, no big technical issues leading to delays are to be expected:

"Technically speaking, when I talk about steel pipes, a well-known product, not a new product, it has already been done so often that delays in terms of technology do not often appear. Unless there are problems with the supply of materials." (interview 1)

Although steel is the most commonly used material for hydrogen pipelines, Groningen Seaports is trying to look at new, innovative ways to construct hydrogen pipelines. Two different techniques will be discussed in the upcoming sections: the construction of pipelines made of thermoplastics (section 4.2.1), and the reuse of existing natural gas pipelines for hydrogen (section 4.2.2). Compared to pipelines made of steel, these two techniques have the benefit that they could potentially provide a quicker and cheaper way to construct hydrogen infrastructure. However, uncertainties about the technical specifications of these new two techniques could become a cause of delay in planning. The two cases will be further explored below:

4.2.1] Constructing new thermoplastic hydrogen pipelines

Groningen Seaports is aiming to construct a reinforced thermoplastic composite pipeline for the transportation of high-pressure hydrogen between Eemshaven and Delfzijl. Thermoplastic composites are materials that have not been used before in the Netherlands as the material for pipelines for high-pressure transportation of hydrogen. Although this material has been used often for the low-pressure distribution of hydrogen in the industry (interview 5). A benefit of a thermoplastic pipeline, compared to steel pipelines, is that construction is quicker and cheaper (interview 16), as is further explained below:

In the case of steel pipelines, steel pipeline parts of around 12 metres long are usually laid down and are welded together. This takes a lot of time, and requires a lot of space:

"The construction of a steel pipeline takes up a lot of space and you must have room for your equipment. The bigger your pipes, the bigger the equipment you need. And that requires a lot of time, because you need to weld the parts together, you have to dig a hole, put the pipe in it, make the connections… So that takes a long time and it causes a lot of nuisance for your environment as well." (interview 16)

In the case of thermoplastic pipelines, however, pipe parts of around 400 metres can be pre-fabricated. This means that fewer parts need to be welded on place, which saves space, time and money (interview 16). There are, however, two technical issues with thermoplastic pipelines that could cause delays during the planning phase: Firstly, the connecting parts of the thermoplastic pipelines are critical parts of the pipelines, and adequate welding should be ensured to keep the risks of leaks as low as possible (interview 1). Secondly, the integrity management of thermoplastic pipelines might differ a bit from steel pipelines. Pipeline operators must prove the integrity of their pipelines. For example, they can use deformation tools to check thermoplastic pipelines for any dents. Currently, however, there is no 'intelligent pig' that can be used for thermoplastic pipelines. An intelligent pig is a technical device that is used to carry out multiple maintenance operations in pipelines. For example, it measures how deep a pipeline can be found underground and it can test the integrity of the walls of the pipeline. Although an 'intelligent pig' is not necessarily required for pipeline integrity tests, it could help to develop such equipment for thermoplastic pipelines for smoother future integrity tests (interview 6).

These minor technical uncertainties about whether thermoplastics can be used to construct high-pressure hydrogen pipelines could become a cause of delay, already during the planning phase. However, when these technical uncertainties are overcome, the construction of thermoplastic pipelines is faster and cheaper than pipelines made of steel, which means that thermoplastic pipelines could actually help to reduce delays in the long run. It is now important to investigate whether thermoplastic pipelines and their connecting pieces are safe to use through material tests (interview 1). Material tests for hydrogen pipelines are carried out in the project NATURALHY of the European Union (interview 6). New insights about safety and properties of new materials like thermoplastics should become part of new pipeline construction regulations. This will be discussed in chapter 4.3.

4.2.2] Reusing existing gas pipelines for the transportation of hydrogen

It is also possible to reuse existing natural gas pipelines for the transportation of hydrogen. In Groningen, this could concern the reuse of natural gas pipelines currently owned by Gasunie or the NAM around Groningen Seaports (interview 5, 7, 11). Gasunie, the present-day operator of gas pipelines in the Netherlands, is currently working on creating a hydrogen backbone in the Netherlands. The aim is to finish this backbone in 2030. The backbone will connect five big industrial clusters in the Netherlands, including Groningen Seaports. The backbone will have a size of roughly 1,100 kilometres. 200

kilometres of the backbone will consist of new pipelines, 900 kilometres will consist of reused gas pipelines for the transport of hydrogen (interview 6).

Worldwide, there are not many cases where natural gas pipelines have been reused for the transport of hydrogen. However, some first pilots have shown that it is technically possible to reuse pipelines to transport hydrogen (interview 11). The technical possibilities for the reuse of existing pipelines for the transportation of hydrogen are studied in the HyWay27-report. This report also calculates expected demand and production of hydrogen until 2050, and takes a look at rules and regulations surrounding the reuse of pipelines. By all means, it is calculated that the reuse of existing pipelines is cheaper than constructing new steel hydrogen pipelines, even though some modifications in the pipelines will be necessary (interview 14). At the moment, an excellent natural gas pipeline network can be found in the Netherlands. It would be a waste of resources not to reuse the existing infrastructure for the transportation of hydrogen:

"In my opinion, it would be a huge shame to throw the existing gas network overboard and say: we are switching to hydrogen and we will construct it all over again. I think we can use the natural gas network very well for hydrogen with some simple adjustments. But that requires enormous coordination." (interview 12)

Although the reuse of gas pipelines for hydrogen looks viable, there are some technical uncertainties about this intervention, which could become a cause of delay in the hydrogen backbone project. It will be important to investigate whether the diameter, material, pressure and compressors of the existing pipelines are suited to reuse the pipelines for the transportation of hydrogen (interview 5). All appendages of the existing pipes (like compressors or lids) will have to be checked and/or replaced, and the pipelines will need to be cleaned before reuse (interview 11).

Furthermore, old pipelines should be checked for potential leaks (interview 4). Especially the connecting parts between pipelines are vulnerable for leaks and should be checked and/or renewed (interview 1). The biggest difference between hydrogen and natural gas is the size of the molecules. Hydrogen molecules are smaller than natural gas molecules, so the chance of leaks is bigger for hydrogen. However, tests have shown that the chance of leaks is not necessarily bigger for hydrogen, compared to natural gas (interview 6). Another issue is 'hydrogen embrittlement': small hydrogen atoms can get into the metal of the pipeline. Under big pressure changes, a leak could appear after some years. This could be averted by preventing big fluctuations in pressure or by applying an oxide layer to prevent hydrogen from getting into the metal wall of the pipeline (interview 5).

4.3] Delay due to planning and regulations

For every new planned pipeline, a planning process is set up, in which multiple steps are followed in order to plan the construction of the new pipeline. A roadmap for the planning of pipelines has been worked out by the Association of Pipeline Owners in the Netherlands (VELIN, Vereniging van Leidingeigenaren in Nederland). Members of VELIN are responsible for the safe construction and management of pipelines carrying hazardous substances, and are most often the initiators of the construction of new pipelines (Driessen, 2020). In most cases, the eight steps in **figure 5** are followed by the initiators during the planning phase of a new pipeline (Lindenbergh, et al., 2018).

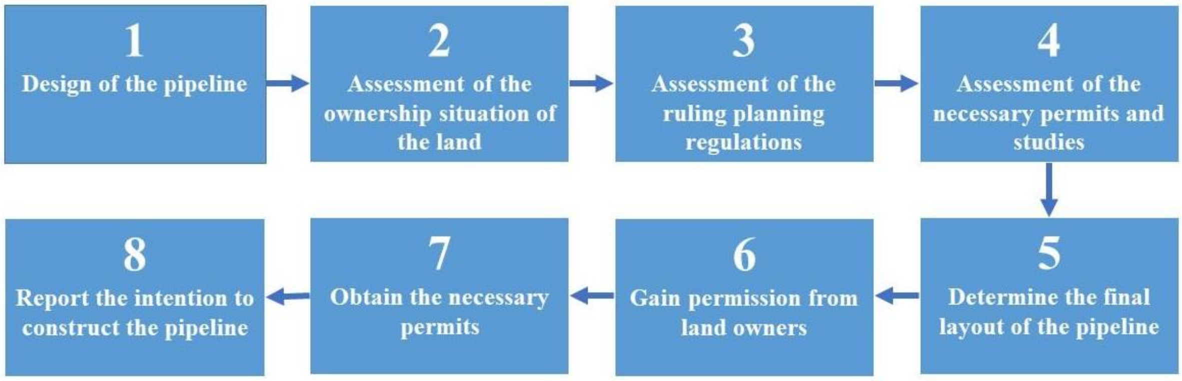

Figure 5: Eight steps of planning a pipeline. *Source: own work, based on Lindenbergh, et al. (2018).*

As a first step, the initiators of a new pipeline will decide on the desirable design of the pipeline. Preferred size, material and pathway of the pipeline will be chosen and will be indicated on a map. After this step, initiators will have to collect a variety of information, like the ownership situation of the land in the land register (step 2), the current zoning plan and its regulations (step 3), and which permits and studies are required for the construction (step 4). The planning of a new pipeline will require studies into the expected (environmental) effects and risks. If necessary, an environmental impact report (milieueffectrapportage) should be drawn up. If no more issues are to be expected from these first steps, the initiators can decide on the definitive design and pathway of the pipeline in step 5.

Before the initiators can start with the construction of the pipeline, they need to gain permission from landowners in step 6 (usually through a ‘Recht van Opstal’), and obtain the necessary permits in step 7. For the construction of the pipeline, all kinds of permits from the (local) authorities will be necessary. This involves permits considering environmental effects, archaeological values, but also permissions when a pipeline crosses another critical infrastructure, like the electricity grid. The initiators need to show through their studies that they meet safety requirements and regulations, before they will receive a permit.

When the required permits are issued, and it becomes certain that the pipeline will be constructed, the initiators should report the intention to construct the pipeline to the land register

(Kadaster). The pipeline will now be taken into account in other spatial plans in the region and the pipeline becomes part of the provincial risk map and the register of hazardous substances (Risicoregister Gevaarlijke Stoffen). This is the eighth step of the planning phase and construction can begin right after this final step has been completed.

The eight steps as shown above are usually followed during the planning process of new pipelines. However, it is new that hydrogen infrastructure is constructed on such a large scale in the Netherlands, and this might bring along bottlenecks when this roadmap is followed in the Groningen Seaports case, due to unclear or missing legislation and guidelines, which lead to delay in the planning process. The following section will discuss any delays that appear in the Groningen Seaports case due to unclear guidelines (for example, in the NEN-regulations) (section 4.3.1), unclarities in the permit issuing process (section 4.3.2), and lastly, any delay that is due to unclarities in safety regulations, as part of the Besluit externe veiligheid buisleidingen (Bevb) and the Regeling externe veiligheid buisleidingen (Revb) (section 4.3.3). Safety of the pipelines is a key issue, since hydrogen pipelines are critical infrastructure. However, actors are looking for a delicate balance between speeding up the planning process and guaranteeing a safe construction and use of the pipelines. This section will therefore conclude with a discussion about the trade-off between efficient planning and guaranteeing enough (external) safety for this critical infrastructure (section 4.3.4).

4.3.1] Unclarities in the NEN-guidelines

The rules and standards for the design of pipelines are made explicit in the NEN-3650 regulations (and NEN-7244 for low pressures of gas). These regulations provide security guidelines for the design, construction and management of pipelines. One could see the NEN-regulations as some kind of management system that ensures that pipelines are constructed in a sufficient way (interview 10). Overall, respondents state that the NEN-regulations for hydrogen pipelines are relatively clear. The NEN-regulations are not medium-specific: it does not necessarily matter what is carried through the pipelines. This means that existing NEN-norms could be applied to hydrogen pipelines as well, though perhaps some small details in the guidelines should be changed, and thorough security research is necessary (interview 11).

There is, however, ambiguity about the use of thermoplastics as a material for high-pressure hydrogen pipelines. The thermoplastics used by Groningen Seaports are a composite. Every composite has its own traits, and that makes it very hard to make one guideline for composite pipelines (interview 16). The NEN-3650-3 regulations for thermoplastic pipelines currently do not contain any guidelines for these types of thermoplastic composite pipelines in relation to the high-pressure transport of hydrogen (interview 1):

"If you buy a composite pipe, it will be dissimilar at every supplier you buy from, and the pipes will consist of different materials, and will have different strengths and behaviour. That makes it very difficult to capture a composite in one standard. So that is the background: it is indeed plastic, but it is not laid down in the NEN nor is there a description of how to handle it." (interview 16)

The lack of NEN-guidelines for the construction of (thermoplastic) hydrogen pipelines is a hiatus in the existing regulations that causes uncertainty, and thus delay, for initiators of a thermoplastic pipeline, such as Groningen Seaports in the case of the hydrogen pipeline between Delfzijl and Eemshaven:

"Then you have the Groningen Seaports pipeline. That is a thermoplastic pipeline. That is the most difficult one, because that pipeline must comply with (...) a number of NEN standards, for example the NEN-3650. And plastic pipes for hydrogen are not included in those NEN standards. So there are no specific requirements for this type of material. (...) Groningen Seaports wants to apply fibre-reinforced thermoplastics. However, the NEN standard does not yet contain any requirements for this application. This means that the plastic pipelines as Groningen Seaports wants to install are actually not covered by regulations. That does not mean that they cannot construct it, but they are treading a new path. A path no one has walked in the Netherlands. And then you run into some problems and delays." (interview 1)

To avoid this problem, initiators of a thermoplastic composite pipeline (like Groningen Seaports) could choose to use an international norm instead of the NEN-3650 when constructing a pipeline. This is allowed under Dutch law. The ILT will check whether such an international norm meets the criteria of the NEN-3650 (interview 1). For example, as a plan B, Groningen Seaports was looking at applying international standards (such as API, ASTM and IGEM) to hydrogen pipelines made of thermoplastics. It is up to the ILT to decide whether these international norms meet the requirements of the NEN-3650 (interview 3).

Following a first study, it looks like it is feasible for Groningen Seaports to construct the thermoplastic composite pipeline according to current NEN-guidelines: with some extra research and justifications to apply the correct parameters, the NEN-3650-3 could be used for the design of thermoplastic composite material for the new pipeline (interview 16). However, it took a lot of time for Groningen Seaports to investigate whether this new material could truly be used according to the NEN-3650 guidelines. Therefore, it would be efficient to try and change the Dutch NEN-3650 guidelines in such a way that they better include thermoplastic composite pipelines as well, not only for the transportation of hydrogen, but for any transported medium. This could help speed up future hydrogen pipeline projects where thermoplastic composites are used (interview 10):

"The NEN regulations must be adjusted, so that plastics are included in the NEN-3650, and also for several applications. Not only for hydrogen transport, but also for other (hazardous) substances above 16 bar. What Groningen Seaports does is specifically request permission for a certain type of plastic:

Soluforce. That is great fun, but there are hundreds, thousands of types of plastic. Legislation needs to become more generic in this regard. Other plastic manufacturers should also become acceptable. That would prevent a lot of delays in the future." (interview 1)

Updating the NEN-regulations will thus help to prevent future delays. Any changes in the NEN-3650 regulations will have to be initiated by the NEN-commission. This commission is formed by pipeline operators, VELIN, the Ministry of Infrastructure and Water Management (I&W), the RIVM, and manufacturers (interview 3, 12). The initiative to change the NEN-guidelines to better include thermoplastic composites could come from any member of the commission, for example, from the manufacturers of the materials (interview 16). The role of the Ministry of I&W is to check whether changes to the NEN-regulations do not violate laws and regulations (interview 10). Such a change in Dutch NEN-regulations could, however, take years (interview 1).

What makes the Dutch NEN-system unique is that it is very detailed, especially compared to other European norms (interview 10). It could be efficient to take a look at European regulations at the same time as well and take a look at how European guidelines for the construction of (hydrogen) pipelines could be streamlined with new NEN-regulations as well (interview 1). However, some respondents think that a European solution will be difficult in this case, because every country has a different approach to risk management and norms. In Germany, for example, risk analyses are not used at all (interview 3).

4.3.2] Unclarities in the permit process & zoning plans

The construction of a pipeline does not require a permit under the Wabo (Wet algemene bepalingen omgevingsrecht, 2018), given that the pipeline fits within the ruling zoning plan. If the latter is not the case, most of the time, a change in zoning plan will be necessary to best create the required legal framework for the planning of a pipeline. However, all kinds of permits and permissions are still necessary to construct a pipeline, for example environmental permits (milieuvergunningen). These permits protect the interests of other parties, reduce risks or provide regulations for the protection of the environment (interview 6, 15).

In the case of hydrogen pipelines, not many issues are to be expected considering permit issuing. There is already some experience with issuing permits for electrolysers and hydrogen pipelines in Delfzijl, for example (interview 13). The environmental effects of pipelines are relatively small: the pipes themselves only require a relatively narrow space and there are almost no emissions, because hydrogen and oxygen are not seen as harmful greenhouse gases (interview 4). Also for private parties, it is usually clear what kind of information they need to provide when applying for a permit: the requirements are all provided in the "Regeling Omgevingsrecht" (Ror) (interview 7). During preliminary consultation, private parties and permit issuers discuss what is necessary for the permit application. Any unclarities will be solved as much as possible before the official permit application (interview 4, 8).

Respondents from the province and municipality in this study communicated that they believe to have the required skills and expertise to make a good assessment of a project and issue the required permits (interview 4, 13). If not, they can be aided by the Omgevingsdienst, but also the Veiligheidsregio (interview 9, 13). The Omgevingsdienst follows the Wabo-regulations for their investigations. These Wabo-regulations are clear most of the time. The only stated issue here is that it sometimes remains unclear if regulations for environmental permits that only state to apply to "(natural) gas" could also be applied one-to-one to "hydrogen". In all likelihood, no big issues are to be expected here, but it is a factor that should be clarified in the future (interview 7):

"There are no permit regulations specifically for "hydrogen", but only for "gas". (...) I asked a lawyer: can I read "hydrogen" instead of "gas" in my permit regulations? And he said: yes you can, why not? (...) If that is true, it means that you can simply fill in "hydrogen", where the regulations now only state *"gas". So that is not really a bottleneck anymore."* (interview 7)

Permit issuing for the national hydrogen infrastructure will probably fall under a so-called "Rijkscoördinatieregeling", in which the national government is responsible for permit issuing. The use of this regulation might not always be desirable, because it 'overrules' the interests of other parties, and might actually reduce the support of other stakeholders for the project, since they are forced to accept the project. The issue of participation and stakeholder support is discussed more elaborately in section 4.4. The "Rijkscoördinatieregeling" could, however, help solve any local issues in capacity or competency (interview 9).

Whenever the permits for a new pipeline are issued by the authorities, the pipeline should also be included in the municipal zoning plans. Under the upcoming Omgevingswet, parties can use a "Projectprocedure" to efficiently change multiple zoning plans (in multiple municipalities) in one go for the construction of hydrogen pipelines. This helps to speed up the procedure to change zoning plans to include new hydrogen pipelines (interview 6). Zoning plans will also need to be changed in the case that an existing natural gas pipeline is reused for the transportation of hydrogen. In most of the cases, it will be enough to use a 'Wijzigingsbesluit'. By using this, the function in the zoning plan will remain the same, only the medium will change from "natural gas" to "hydrogen" (interview 13).

Permit issuing and the "Inpassingsprocedure"

Pipelines that carry hazardous gases and/or that are under high pressure (>16 bar) must follow legislation from the so-called "Besluit externe veiligheid buisleidingen" (Bevb). These pipelines receive a permit from the Dutch national government. Spatial integration is required through a mandatory "Inpassingsprocedure". Such a procedure can be lengthy. Pipelines that do not fall under the rules and regulations of the Bevb, for example because they do not carry any hazardous materials or transport a gas under low pressure (<16 bar), receive a permit from the municipality and the province. In this case, an "Inpassingsprocedure" is not mandatory, which could save a lot of time in the planning process (interview 16):

"If you ask me about the planning process: where can we save time during the planning for these types of pipes? I think that is in avoiding the risk of an "Inpassingsprocedure". If you can avoid those, you actually have control over the entire time frame." (interview 16)

To speed up the planning of hydrogen pipelines, the requirements for an "Inpassingsprocedure" under the Bevb might be eased for high-pressure pipelines. However, as a short-term solution, constructing a hydrogen pipeline under low pressure (<16 bar) in order to prevent an "Inpassingsprocedure" might be the fastest way to speed up the planning process. This is quite a new and out-of-the-box solution that could be investigated in the upcoming years, and could surely save time in the planning process of future hydrogen infrastructure (interview 16).

New institutions are probably necessary here. Currently, high-pressure pipeline transport is managed by Transport System Operators (TSO's), like Gasunie. These parties construct (hydrogen) pipelines with a pressure higher than 16 bar that must meet the regulations from the Bevb (interview 7). On the other hand, there are the Distribution System Operators (DSO's), like Enexis or Stedin. These parties construct low-pressure (hydrogen) pipelines. These DSO's usually focus on pipelines with a pressure lower than 8 bar (interview 1). This means that there is a lack of focus on constructing pipelines between 8 and 16 bar, and there is currently no party looking at this type of pipeline. Since pipelines in this range still do not fall under the Bevb, no "Inpassingsprocedure" is necessary, and this could seriously save time and prevent delays in future planning processes:

"The entire pressure range from 8 to 16 bar is an unexplored area. (...) If we want to have an energy transition and want to make progress with that, then these kinds of unexplored areas might have to be explored in order to be able to accelerate the process." (interview 16).

Thus, in short, no big issues are to be expected with permit issuing and zoning plan changes for hydrogen pipelines. If parties want to speed up this process, a "Rijkscoördinatieregeling" could be used for pipelines of national importance, or the possibilities to avoid an "Inpassingsprocedure" could be investigated in the future, for example by exploring the 8-16 bar pressure range.

4.3.3] Unclarities in the risk analyses

Hydrogen infrastructure has to be placed in the existing ports of Groningen Seaports. There, the pipelines need to be placed in such a way that they fit between already existing uses. External effects, like noise pollution, but also safety risks, need to be taken into account: the construction of hydrogen infrastructure should not lead to an increased risk for the environment. There are multiple ways to measure the risks of hydrogen infrastructure and mitigate the risks. Central in the Dutch risk approach is that there are certain contours around hazardous infrastructure with different types of risks and regulations that have to be taken into account.

To mitigate the risks surrounding hazardous infrastructure, pipelines are subject to multiple regulations considering external safety. Firstly, rules for assessing the external safety risks of pipelines are drawn up in the 'Besluit externe veiligheid buisleidingen' (Bevb, 2018) and the 'Regeling externe veiligheid buisleidingen' (Revb, 2020). Safety rules for installations can be found in the Dutch Public Safety Decree (Bevi, 2016) and the Dutch Major Hazards Decree (BRZO, 2015). These ordinances lay out the rules for assessing the external safety risks surrounding pipelines and the possibility to grant permits in vicinity to high-risk land uses. Authorities are obligated to take the external safety of pipelines into account when making a zoning plan for an area. The Revb provides guidelines on how to make fitting Quantitative Risk Assessments (QRAs) to get a fair idea of the different risks surrounding the pipelines and how to respond to them. Pipeline owners are legally obliged to ensure a safe design, construction and management of the pipelines. It is important to state that these rules only apply to hazardous pipelines carrying gases at a pressure of 16 bar or higher.

Compared to other modalities to transport hazardous materials (like boats, trains or trucks), pipelines offer a safe alternative that also works 24/7 (interview 12). However, safety measures are key in order to ensure a safe construction and operation of hydrogen pipelines. The risks of hydrogen pipelines are similar to pipelines carrying natural gas, although there are some differences. One great risk of hydrogen is that, in the right oxygen-hydrogen ratio, hydrogen could be very explosive. Furthermore, when there is a fire caused by hydrogen, it will be quite difficult to extinguish it, because a hydrogen fire is invisible. That is why the Instituut Fysieke Veiligheid (IFV) is looking at the best ways to extinguish hydrogen fires (interview 1). However, compared to natural gas, hydrogen is a very light-weighted gas. If there is good ventilation, the gas will volatilize quickly into the air, actually reducing the risk of explosions. Nevertheless, this remains something that needs to be studied more elaborately through tests (interview 7).

Explosion risks are kept to a minimum through all kinds of safety regulations. Initiators of new pipelines are required to make Quantitative Risk Analyses (QRA's) in order to gain insight into the expected risks of the pipeline construction and operation. The RIVM prescribes how risk analyses for pipelines should be carried out. The RIVM cooperates with the Omgevingsdiensten and operators for carrying out these analyses. The RIVM manages the instructions and calculation models for making risk analyses. (interview 3). There are currently two main risk calculation models for pipelines: *CAROLA* is used for calculating the risks of natural gas pipelines, and *Safeti-NL* is used for other pipelines, like hydrogen pipelines (interview 16). If the material of the pipeline, the used pressure, size and transported gas are well-known, creating a suitable risk analysis is not expected to be a big issue, especially when it concerns a pipeline made of steel (interview 7). However, some problems do appear specifically for hydrogen pipelines and/or pipelines made of other materials than steel, like thermoplastics, or when older pipelines are reused for the transportation of hydrogen. These problems are explored in the upcoming two sections.

General unclarities in the calculation of risks for hydrogen pipelines

The RIVM manages its risk calculation models, like Safeti-NL, and private parties use these calculation programmes to make a fitting estimate of the hazards and effects of hydrogen pipelines in order to calculate their 'chance of failure' (interview 10). This concept indicates how often something goes wrong, what the effects of a possible failure are, and what could be suitable measures to mitigate the risks of a pipeline. For natural gas pipelines, Dutch data about the 'chance of failure' are used, because there is already much data available about these types of pipelines. These numbers are relatively opportune, because strict safety measures in the Netherlands are imposed and the frequency of disasters with natural gas pipelines in the Netherlands is relatively low. This leads to a relatively low 'chance of failure' for natural gas pipelines (interview 9)

However, for hydrogen, international data to calculate the 'chance of failure' have to be used, because Dutch data are scarce, since large-scale high-pressure hydrogen transport is relatively new in the Netherlands. The current methods to calculate the risk for hydrogen pipelines therefore use unfit, international data to calculate hydrogen infrastructure failure risks in the Netherlands. These data are probably not perfectly applicable to the Dutch situation, because the actual 'chance of failure' is presumably lower. This leads to a bigger 'chance of failure frequency' for hydrogen, and thus more strict safety requirements for the infrastructure than might perhaps be necessary in the Netherlands (interview 9). Such stricter safety requirements could delay or complicate the planning of new hydrogen infrastructure.

New experiences and research could help to upgrade the current risk calculating programme Safeti-NL to better include a risk calculation model for hydrogen pipelines. It is expected that the RIVM will give an update later in 2021 about renewed calculation models for the QRA's for hydrogen pipelines (interview 10). Based on the advice and the studies of the RIVM, the Ministry of I&W will at the end be the appointed party to decide whether the risk calculation methods for hydrogen pipelines will be changed (interview 10). Gasunie, VELIN and multiple Dutch seaports are also involved in the research process. Gasunie, for example, is studying the safety and risks of hydrogen pipelines in the Netherlands through theoretical studies that focus on international experiences. They want to find out in what ways the transport of hydrogen has similar risks as the transport of natural gas and whether experiences and risk data from natural gas pipelines could also be applicable for hydrogen pipelines (interview 9). Also in the "Vierjarige Waterstof Veiligheid Innovatie Programma", the safety of hydrogen pipelines is investigated and policy interventions to keep risks low are discussed (Wiebes, 2020).

Unclarities in calculating the risks of thermoplastic composite hydrogen pipelines

Considering the application of thermoplastic composite pipelines in Groningen Seaports, the current risk analysis methods of the RIVM are unable to calculate the QRAs for thermoplastic composite pipelines, simply because there is little experience with calculating risks for this type of material. Because there is no comparison material, the 'chance of failure' of thermoplastic composite pipelines is thus unknown (interview 16). This uncertainty leads to severe delays in the planning process, due to a lack of available data on the chance of failure of these pipes:

"An example is the thermoplastic pipeline of Groningen Seaports. A certain thickness has been used for the pipeline. That thickness is actually thicker than it should be. So you could say: the chance that this pipeline will tear open or break is therefore smaller than the chance that is currently used. So you could translate that into a smaller chance of failure. If there were enough test data for that, you could also apply it. (...) But there must be enough users and there must also be enough information about it." (interview 10)

The Ministry of I&W and the ILT have now asked the RIVM to study the risks of thermoplastic pipelines for the transportation of hydrogen (interview 3). The RIVM is studying whether the risks of the thermoplastic pipelines are comparable to hydrogen pipelines made of steel (interview 10). Based on research, the RIVM is exploring the chances of failure of thermoplastic pipelines and will update its calculation models. There is, however, little information about failures in thermoplastic pipelines. Because there is such a lack of information, the RIVM will in the end probably take a safe margin for the risk analyses for thermoplastic pipelines (interview 10).

Groningen Seaports has now made its own calculation of the expected risks. Earlier this year, the RIVM and the Ministry of I&W gave positive feedback on this new calculation method for thermoplastic high-pressure hydrogen pipelines (interview 16). More studies into the 'chances of failure' of thermoplastic pipelines will help to make risk calculations quicker in the future, and will reduce delay due to research into the expected chance of failure frequencies.

Changes in risk contour regulations

To take the risks surrounding pipelines into account, different contours are created around hazardous infrastructure as well (see **figure 6**). Firstly, there is a barrier contour (belemmeringenstrook) of four or five metres around the axis of the pipeline. This is an area with strict regulations to prevent activities that could harm the pipeline or cause explosions, like drilling into the ground. Almost all types of objects are not allowed in this contour to guarantee access to the pipeline whenever necessary. Secondly, there is the place-bound risk (plaatsgebonden risico) contour that is usually around 35 metres around the axis of the pipeline. No vulnerable uses may be placed within this contour at all. Thirdly, there is the group risk (groepsrisico) contour. In this contour, some uses are allowed, but there are limitations on the amount of people that may be present in this contour, because there is a high risk of mortality for the people present in this contour during a calamity. Local authorities must weigh the risks whenever they place a new function in this contour. Risks could be mitigated by multiple actions, like strengthened supervision or by applying a warning ribbon on the entire pipeline to warn anyone who digs close to the pipeline (interview 16).

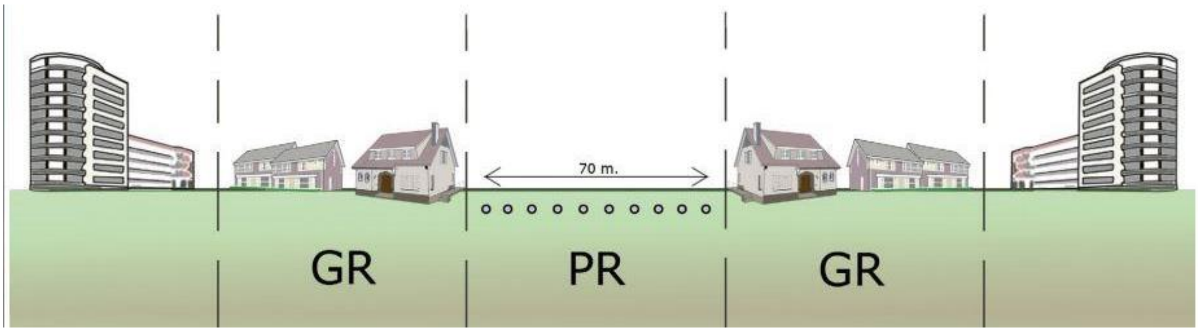

Figure 6: Pipeline with place-bound risk (PR) and group risk (GR). Source*: Ministerie van I&M*

Risk contour requirements will change in the upcoming Omgevingswet, which will take some time getting used to (interview 3). Under the Omgevingswet, the PR-contours will remain at10^{-6}, but new “Aandachtsgebieden” will be introduced as well, with three types of risks: fire, explosions and toxicity. Toxicity will not be a big issue in the case of hydrogen. However, explosions and fires are an important risk. In the new so-called “Voorschriftgebieden”, there are restrictions on the construction of vulnerable objects, like hospitals (interview 10).

According to VELIN, some issues are to be expected here, since these new Aandachtsgebieden around pipelines are complex and quite subjective. It is expected that Aandachtsgebieden will not sufficiently take into account the risks and mitigation possibilities for buildings close to high-pressure pipelines. Mitigation regulations for buildings close to high-pressure pipelines should be expanded, because right now there is a false feeling of security. It seems that there is a lack of knowledge in practice about which mitigating actions truly work in Aandachtsgebieden, which leads to increased risks for the people in buildings close to hazardous pipelines. VELIN is now talking about these issues with authorities like the Ministry of I&W and RIVM, and is writing an action plan to improve safety close to pipelines (interview 12).

4.3.4] Critical infrastructure: finding a balance between speeding up and ensuring safety

The rules and regulations discussed in this section are mostly imposed to ensure a safe construction and operation of the hydrogen infrastructure. Hydrogen infrastructure is critical infrastructure and poses certain risks to the environment. These risks should be taken into account in the planning process for hydrogen infrastructure, no question about it. As discussed, some unclarity in the rules and regulations does cause delay in the planning phase and actors are looking at ways to speed up the planning process. During the planning process for hydrogen infrastructure, a constant balance should be found between an efficient and quick planning of the infrastructure and the (increase in) risk. We should keep in mind that this is a very delicate debate. All respondents clearly state that safety measures should always be the number one priority. However, some respondents voice some critique about the Dutch approach of dealing with risks, because it threatens a fast and efficient roll-out of new pipelines and other hydrogen infrastructure.

First of all, the current way of dealing with risks in the Netherlands takes insecurity as a starting point. However, because of this tight focus on risks, safety and risk-reducing regulations can become so strict that the construction of hydrogen infrastructure can become too expensive, due to all kinds of adaptation and mitigation actions. Secondly, safety is important, but risks are always relative. Risks need to be placed in perspective, and sometimes, we should not try to overregulate things. This could seriously harm a quick and efficient planning of hydrogen infrastructure (interview 9):

"One of the aspects of our current approach to safety is that it is always based on insecurity. Rightly so, of course, but if you realize that pipelines are the safest mobility there is, compared to inland shipping, but certainly also compared to road or rail, then the calculations should actually show that a pipeline is safe. But the rules are about insecurity and before you know it, you have calculated the safest mobility so strictly that it becomes unaffordable to construct it. You might end up in a situation in which transport by road is possible within the rules, but where transport via pipelines becomes unaffordable. That is something you would not want." (interview 9).

This is where planning of hydrogen infrastructure becomes political as well. Politicians will be very risk-averse, because they do not want to be responsible for disasters. That is why authorities are trying to identify every risk possible and impose strict safety norms, almost wanting to totally erase risks. This could lead to such strict safety regulations that it becomes almost impossible to plan hydrogen infrastructure anymore, or that planning takes a very long time, because the initiators of a new pipeline will have to meet very strict safety requirements (interview 9):

"A politician will never say: "That is safe enough". So if a risk is identified, they almost want to eliminate it. Before you know it, you make it impossible to construct new things. So we have to keep looking at risks in perspective." (interview 9).

One solution to this issue could perhaps be to ease QRA requirements in low density areas, like in the case of the new pipeline between Delfzijl and Eemshaven. QRA's are mostly suited for urban areas, where pipelines conflict with many other uses. But it can be investigated whether such elaborate QRA's are also necessary in low density areas. Most of the infrastructure is laid down in low density areas. To save time, it could be investigated whether there could perhaps be less strict risk methods for these areas (interview 12).

4.4] Delay due to participation

Planning is not all about the technicalities. Pipelines require space and affect neighbouring uses and people as well. This could lead to conflicts of interests that delay the planning of the pipeline infrastructure, for example through lengthy objection procedures. This section will discuss delays that appear due to the participation process with residents (section 4.4.1), land owners (section 4.4.2), and public authorities (section 4.4.3), and how this type of delay could be taken into account in the Groningen Seaports case. Public engagement could become one of the biggest factors of delay during planning (interview 11):

"What is most complex about pipeline construction projects in the built environment is the environment itself. The technical construction of a pipeline is, in short, a trick that we have been doing for many years. A trick that we have mastered well. But the environment… you have an impact on the environment, both during the construction phase and during the operation of the pipeline. So you have to arrange that in a proper way. And if you go too fast, or if you do not include parties, or include them in a wrong way, that is the biggest chance of delay you can get." (interview 11).

4.4.1] Public participation

In many cases, the wider public is quite ignorant about the presence of nearby pipelines. Many people might not even know about the underground pipelines that are nearby: "they are out of sight, out of mind" (interview 1, 4). And when existing gas pipelines are reused for the transportation of hydrogen, it is hard to see any change: the pipes are still there, they only carry a different gas (interview 14). Many residents do know that 'something' is happening with hydrogen, but it remains relatively unbeknownst. The study Hyway27 (interview 6) indicates that the public opinion about hydrogen in general is actually quite good. The general public has heard about hydrogen and its benefits as a clean gas in the future energy system.

Worries about the safety of hydrogen infrastructure are present, but many residents trust that the companies responsible for the transport of hydrogen keep the safety regulations into account. It helps that no big disasters with hydrogen infrastructure have taken place in the Netherlands so far (interview 6). Worries of residents around the new pipeline project are mostly related to fears of explosions, nuisance during construction, noise, or degradation of the (cultural) landscape. Here, it is important to show neighbours that authorities and initiators plan the infrastructure in a careful way to minimize risks (interview 4). However, some respondents (interview 5, 12) state that sometimes, NIMBY-ism can appear for pipeline projects, where residents oppose the construction of new pipelines, mostly because they fear the risks (interview 13). In some cases, protests of neighbours completely cancel pipeline projects:

"*Before you know it, society will turn against you and your project will no longer be possible."* (interview 12).

A specific bottleneck that is important for the case of Groningen Seaports is that especially in the province of Groningen, there is a growing distrust in authorities and participation processes:

"In any case, I notice that people have less confidence in the authorities. The moment a municipality, or a party such as the Ministry of EZK, or whoever, reaches out to a resident, the resident will think: 'Oh dear, I have to brace myself, now something is probably going to happen… something that I probably do not want to see happening.'" (interview 15)

One subject that is particularly sensitive in the Dutch province of Groningen is the storage of hydrogen in underground salt caverns. Residents are very critical, due to the earthquakes that happen in the region, caused by previous gas extraction. Residents are sceptical of any new plans that involve drilling into the underground of Groningen. It will be crucial to involve neighbours in any hydrogen plans that concern the underground as early as possible to avoid lengthy opposition processes (interview 4, 15):

"Look. In Groningen (and that is of course the complex story): because of the earthquakes as a result of the gas extraction, everyone is now really like: 'We do not want any rumbling in the soil anymore. That must stop.' I cannot even judge whether this feeling is justified or not, but it is a sentiment that prevails here. And you have to keep that into account." (interview 15)

Most of the time, hydrogen infrastructure is created at industrial sites without many neighbours (interview 14). However, when infrastructure is created at a location that impacts nearby people, it is important to involve residents in a participation process. A clear benefit of organizing participation is that it can lead to more integral, widely supported or accepted solutions to spatial projects. A good participation process might prevent later opposition and delay to plans (interview 15). Nowadays, residents often participate quite late in the process: when the plans are almost finished and construction (almost) starts. That is the moment that neighbours start to oppose the project and could cause delay to the planning process (interview 4, 9). That is why it is important to organize participation at an early moment, to prevent later delays (interview 4). The aim of participation processes is to at least create acceptance of the plans. This is something different than creating support for the projects. Residents might still not support a project, but might at least accept the project, for example, because some kind of compensation is guaranteed (interview 15):

"I consciously avoid the word "support". For me, support is different from acceptance. Acceptance can also mean: 'I do not want it, but in the end I can live with it.' That is fundamentally different from: 'I am all in favour of this project.' Sometimes you cannot expect such support from people." (interview 15)

There should also be a clear added value of organizing a participation trajectory in infrastructure projects. In front, it should be clear how much influence residents still have on the projects. If residents have the feeling that they still have the power to alter plans, but in reality, this is not the case, this might lead to disappointment and more opposition to the plans (interview 15):

"Look. I sometimes find the concept of participation a bit misleading. That is a strong statement. The moment you actually already know what you want and how you want to do it, the question is: what is there still to participate in? In such a case, you must also be honest and say: listen, dear people, it is not a question of whether this pipeline will come here, in fact, we already know where it will come and how deep it will lie. The question is: how can we ensure that the impact on the environment is reduced? (...) But in participation processes, residents often think that they still have maximum influence on what might come next. And that clearly leads to disappointment." (interview 15)

That is why the organizers of participatory meetings about infrastructure projects should be very clear in advance whether a meeting is organized to offer residents true participation power, or that it is just a meeting to inform neighbours, without giving them true influence on the plans. Furthermore, the steps in a participation trajectory should be clear and the entire process should not take too long (interview 15):

"So: in my opinion, participation only makes sense if there is a clear question on the table, and residents can do something with that. Otherwise, it is just communication, as far as I am concerned. In that case, you just tell what will happen and what the project looks like and residents can only indicate some minor things that should be taken into account. Participation really assumes that residents can think along and can co-decide to a certain extent, and can steer the project." (interview 15)

Usually, during infrastructure projects, the initiating party and the municipality organize public participation and/or consultation meetings with neighbours and other stakeholders. Companies could also outsource the set-up of this participation process to a specialised organisation that is responsible for this "Omgevingsmanagement" (interview 16). During such meetings, more information is provided about the time schedule of the projects, why the project is necessary, the effects of the project and to whom residents can send their questions or remarks (interview 13). One way to really give citizens influence on the project is by using a multi-criteria analysis to identify all occurring interests and their importance (interview 16). It is important that such information is communicated in a clear language, so that the project and its effects are understandable to everyone:

"We should watch out. If people do not understand the project, they might protest against it. We must have a clear PR story in which we clearly explain the risks. I might express myself quite strongly now, but we need to use "Jip-en-Janneke language". I think the average Dutch person has never heard of a QRA and then this person might give its own weight and opinion about it, which is of no use to the pipeline constructors. So we all have to act in a very coordinated and careful way." (interview 12)

Especially when residents do not understand what is going on, they are more prone to oppose plans, which could cause delays. That is why there is a need for clear PR-strategies and participation trajectories for pipeline projects close to neighbourhoods, that clearly explain what is going on, why the project is necessary, and what the true risks are (interview 12). Education, for example information campaigns, could help to show the public the benefits of hydrogen and how the risks of the infrastructure are minimized by all kinds of measures. This could help raise public support for hydrogen infrastructure (interview 6).

VELIN and/or private parties could also play a role in providing more education about pipelines and their risks. Overall, pipelines are a safe mode of transport, regardless of what is being transported. Especially when compared to transportation of hazardous materials by train, boat or in trucks, pipelines can offer a safe alternative that works 24/7 (interview 12). Public support could be improved by being clear about the need for hydrogen, the expected risks, and the costs of the infrastructure (Raad voor de leefomgeving en infrastructuur, 2021). If participation is organized in a timely manner, and acceptance of the plans has been reached early, this could seriously prevent later delays.

Under the upcoming Omgevingswet, participation will have renewed attention. For example, participation will be mandatory when a “Projectbesluit” is used under the Omgevingswet (interview 6). Initiating parties must look in advance which parties are present at a location and how they are involved in the process and are informed before, during and after the project's duration (interview 13). This means that it is important to take into account the important stakeholders at an early moment, to prevent later delays. That does not mean that all stakeholders should be involved from the start, but it is important to speak with all parties and search for solutions that are at least acceptable (interview 11).

4.4.2] Land ownership

Perhaps the most important topic concerning participation in the Groningen Seaports pipeline project is land ownership. The new pipeline will have to cross the land of many different owners, often local farmers. It is important that landowners are always adequately compensated when a pipeline is constructed on their land. If a landowner misses any income from the land, because of the construction works or operation of the pipeline, this should be adequately compensated (interview 13). The quickest way to construct a new pipeline is by buying all the land. This, however, requires too large investments, and is therefore not a real solution. That is why it is important to come to an agreement, a so-called ‘Zakelijk Recht van Opstal’ with the current owners of the land (interview 16).

In the province of Groningen, Gasunie and NAM currently own multiple gas pipelines that might be reused for the transportation of hydrogen. If these pipelines fit in the future hydrogen backbone, Gasunie, or other operators, could reuse these pipelines for their operations (interview 6). The problem, however, is that these parties do not own the land that these existing pipelines are in. That is why there are currently exclusive rental agreements with the owners of the land, so-called ‘Zakelijk Recht van Opstal”. In this case, the land is still owned by the land owners, and the pipeline operators only own the pipelines that cross the land. Sometimes, some rules apply to the owners of the land considering a safe use of the land, in order to not disturb the pipelines (interview 6). If another party, like Groningen Seaports, wants to take over the pipelines, new rental agreements will have to be concluded with the owners of the land. These owners might not always be willing to cooperate, or they might demand a (too) high rent. These negotiations with land owners can take quite a while. That is why it is important to include the landowners early on in the participation process, to avoid delays due to land ownership (interview 5).

If land owners do not want to cooperate, and there are no alternative routes, a so-called Tolerance Procedure (Gedoogplicht) can be used, in which a landowner can be forced to allow the pipeline on his or her land (interview 6). However, this really is a last resort and a ‘Gedoogplicht’ can only be used if there is a realistic prospect that a permit will be issued for the pipeline, if the initiator has made multiple attempts to reach an agreement, and if there are no alternatives (interview 13). It helps when pipelines are marked as ‘in national importance’, since that makes it easier to use the ‘Gedoogplicht’ and speed up the planning of a pipeline. However, these final solutions should only be used as a last resort, because other parties are now forced to accept the project on their land. This could seriously harm other parties’ acceptance of the project and could make them sceptical about any future cooperation or new plans (interview 16).

4.4.3] Participation with local authorities

Overall, there is a wide commitment of local authorities to local hydrogen developments (interview 16). According to a few respondents, however, public authorities are sometimes reluctant in supporting hydrogen projects, because there are still so many uncertainties about the techniques and (safety) regulations that should apply. These respondents also voice that they have the feeling that some municipalities lack knowledge about pipelines in their territory and oftentimes, other local interests are deemed to be more important than the pipelines, that are “out of sight, so out of mind” (interview 1, 8, 12). All the new safety regulations and requirements will demand lots of attention from public authorities. Large municipalities in the Netherlands will probably have enough expertise to respond to new developments in hydrogen infrastructure. However, smaller municipalities will often lack expertise and will find it more difficult to support pipeline projects in their region. However, municipalities will always receive support from the “Omgevingsdienst” and “Veiligheidsregio” about the pipelines (interview 3, 8). To tackle the lack of knowledge in local authorities, VELIN is thinking about making an instruction manual about pipelines to offer more information about pipelines to local authorities (interview 12).

A concrete example of this lack of attention from local authorities is the case of the pipeline corridors in the ‘Structuurvisie Buisleidingen’ (SVB). These pipeline corridors should be kept free by the municipalities that they are in, to ensure a quick and safe planning of future pipelines. The corridors can then be used for the construction of pipelines of national importance. Hydrogen pipelines (at Groningen Seaports) might become of national importance in the future as well and could then be laid down in these corridors (interview 9). It is, however, visible that some municipalities do not reserve the space for indicative corridors according to the Structuurvisie Buisleidingen. If the space is not well reserved, this could severely delay the planning of the pipelines in the corridor, for example, because a detour has to be made. The required space for these indicative pipeline corridors should be reserved in the municipal zoning plans, but in reality, the space is often used for other uses. This means that there is a conflict between national and local interests (interview 13).

Some municipalities use the space that should be reserved for indicative SVB-pipelines to plan wind turbines or solar power plants. This disturbs the construction of pipelines and shows that the reservation of land for future pipelines does not have full attention in all municipalities (interview 2). The responsibility to check whether SVB-corridors remain reserved for pipelines lies with the provinces and the municipalities themselves (interview 10). If there is already a pipeline operator, this operator has the duty to alarm whenever a vulnerable object is built too close to the pipelines. However, in the case of the SVB-corridors, there is not always an operator to check this, because sometimes no pipelines have been constructed yet in a corridor (interview 10). As a solution, it might be necessary to appoint a new institution to check whether the SVB-corridors are well reserved in municipal plans (interview 2). The current conflicting interests were made very clear in interview 9:

"It is also important that you can actually use those corridors from the Structuurvisie Buisleidingen. We want to avoid the situation in which the corridors are reserved, but there are different thoughts about the use of this land in local plans. This is still a field of tension in the increasing decentralization of Dutch spatial planning. There is a central governmental vision, but there are also local interests that play a role. It is important that the national plans are followed, including in local zoning plans. Unfortunately, that does not always happen in practice." (interview 9)

Decentralization of spatial planning powers is also delaying the planning of new pipelines. Under the Omgevingswet, spatial planning in the Netherlands is becoming more decentralised to local authorities. In the past, big infrastructure projects could be easily coordinated by the Ministries; now, due to decentralization, private parties will have to deal with multiple municipalities whenever they have a project covering multiple municipalities:

"We used to be able to talk to the Ministry of EZK, the energy ministry, and the Ministry of BZK for spatial planning, to get things done. Soon, we might have to discuss the construction of a new pipeline with 24 different municipalities at the Veluwe." (interview 12).

Because of poor coordination between multiple municipalities, conflicting interests between all different municipalities, and the extra time it takes to talk to all the different municipalities, this could delay the planning of hydrogen pipelines (interview 12). More (national or regional) coordination, and/or new institutions could aid to streamline planning here. This is discussed more extensively in upcoming section 4.5.

4.5] Overarching institutional solutions for a more efficient planning of hydrogen infrastructure

The previous sections 4.2, 4.3 and 4.4 have respectively dealt with the technical, regulatory and participatory causes of delay in hydrogen infrastructure planning. Solutions that have been named so far for these factors of delay have mostly aimed at changing the rules of the game for the planning of hydrogen infrastructure, and making them more simple. In the final, upcoming section, more overarching institutional solutions will be discussed that will help to speed up the planning of hydrogen infrastructure.

One of the biggest reasons why there is no extensive hydrogen network in the Netherlands yet is because currently there is not enough hydrogen production to supply a large-scale national hydrogen system, and hydrogen has to compete on the market with natural gas. The market for hydrogen simply does not exist yet, and needs to be created (interview 9). A first issue is that hydrogen and hydrogen infrastructure are too expensive at this moment, compared to alternatives. Scaling up the hydrogen economy (e.g. by constructing wind parks at sea and electrolysers) can help lowering prices for hydrogen (interview 6). The future price of hydrogen will depend on the costs of production, distribution, but also the security of supply of the hydrogen through buffering (interview 15). Secondly, the lack of information about off-takers for hydrogen is a serious issue. If there is no certainty that there will be enough off-takers for the produced hydrogen, it will be risky for involved parties to construct the pipeline infrastructure. If you make big investments in infrastructure, but no one will use it, you have a serious problem (interview 13):

"It is the story of the chicken-and-egg: you need to have an off-taker for what you put through your pipe. If you first install all your pipelines, without a customer, then you have a lot of costs, and you do not know whether you will be able to sell your hydrogen." (interview 13)

At the same time, off-takers and net managers have little information about the (expected) production of hydrogen and its (future) prices. That will make it hard for the industry to take the step and switch to using hydrogen (interview 13):

"It is a tricky game: you do not know the electricity prices in ten years, you do not know the green hydrogen price, you do not know the availability, nor the security of supply." (interview 14).

To scale up the future hydrogen market, cost reductions and innovations will be necessary. Creating such a hydrogen market requires new institutions that focus on (national or regional) coordination, and almost certainly the introduction of exploitation grants and/or levies. Such institutional changes will help the creation of a hydrogen market, and will thus aid to speed up the planning of hydrogen pipeline infrastructure, like in Groningen Seaports. The upcoming section covers four final solutions that relate to desired overarching changes in institutional arrangements to speed up the planning of hydrogen infrastructure. These overarching solutions respond to all three types of delay discussed so far. It concerns the following four institutional changes: national and regional programmes (section 4.5.1), the provision of grants and levies (section 4.5.2), the creation of a national hydrogen net (section 4.5.3), and the possibility of creating a pipeline corridor at Groningen Seaports (section 4.5.4).

4.5.1] National and regional programmes

Speeding up the creation of a national hydrogen market will most of all require national coordination and commitment:

"There is a broad consensus that the hydrogen economy emerges only slowly, if at all, under "Business as Usual" scenarios. Rapid transitions to hydrogen occur only under conditions of strong governmental support" (McDowall & Eames, 2006, p.1236)

Multiple Ministries play an important role in this matter. The Ministry of EZK, and the Cabinet, will have a coordinating role in steering the hydrogen economy, for example by implementing policies and writing visions (interview 6, 14). The Ministry of I&W mostly plays a role in checking the spatial integration of the hydrogen infrastructure, and making sure that spatial (safety) rules and regulations are followed (interview 10). The Ministry of BZK is mostly involved in the spatial planning regulations (interview 14).

In creating a market, it will be important that the authorities take on a facilitating role. This means that the (national) government coordinates the steps necessary towards the future hydrogen economy through visions, grants, and the creation of public support (interview 14). Authorities should spread a feeling of urgency about hydrogen and tempt companies to invest in hydrogen. Furthermore, companies must be willing to think about the long term (e.g. 2030, 2050) if they want to partake in the hydrogen economy. Businesses should take their responsibility to see how they could contribute to the energy transition (interview 10). Taking the step towards the hydrogen economy will thus require some courage. Parties need the boldness to dare to take a step forward and invest in the hydrogen infrastructure. The change needs to start somewhere:

"We need some kind of 'Steve Jobs'-like courage to invest in the large-scale development of hydrogen infrastructure" (interview 9).

There is one disclaimer that should be provided here. There will always be some unexpected factors and uncertainties in the future that are hard to keep into account by any change in institutions or regulations. The development of the hydrogen market will depend on macro-economic developments in the future that are hard to predict now. For example, an unexpected new global (financial) crisis could delay hydrogen planning as well (interview 10). Furthermore, new policies as a response to the current PFAS and nitrogen issues will be key as well to avoid future delays (interview 2):

"But we also see threats and possible delays when it concerns issues like nitrogen and PFAS and things like that. Those are issues that will come to the fore, for which we have not set everything up. We see that as a threat." (interview 2)

National programmes

New strategy documents will best aid to guide the transition to a hydrogen economy. There are multiple programmes that are aimed at improving cooperation on a national level:

1. *Programma Energiehoofdstructuur (PEH).* The Ministry of EZK is now working on this vision document in which the future energy infrastructure and energy demand in the Netherlands is described for all kinds of energy sources, with a large focus on the role of hydrogen as well (interview 9). The PEH focuses on the spatial integration of the hydrogen infrastructure in the Netherlands and provides spatial reservations for this infrastructure and a vision on future development (interview 14).
2. *Nationaal Programma Infrastructuur en Duurzame Industrie (PIDI).* This programme includes the ambitions for making the industry in the Netherlands more sustainable. An important aim of the document is trying to gain more insight into the future demand for hydrogen from industry (interview 14).
3. *Cluster Energie Strategieën (CES).* The hydrogen strategies for the large Dutch industrial clusters, like Groningen Seaports, are included in these strategy documents. As part of CES, safehouses have been appointed as well, where sensitive company information could safely be shared between stakeholders (interview 14).
4. *Meerjarenprogramma Infrastructuur en Klimaat (MIEK).* In this programme, multiple stakeholders in the Netherlands truly commit themselves to concrete sustainable projects in the Netherlands, like investments in hydrogen (interview 14).

All these new institutions could provide the vertical and horizontal connectivity (Huck, et al., 2019) that is necessary to better coordinate the planning of hydrogen infrastructure and guide a quick rollout of hydrogen infrastructure. There might, however, still be institutions that are missing that might also help to speed up the planning of new hydrogen infrastructure. It is, for example, interesting to look at creating new institutions that could check the reservation of the SVB-corridors (interview 9) or install an institution that investigates the possibilities to create pipelines for the transportation of hydrogen at pressures between 8 and 16 bar, as has been explained in section 4.3 (interview 16).

Regional programmes

At a more regional level in the province of Groningen, there are already efforts to make institutional changes and to streamline the development of a hydrogen ecosystem in the region. Such territorial connectivity (Huck, et al., 2019) is pursued by the province of Groningen through the creation of a "Transformation and Coordination Office". This provincial office will be responsible for three things (interview 4):

1. Coordinating all the hydrogen projects in the province of Groningen, like the hydrogen backbone, HEAVENN or NortH2 (interview 8, 13).
2. External communication to streamline the communication about (the benefits of) the hydrogen economy to the wider public (interview 15).
3. Communicate with The Hague and Brussels about the hydrogen efforts in the northern Netherlands. The office will try to receive subsidies for the region from the Dutch national government and the European Union (interview 14).

The province actively promotes regional cooperation and helped write a Hydrogen Investment Agenda and Hydrogen Plan for the province. In its energy transition and economic policies, the province is actively promoting the development of a new hydrogen ecosystem, in which hydrogen will be used in mobility, industry, and in the energy sector. Groningen has the space for the required infrastructure and there is current knowledge and expertise about gas infrastructure and the trade in gases. The province wants to use this potential to steer the hydrogen ecosystem. Hydrogen could be produced in Groningen and be transported to off-takers all over Europe. This will also contribute to the creation of new jobs related to hydrogen in the province. The province welcomes these new jobs, since jobs related to the natural gas industry will be lost due to the discontinuation of the gas industry in Groningen (interview 4).

Municipalities usually have a facilitating role in stimulating hydrogen projects. However, in the case of Groningen Seaports, the municipalities of Het Hogeland and Eemsdelta are a bit more involved, because (together with the Province of Groningen) they are shareholders in Groningen Seaports, which is an important actor in the hydrogen projects in the region (interview 13). Stimulating the hydrogen economy is mostly important for the municipalities in Groningen, since they expect a rise in jobs due to the hydrogen economy. Regional plans for hydrogen are part of the Regional Energy Strategy (RES) that is drawn up by local authorities (interview 13).

The new national and regional institutions mentioned in this section will aim for improved vertical, horizontal and territorial connectivity, which could help a faster roll-out of the hydrogen infrastructure. However, these programmes will need adequate funding in order to really get started. The upcoming section will discuss this matter.

4.5.2] Exploitation grants and levies

Financial funds will be vital to remove the current unprofitable top of hydrogen projects and make sure that hydrogen can compete with alternatives. Here, there will be an important role for the Ministry of EZK to create incentives to steer the hydrogen economy. For example, the ministry could provide (exploitation) grants to hydrogen infrastructure projects to remove the unprofitable top (interview 14).

More money will certainly help a quicker roll-out of hydrogen infrastructure (interview 4, 8). Investing in hydrogen will likely cost billions of euros. Subsidies from the Dutch national government and the European Union (European infrastructure grants) will be essential to realize the high ambitions for hydrogen in time (interview 9):

"But the big battle is yet to come. And I think the next steps in the hydrogen economy are much more dependent on the affordability, i.e. the subsidy structure, than on spatial issues." (interview 4)

Currently, there are two types of grants available to infrastructure projects. Whenever a technology is new, and needs to be tested, for example in pilots, some innovation grants are available, like DEI+. When a technology is mature, exploitation grants are available, like SDE++ (interview 14). However, the current state of the technology necessary for hydrogen transportation is somewhere between the pilot-phase and being mature. That is why a new type of financial grant should be designed for hydrogen infrastructure: the Ministry of EZK is currently looking at a new, temporary kind of grant that could become available especially for hydrogen infrastructure (interview 14):

"Hydrogen is a bit overlooked. It is too big for the demos or the innovation support, but hydrogen still cannot compete in the SDE++ with other CO2-reducing technologies that are much more mature. For hydrogen, you might actually need a new type of subsidy in between these two." (interview 14).

Investments are also possible through funds, like Invest-NL, which is a revolving fund that might be used for investments in hydrogen infrastructure as well (interview 14). Lastly, financial aid is possible through "contracts-for-difference" in which manufacturers of products that were made with an expensive technology, can get financial grants from the government (Raad voor de leefomgeving en infrastructuur, 2021).

Other measures to financially help speeding up the development of the hydrogen market can be considered as well, like CO2-taxes or a 'Bijmengverplichting' to oblige companies to have a certain percentage of sustainable energy in their portfolio or to mix hydrogen in their natural gas net (interview 6). At the European scale, such regulations already exist and are part of the Renewable Energy Directive (RED II) of the European Union. For example, CO2 is already taxed in the current ETS-system (interview 8).

4.5.3] Managing the national hydrogen Net

Even though there are big plans for programmes and grants for hydrogen infrastructure in the Netherlands, it remains unsure who is going to manage the future national hydrogen infrastructure (interview 2). At this moment, hydrogen transportation is a purely private business and pipeline operators have a natural monopoly. If somewhere in the future a national hydrogen network will be created, with multiple sources and off-takers of the hydrogen, new regulations will have to be created about the exploitation of this national network (interview 9, 14). Such regulations already exist right now for the natural gas network (interview 4). Because a national hydrogen network is of vital importance to the Dutch economy, the Ministry of EZK will appoint a party that is responsible for the management of this national hydrogen network. The State could be the shareholder of such an organization (interview 14). When a national manager of the hydrogen netwerk is appointed, this will certainly help speeding up hydrogen pipeline projects all over the Netherlands:

"Right now, we mostly see intentions for hydrogen projects, but once it is clear who will be the national manager of the hydrogen system, that party will also have the mandate to get started with constructing the hydrogen infrastructure. That in turn will automatically generate the required hydrogen market. Companies will then also see that something is happening, and enthusiasm will grow. People will see that hydrogen is really coming. Then you will automatically get a change." (interview 6).

In such a framework, there is an 'Aansluitplicht', in which the institution responsible for hydrogen transport will be obligated to connect any party that wants to be connected to the national hydrogen system (interview 6). If an operator of a national hydrogen network is appointed, this could surely help to generate more (legal) certainty about the future hydrogen infrastructure, which could speed up hydrogen projects all over the Netherlands, including in Groningen Seaports. It is expected that the Ministry of EZK will appoint the national manager of the hydrogen network later in 2021.

4.5.4] Pipeline corridor

As a final concrete institutional solution to speed up the planning of the hydrogen pipeline in Groningen Seaports, a pipeline corridor could be considered. In such a corridor, an organization is responsible for the asset management of the corridor itself. The pipelines inside the corridor are owned by the respective operators (interview 2). Because such a pipeline corridor is already part of zoning plans, no change in zoning plans are required when new pipelines are constructed. Furthermore, almost no extra permits will have to be granted, because they have already been granted to the corridor as a whole. Initiators will, however, still be responsible for executing a quantitative risk assessment (interview 1). The appointment of a pipeline corridor greatly reduces the amount of time necessary to plan a pipeline.

At the moment, there is only one such corridor in the Netherlands: LSNED (Leidingenstraat Nederland). This corridor is roughly located between the seaports of Rotterdam and Antwerp (interview 2). When LSNED was founded, the Dutch state expropriated the land necessary for the corridor. The ground is leased from the national state to LSNED. By using a tenancy system, farmers can use the land above the pipelines for light agricultural work. As a result, LSNED is able to provide a corridor without any obstacles to pipeline operators. Operators will have to pay a start fee to place a pipeline in the corridor and they will have to pay a yearly fee, based on the size and length of their pipeline. Providing a pipeline corridor is one of the most efficient ways to avoid delays. For example, it is possible to obtain the required permits for a new pipeline and start construction in the LSNED corridor within six months. The appointment of a corridor makes sure that planning of new pipelines is quick, obstacle-free and LSNED has regular contact with neighbouring parties for consultation (interview 2).

A pipeline corridor thus seems to be an optimal solution to more efficiently plan new pipelines. However, with the current high land values in the Netherlands, it will be unsustainable to roll out pipeline corridors all over the Netherlands, or, for example, along the paths of the Structuurvisie Buisleidingen. This means that a pipeline corridor will only be a solution in very particular locations with a high demand for pipelines (interview 2).

Stichting Buizenzone Eemsdelta

There have been plans for a pipeline corridor between Eemshaven and Delfzijl for many years, managed by "Stichting Buizenzone Eemsdelta". In the early 2000s, the Stichting Buizenzone (Pipeline Corridor Foundation) was founded by Groningen Seaports and the Northern Development Company (NOM, Noordelijke Ontwikkelingsmaatschappij). The aim of this foundation was to explore the possibilities for a pipeline corridor between the Eemshaven and the seaport of Delfzijl. The assignment of such a corridor claims the space for the realization of potential future pipelines. In 2011, an Environmental Impact Assessment (Milieu Effect Rapport Buizenzone Eemsdelta, 2011) was carried out to explore three possible trajectories for these pipelines. The planned pipelines between the two ports could be used for the transportation of energy, gases and liquids. In total, a maximum of 25 pipelines could be placed in the reserved corridor, of which some pipelines could have been used for the transportation of hydrogen as well.

For multiple years, this corridor was reserved in the spatial plans of the province. The indication of the pipeline corridor meant that no other structures could be built in this corridor and that the corridor was totally reserved for the placement of pipelines. However, no pipelines were laid down in this corridor at all during the time of reservation and the plans for the pipe corridor were cancelled in 2016, because the economic situation changed and at that time there was no need for such a pipeline corridor anymore. That is why the province of Groningen erased the corridor from its spatial plans as well (interview 13).

Between 2015 and 2018, the Stichting Buizenzone Eemsdelta has been inactive. In 2018, the Stichting Buizenzone was revived by Groningen Seaports, Stedin, Vattenfall and A.HAK, and later also Gasunie joined. These involved parties want to review the potential for new pipelines, not only between the Eemshaven and the seaport of Delfzijl, but also wider in the province of Groningen and Drenthe.

Stichting Buizenzone Eemsdelta is now broadly focusing on facilitating, coordinating and stimulating the placement of pipelines in this geographical area. It is now calculated that there is probably potential for around seven pipelines between the two seaports. Whether the revived Stichting Buizenzone will proactively plan new pipelines remains to be seen (interview 16). However, this new institution is the most promising coordinating institution that could help to speed up the plans to create a new hydrogen pipeline between Eemshaven and Delfzijl.

At the moment, the projected hydrogen pipeline between Eemshaven and Delfzijl is not indicated as a pipeline of national importance. In the Structuurvisie Buisleidingen 2012-2035 (Ministerie van Infrastructuur en Milieu, 2012), it is merely seen as a regional pipeline, meaning that no special national priority or rights apply to this location. The question right now is whether the hydrogen pipeline between the two Groningen seaports could be seen as 'of national importance'. If the pipeline is considered to be 'of national importance', then specific rights apply to it, like the right to expropriate land and other parties' possibilities to oppose or block the pipeline plans are limited. These rights could help a quicker planning of the new pipelines, although it might not always be desirable to use these rights, because it could actually reduce the support of other stakeholders for the project, because other parties are forced to accept the project. That is why the aim of the Stichting Buizenzone Eemsdelta is to be prudent, and to carefully plan the new pipelines in good consultation and coordination with local stakeholders (interview 16).

Besides, it would take some time to make the pipeline one of national importance, and speed is required right now. Whenever the hydrogen pipeline between the two seaports is already constructed, there is not much added value to make the pipeline one of national importance, because most benefits of being of national importance apply to the planning and construction phase of the pipeline (interview 16). That is why in the short term, making the Eemshaven-Delfzijl pipeline of 'national importance' does not seem to be a fitting solution to speed up the planning process, for it will take several years to attain this status. However, it could be a working strategy to apply for such a status for other pipelines that are planned in a couple of years from now.

4.6] Synthesis of the results chapter

The current results chapter has provided an overview of found causes of delay and possible solutions to speed up the planning decision-making process for the construction of hydrogen pipeline infrastructure. All found causes and solutions for delay have been categorized, based on the three types of delay distinguished in the literature review. A summary of found factors of delay and noted solutions from this study is given in **table 3**. This table summarizes and categorizes all information that has been provided in chapter 4.

Table 3: Synthesis of the explored causes and solutions for delay, as discussed in section 4.2, 4.3, 4.4, and 4.5.

Type of delay	Examples of causes of delay in Groningen case	Proposed Solutions
1] Technological	● Some minor unclarities about the technicalities of constructing thermoplastic hydrogen pipelines or reusing natural gas pipelines for hydrogen.	● Research and pilot projects. For example, as part of the NATURALHY or HyWay27 projects.
2] Planning & Regulations	● Missing information in the NEN-3650(-3) about thermoplastic composite pipelines. ● Missing information on hydrogen in the Wabo-regulations for issuing permits. ● Missing data to calculate the 'chance of failure' for hydrogen pipelines in calculation models. ● Missing data to calculate the 'chance of failure' for thermoplastic composite pipelines. ● Issues are expected with risk mitigation in the introduction of the new Voorschriftgebieden. ● Lengthy planning process due to the need of an "Inpassingsprocedure" at pressures >16 bar. ● Delay due to (too) strict safety regulations.	● The NEN-commission should adjust the NEN-guidelines to include guidelines for thermoplastic (composite) pipelines too. ● It should become clear whether you can read "hydrogen" where it only states "gas" right now in some environmental permit regulations. ● More (international) experience and data for the risks of hydrogen pipelines is necessary to update the calculation models of the RIVM. ● More (international) experience and data for the risks of thermoplastic composite pipelines is necessary to update the calculation models of the RIVM, for example through tests. ● VELIN is talking about these issues with authorities and builders. More information about fitting mitigation actions near pipelines is required. ● Change the regulations of the "Inpassingsprocedure" or find new parties that are willing to provide hydrogen transportation at 8-16 bar, to avoid a lengthy "Inpassingsprocedure". ● Investigating the possibility to ease QRA requirements in low density areas, like the seaports.
3] Public participation	● Distrust of residents in Groningen, especially when it concerns projects in the underground. ● Having to deal with multiple land owners near Groningen Seaports. ● Lack of skill or urgency at local authorities, for example by not adequately reserving the SVB-corridors. ● Decentralization of authority.	● Provide clear information and be open about the aims of participation, organize it soon enough, and seek at least neighbour's acceptance. ● Include landowners early in the participation process. Provide enough compensation. ● VELIN is working on a guideline for (local) authorities about the SVB-corridors; A new institution could better manage the reservation of SVB-corridors. ● A more coordinated national or regional response (see overarching institutional solutions in point 4).
4] Overarching institutional solutions		● More national coordination to create a hydrogen market, for example through programmes like PEH, PIDI, and MIEK, and a provincial Transformation and Coordination Office in Groningen. ● New, specific, and temporary hydrogen exploitation grants and levies, imposed by the Ministry of EZK. ● The appointment of a national hydrogen net manager by the Ministry of EZK. ● The installation of a pipeline corridor between Eemshaven and Delfzijl, managed by Stichting Buizenzone Eemsdelta. ● Assessing the possibilities to make the Eemshaven-Delfzijl pipeline one of 'national importance' by the Ministry of EZK.

Table 3 follows the same layout as **table 1** from the literature review. Column one in **table 3** summarizes the found technical causes of delay and respective solutions, column two shows causes and solutions related to planning and regulations, and column three shows causes and solutions related to the participation process. In each column, the proposed solutions displayed in the third row directly respond to the mentioned cause of delay next to it. Finally, the fourth column states overarching institutional solutions to speed up the planning process, as mentioned in section 4.5. The contents of this table will be further discussed in the conclusion and discussion chapters of this document.

5] Conclusion

The aim of this study was to provide an answer to the research question: "*What are the causes of delay in the planning of hydrogen pipeline infrastructure and how could institutional and regulatory change provide solutions to more quickly plan this critical infrastructure?"*. Three sub-questions have been designed to provide an answer to the research question. To answer the first sub-question about what exactly can be considered to be delay in planning decision-making processes, delay in this study was defined as *"any period over and above what is necessary or, perhaps, what is reasonable to determine an application"* (Keogh & Evans, 1992, p.689).

The second sub-question aimed at finding the causes of delay in hydrogen pipeline planning processes, focusing on interviews with key actors in the case of Groningen Seaports. When looking at the case of a new hydrogen pipeline between Eemshaven and Delfzijl, the respondents in this study univocally stated that delay during the planning phase of hydrogen pipeline infrastructure is present and should be addressed, mostly to be able to meet the climate ambitions of the government and companies in time, but also to avoid private costs.

Multiple causes for delay and possible solutions through institutional and regulatory change have been discussed. It seems that technical issues are not the biggest bottlenecks that stand in the way of an efficient roll-out of hydrogen pipeline infrastructure, although more (material) research is necessary. However, as Moroni and Buitelaar (2020) already stated, we mostly need simple rules for a quicker planning of new hydrogen infrastructure. This means that any missing information about hydrogen pipelines, be it thermoplastic composite pipelines or not, should be added to guidelines like the NEN-3650 and the calculation models for the QRA's. This would help to prevent future delays in planning, and, if done well, should not increase the risks of a faster planning of this critical infrastructure. Furthermore, (public) participation should be organized at an early stage, to prevent last-minute opposition and objection procedures to the plans. Especially since pipelines cross the land of many land owners, these are actors that should be involved at an early stage and should be offered adequate compensation.

Lastly, the third sub-question aimed at finding institutional reforms to responsibly provide solutions to speed up the planning of the critical infrastructure. Institutional reforms will aid to more efficiently plan the necessary hydrogen pipeline infrastructure. Strong governmental support will be key to speed up the transition towards a hydrogen economy. This thesis concluded with four types of institutional solutions that might help prevent delay in the future by striving towards vertical, horizontal and/or territorial connectivity through new (national or regional) cooperations, programmes or offices (Huck, et al., 2019). These institutional reforms concern (national or regional) coordination institutions, grants and levies, a national hydrogen net, and the possibility of a pipeline corridor between the seaports of Groningen Seaports. Finally, it is proposed in this study that new institutions could be created that focus on better reserving the SVB-corridors and it is advised that regional parties must start looking at providing hydrogen pipeline transportation between 8 and 16 bar, for this could help to speed up the planning process and avoid future delays.

Together, the responses to the three sub-questions of this thesis provide an answer to the research question of this research. It seems that delay during the planning decision-making process for hydrogen pipeline infrastructure does appear. The technology to construct the (thermoplastic composite) hydrogen pipelines is already there and will not cause many delays. However, most delays can be attributed to missing rules and regulations, and/or a missing or ill-designed participation process. Stated institutional and regulatory solutions in this thesis will help any individual involved in the planning of hydrogen pipeline infrastructure to more efficiently and responsibly speed up the planning process for this critical hydrogen pipeline infrastructure.

6] Discussion

The outcomes of this research provide more insight into the causes of delay in hydrogen infrastructure projects in the Netherlands, and possible responses to tackle delay. The outcomes could aid policy makers, companies, and planners to gain more insight in the nature of delay and possible solutions. Specifically for the case of Groningen Seaports, the current causes of delay have been distinguished in this research. Actors in this region can use the information from this study to take concrete steps to speed up the planning of hydrogen pipeline infrastructure in Groningen. New institutions like the provincial Transformation and Coordination Office and Stichting Buizenzone Eemsdelta will play a key role to streamline and coordinate these actions. It will also be important to start the participation process for the new pipeline at an early moment. Most of all, land owners around the seaports should be involved at an early stage, to make sure that any issues concerning land ownership will be resolved in a timely manner, for example, by offering adequate compensation.

Furthermore, in the short term, Groningen Seaports could look and see whether it is possible to transport hydrogen at lower pressures (< 16 bar) between the two seaports. This could prevent an “Inpassingsprocedure”, which also saves time. In the long run, Groningen Seaports might explore the possibilities of making future hydrogen pipelines of national importance to realize a quicker planning process. Whenever more information about thermoplastic composites and its properties is available, this information should be added to the NEN-3650(-3) guidelines (via the NEN-commission) and the risk calculation models of the RIVM (with permission of the Ministry of I&W). This will help to prevent any delays in the current project and future projects that use the same thermoplastic composite material for hydrogen pipelines.

As an addition to literature, this research has qualitatively shown the causes of delay for a new type of critical infrastructure (namely high-pressure hydrogen pipelines) and has shown that the theories of Huck, et al. (2019) and Moroni and Buitelaar (2020) help to provide fitting and responsible solutions to speed up the planning process for this critical infrastructure. Existing literature has expressed a dire need for more insights into how to speed up the hydrogen economy (e.g. McDowall & Eames, 2006), and the need to add more qualitative, in-depth knowledge about delay in hydrogen infrastructure planning (e.g. Yang, et al., 2020). It was interesting to see that the vertical, horizontal and territorial connectivity as proposed by Huck, et al. (2019) is already pursued by different parties in the Netherlands through new national and regional institutions and programmes.

The found causes of delay in this study could relatively easily be grouped in one of the three categories distinguished in the literature review. Therefore, no changes to this classification of causes of delay are proposed. Most found reasons for delay could be attributed to missing rules and regulations, and/or missing or badly designed participation between parties, and not so much to missing technology. This means that future research into delays in hydrogen pipeline infrastructure planning does not necessarily need to focus on technological issues anymore, but should focus more on legislation, institutions and participation processes. Furthermore, the found reasons for wanting to speed up the construction of the hydrogen infrastructure did not differ from the ones named in the literature review, mostly being environmental and economic reasons.

What is new, however, in this research, is that the focus was put on critical infrastructure that is relatively new in the Netherlands. During interviews with the respondents, it became clear that safety is priority number one during the planning of the new hydrogen infrastructure. However, there are different perspectives on the risks of hydrogen infrastructure and the need for a large-scale approach to the roll-out of the hydrogen network. It could be that the perception of delays differs for critical infrastructure, compared to non-critical infrastructure. This is something that could be investigated in future research. Furthermore, there are some shortcomings in this study that could be addressed in future research. Three shortcomings are elaborated on in the upcoming paragraphs.

One shortcoming of this research is that the planning of hydrogen in the Netherlands is still in its infancy. This could sometimes make it relatively hard to get adequate information from respondents about some topics in this study, because actions have yet to happen in the future. For example, the outcomes of the extensive HyWay27-rapport are yet to be published and the manager of the national hydrogen net in the Netherlands will probably be appointed by the Ministry of EZK later in 2021. Furthermore, because many steps in the hydrogen projects still have to be taken in the future, respondents could not provide an adequate answer to the question 'when' delay exactly happens in the process. The result of these issues is that if this study would be redone in a few years from now, probably new information will appear about delays in the hydrogen infrastructure that is not yet part of the current thesis.

Furthermore, the found issues and solutions mostly apply to the Dutch context, although some of the found issues and solutions might also be applicable to places abroad. For example, the information about the technicalities and guidelines for (thermoplastic) hydrogen pipelines could be useful for an international audience as well. Still, the lack of international comparison in this research is a flaw of this study. Future research could add international comparisons to the study in order to compare causes of delay and possible solutions between different (seaport) areas in the world.

Lastly, quantitative research into delay will be a valuable addition to this qualitative research. Data about the duration of infrastructure projects could be collected, and the impact of the solutions named in this thesis on the duration of the projects could be statistically investigated. This is perhaps possible with the use of linear regressions, in which the quantitative dependent variable is 'duration of infrastructure project' and the independent variables are all variables that relate to the solutions noted in this thesis. This kind of research would help to test the solutions named in this study and to see which solutions have a statistically significant impact in decreasing the length of a pipeline project and could help to create a ranking of the found solutions from most promising to least promising.

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8] Appendices

8.1] Topic-list interviews

Hartelijk dank voor uw deelname aan dit interview. Dit interview is onderdeel van mijn scriptie voor de master Planologie aan de Universiteit Utrecht. Ik schrijf mijn scriptie over vertraging tijdens het planproces voor de aanleg van waterstofinfrastructuur tussen de havens van Groningen Seaports (de Eemshaven en de haven van Delfzijl). Voor mijn scriptie maak ik een analyse van de verschillende soorten ervaren vertraging tijdens het planproces en ga ik op zoek naar mogelijke oplossingsrichtingen voor een efficiënter planproces voor de waterstofinfrastructuur. Voor het onderzoek focus ik in het bijzonder op de aanleg van een nieuwe waterstofpijpleiding tussen de Eemshaven en Delfzijl.

Voor dit onderzoek voer ik interviews uit met verschillende private en publieke partijen in de regio. De informatie die u in dit interview geeft, zal enkel gebruikt worden voor het schrijven van mijn scriptie. Ik neem ook graag het interview op, zodat ik achteraf het complete interview kan uittypen. Het interview zal plaatsvinden via een online Teams-verbinding. Indien u liever voor een ander medium kiest of als u bezwaar heeft tegen het opnemen van het gesprek, dan hoor ik dat graag. Ik zal een transcript van het interview naar u opsturen na het interview. Indien gewenst kunt u dan ook nog reageren op het transcript (bijvoorbeeld als u dingen wilt verbeteren of aanvullen). In de uiteindelijke scriptie zullen de interviews geanonimiseerd worden, wat betekent dat er geen namen terug te vinden zullen zijn. Indien u hier nog vragen over heeft, dan hoor ik dat graag.

Tabel A.1: Complete topic-list voor dit onderzoek

Topic	Vraag
1] Introductie	• Kunt u uzelf kort introduceren? Wat is precies uw functie binnen uw organisatie?
2] Rol bij waterstof in Groningen	• Wat is de rol van uw organisatie bij het aanleggen van waterstofinfrastructuur bij de havens van Groningen Seaports? • Hoe kwam de samenwerking voor het plannen van de waterstofinfrastructuur tot stand? Bent u actief bij deze ontwikkeling betrokken?
3] Vertraging (algemeen)	• Ervaart u dat er tijdens het planproces van waterstofinfrastructuur vertraging optreedt? Wat zijn de gevolgen van (mogelijke) vertraging voor uw partij? • Ziet u een noodzaak om deze vertraging te minimaliseren? Hoe zou dat uw partij kunnen helpen?
4] Vertraging door technische aspecten (I)	• Zijn er op dit moment technische knelpunten die de aanleg van de waterstofleidingen verstoren? Denk bijvoorbeeld aan gebrek aan technische kennis, fysieke barrières, onduidelijkheden over het materiaal of de uiteindelijke omvang van de buizen.

	● Wat zijn de gevolgen van zulke technische knelpunten voor de duur van het planproces? Komt het vaak voor dat een ontwerp moet worden aangepast? En op welk moment in het proces precies? ● Ziet u vanwege de risicovolle aard van de infrastructuur (‘critical infrastructure’) kansen voor een korter planningsproces? Of worden daarmee volgens u te grote risico’s genomen voor mens en milieu? ● Op welke manier zouden knelpunten die hier ontstaan verminderd kunnen worden? Zijn er technische innovaties die zouden kunnen helpen om sneller te plannen?
5] Vertraging door publieke participatie (II)	● Hoe is de publieke opvatting over de aanleg van de waterstofleidingen? Bestaan er partijen die bezwaar hebben gemaakt tegen de komst van waterstofinfrastructuur? En waarom? ● Op welke manier wordt er aan publieke participatie gedaan tijdens het proces van het aanleggen van de waterstofleidingen? Welke partijen zijn hierbij aanwezig? Op welk moment komt publieke participatie tot stand? ● Hoe welwillend staan landeigenaren tegen de komst van nieuwe leidingen? ● Op welke manier kan worden omgegaan met dit verschil in eigendom? Kunnen initiatiefnemers aanspraak maken op het Recht van Opstal of de Gedoogplicht in deze case? ● Op welke manier zouden knelpunten die ontstaan door publieke participatie verminderd kunnen worden? Zou participatie op een andere wijze ingericht kunnen worden?

6] Vertraging door het planproces en regelgeving (III)	● Is er op dit moment genoeg helderheid over de wet- en regelgeving voor waterstofinfrastructuur? Denk aan:
	  ○ NEN-voorschriften.
	  ○ Veiligheidsvoorschriften Bevb/Revb.
	  ○ QRA’s
	● Verandert er nog iets aan deze wet- en regelgeving in de nieuwe Omgevingswet?
	
	● Heeft u het gevoel dat het betrokken bevoegd gezag genoeg kennis en expertise heeft om de wetgeving omtrent de aanleg van waterstofleidingen toe te passen en te controleren?
	● Zou het helpen als de leiding in Groningen zou worden aangemerkt als leiding van nationaal belang in de nationale Structuurvisie Buisleidingen?
	
	● Welke onduidelijkheden zijn er op dit moment omtrent de vergunningverlening voor waterstofinfrastructuur? Hebben initiatiefnemers genoeg duidelijkheid dat het door hun genomen waterstofinitiatief op een vergunning kan rekenen?
	● Is het duidelijk wanneer een wijziging van het bestemmingsplan moet worden aangevraagd voor een nieuwe buisleiding en wanneer niet?

	• Wat zijn de gevolgen van knelpunten in de wet- en regelgeving op de planning van waterstofinfrastructuur? Op welke manier zou de vertraging die hier ontstaat verminderd kunnen worden?
7] Mogelijke oplossingen	• Wat zijn volgens u nu de belangrijkste oplossingsrichtingen om de vertraging te verminderen? • Zijn er nog issues en oplossingsrichtingen die tot nu toe niet in dit gesprek naar voren zijn gekomen? • Zijn hiervoor nieuwe samenwerkingsverbanden nodig, bijvoorbeeld binnen bestaande instituties of binnen bepaalde regio's?
8] Afsluiting	• Heeft u verder nog vragen of aanvullingen op mijn onderzoek? • Zijn er partijen of personen die ik zeker nog moet spreken voor mijn onderzoek?

8.2] Code tree

The interviews of this study have been coded in the programme NVIVO. The following codes have been used:

- **Perception of delay**
    - Existence of delay
        - There is delay
        - There is no delay
    - Required response to delay
        - Delay should be tackled
        - Delay should not be tackled
- **Statements about technicalities**
    - Steel pipelines
    - Thermoplastic pipelines
    - Reuse of natural gas pipelines
    - Solutions to technical issues
- **Statements about planning and regulations**
    - NEN
    - Permits
    - Zoning Plans
    - Risks
        - Bevb/Revb
        - Risk contours
        - QRA's
        - Calculation Models
        - Finding a balance
- **Statements about participation**
    - Occurance of NIMBY
    - Participation Process
    - Land ownership
    - Role of authorities
        - Local
        - Province
        - State
- **Overarching solutions**
    - Creating a hydrogen market
    - Institutional changes
    - Grants
    - Levies
    - National Hydrogen Net
    - Pipeline Corridor
    - Other

8.3] Original Quotes

Quotes that were originally in Dutch have been translated into English in the text of this thesis. The original, Dutch quotes can be found below:

Page 12:

"Een passende en tijdig beschikbare waterstofinfrastructuur is een noodzakelijke voorwaarde voor het behalen van de klimaatdoelen, het behouden van al aanwezige industrie en het aantrekken van nieuwe bedrijven naar Nederland" (Wiebes, 2020).

Page 24:

"Groene waterstof helpt ons om de doelen van het Parijsakkoord sneller te behalen dan we dachten en het creëert nieuwe duurzame banen in Noord-Nederland. We moeten nu vaart maken." (interview 14)

Page 25:

"Als je dan kijkt naar hoe dat in elkaar grijpt met vertraging, dan hebben al die partijen een eigen planning, maar die kan pas doorgaan als er in de planning van een andere partij een vinkje ergens op groen komt te staan. Dus het is niet zo dat je je eigen planning maakt en dat je die route helemaal kunt aflopen. Om voortgang te bereiken ben je regelmatig afhankelijk van een groen vinkje in één van de parallelle planningen. En als daar vertraging in ontstaat, dan stort eigenlijk het hele proces in." (interview 16)

Page 26:

"Technisch gezien, als ik praat over stalen leidingen, een bekend product, niet een nieuw product, dan is het qua techniek al zo vaak gedaan dat daar niet vaak vertragingen uit voortkomen. Tenzij er problemen zijn met de levering van materialen." (interview 1)

Page 27:

"De aanleg van een stalen buisleiding neemt allemaal heel veel ruimte in beslag en je moet ruimte hebben voor je equipment en om er langs te rijden. Hoe groter je buizen, hoe groter het materieel dat je nodig hebt. En dat gaat natuurlijk niet zo snel, want je moet elke keer die lassen aan elkaar maken, je moet een gat graven, die pijp erin leggen, dan moeten er nog verbindingen worden gemaakt. Dus dat duurt lang en het levert heel veel overlast voor je omgeving op." (interview 16)

Page 28:

"Het zal in mijn ogen gigantisch veel zonde zijn om dat gasnetwerk overboord te gooien en te zeggen: we gaan naar waterstof en we gaan het even overnieuw doen. We kunnen het aardgasnetwerk denk ik met wat simpele aanpassingen heel goed gebruiken voor waterstof, maar dat vergt gewoon een gigantische coördinatie." (interview 12)

Page 31:

"Als jij een composiet koopt, dat is bij elke leverancier waar je koopt anders, en bestaat weer uit andere materialen, andere sterktes, ander gedrag van zo'n buis. Dus het is heel moeilijk om dat in één norm vast te leggen. Dus dat is de achtergrond: het is wel kunststof, maar niet in de NEN vastgelegd, of er staat niet omschreven hoe je ermee om moet gaan." (interview 16)

"Dan heb je de Groningen Seaports-leiding. Dat is de kunststof leiding. Dat is ook meteen de meest moeilijke, omdat die buisleidingen moeten voldoen aan (...) een aantal NEN-normen, bijvoorbeeld de NEN-3650. En kunststof leidingen voor waterstof staan niet in die NEN-normen. Dus daar zijn geen specifieke eisen voor opgesteld. (...) Groningen Seaports wil dat vezelversterkte thermoplasten worden toegepast. De NEN-norm bevat voor deze toepassing echter nog geen eisen. Dus de kunststof leiding zoals Groningen Seaports nu wil aanleggen is eigenlijk niet afgedekt door regelgeving. Dat wil niet zeggen dat het niet mag, maar ze bewandelen een nieuw pad. Iets wat nog niemand gedaan heeft in Nederland. En dan loop je tegen een aantal problemen en vertraging aan." (interview 1)

Page 31-32:

"De NEN-regelgeving moet aangepast worden, vooral zodat kunststof in de NEN-3650 wordt opgenomen, en ook voor meerdere toepassingen. Niet alleen voor waterstof, maar ook voor andere (gevaarlijke) stoffen boven de 16 bar. Wat Groningen Seaports doet is specifiek toestemming vragen voor een bepaald type kunststof: Soluforce. Dat is heel leuk, maar er zijn honderden, duizenden soorten kunststof. Dus die wetgeving moet wel meer generiek worden wat dat betreft. Dat ook andere fabrikanten van kunststof acceptabel zijn. Dat zou in de toekomst een hoop vertraging besparen." (interview 1)

Page 33:

"Maar voor waterstof specifiek is er dus geen regelgeving, maar alleen voor "aardgas". (...) Ik heb een jurist gevraagd: mag ik dan in plaats van aardgas "waterstof" lezen in mijn wet- en regelgeving? En hij zei: ja dat kan, waarom niet? (...) Dan kun je gewoon waterstof invullen, daar waar in de regelgeving het nu aardgas is. Dus dat is eigenlijk geen knelpunt meer." (interview 7)

Page 34:

"Als je nu praat over de planning: waar kun je winnen op de planning voor het leggen van dit soort leidingen? Dan is dat bij het vermijden van het risico van een Inpassingsprocedure. Als je die kunt vermijden heb je het tijdspad eigenlijk zelf in de hand." (interview 16)

"Dus die gehele druk-range van 8 tot 16 bar, dat is een onontgonnen gebied (...) Ja, als we een energietransitie tegemoet willen gaan en we willen daar voortgang in krijgen, dan zullen dit soort gebieden misschien toch ontgonnen moeten worden om te kunnen versnellen." (interview 16).

Page 37:

"Een voorbeeld is de kunststofleiding in Groningen Seaports. Er is een bepaalde dikte aangemeten. Die dikte is eigenlijk dikker dan het zou moeten zijn. Je zou dus kunnen zeggen: de kans dat die dus zal openscheuren of zal breken is dus kleiner dan de kans die nu gebruikt wordt. Dus de marge die daar op zit zou je dus ook door kunnen vertalen naar een kleinere kans op een breuk. Als daar genoeg testgegevens van zijn zouden zijn, dan zou je het ook kunnen toepassen. (...) Maar er moeten wel genoeg gebruikers zijn en er moet ook wel genoeg informatie over zijn." (interview 10)

Page 39:

"Eén van de aspecten van het veiligheidsdenken is dat het altijd uitgaat van onveiligheid. Terecht op zich natuurlijk, maar als je je beseft dat buisleidingen de meest veilige mobiliteit zijn die er is, ten opzichte van binnenvaart, maar zeker ook vergeleken met weg of spoor. Dan zou eigenlijk uit de sommetjes moeten komen dat een pijpleiding veilig is. Maar de regels gaan over onveiligheid en voor je het weet heb je de meest veilige mobiliteit zodanig streng berekend dat die onbetaalbaar wordt. Wat je dan krijgt is dat transport over de weg gewoon kan binnen de regels, maar dat transport via buisleidingen onbetaalbaar wordt. Dat is iets wat je niet zou willen." (interview 9).

Page 40:

"Een politiek verantwoordelijke zal nooit zeggen "dat is wel veilig genoeg". Dus als een risico geïdentificeerd wordt, dan moeten we dat eigenlijk wegregelen. Voor je het weet maak je het onmogelijk om dingen te doen. We moeten dingen dus in perspectief blijven bekijken." (interview 9).

"Wat het meest complexe is aan leidingbouwprojecten in de bebouwde omgeving is de omgeving zelf. Kijk: het technisch aanleggen van een leiding, dat is plat gezegd een kunstje dat we al heel veel jaren doen. Een kunstje dat we goed in de vingers hebben. Maar de omgeving: je hebt impact op de omgeving, zowel bij de constructie als bij het gewoon liggen van de leiding. Dus dat moet je netjes regelen. En ja, als je daar te snel gaat, of partijen niet meeneemt, of op een verkeerde manier meeneemt, dat is zegmaar de grootste kans op vertraging die je kunt krijgen." (interview 11).

Page 41:

"Voor je het weet keert de maatschappij zich tegen je en dan kan je project niet meer" (interview 12).

"Ik merk in ieder geval dat mensen de overheden minder vertrouwen. Dus op het moment dat een gemeente, of een partij zoals het Ministerie van EZK, of weet ik veel wie, zich ergens bij een burger meldt, dan denkt de burger: Oh jee, nu moet ik me schrap zetten, nu gaat er waarschijnlijk iets gebeuren wat ik waarschijnlijk niet wil." (interview 15)

"Kijk. In Groningen, en dat is natuurlijk het complexe verhaal: door die aardbevingsproblematiek als gevolg van die gaswinning heeft iedereen nu echt zoiets van: dat gerommel in de bodem moet nu eens afgelopen zijn. Of dat terecht is, dat kan ik niet eens beoordelen, maar het is wel een sentiment dat hier heerst. Daar heb je je wel toe te verhouden." (interview 15)

Page 42:

"Het woord draagvlak vermijd ik bewust. Voor mij is draagvlak dan weer anders dan acceptatie. Bij acceptatie kan er ook sprake zijn van: ik wil het niet, maar ik kan er uiteindelijk wel mee leven. Dat is fundamenteel anders dan: ik ben er nu helemaal voor. Dat kun je soms niet van mensen verwachten." (interview 15)

"Kijk, het begrip participatie vind ik af en toe wat misleidend. Dat zeg ik misschien een beetje scherp. Op het moment dat je eigenlijk al weet wat je wilt en hoe je het wilt gaan doen, dan is de vraag: wat is er dan nog te participeren? Dan moet je dus ook eerlijk zijn en zeggen: luister, beste mensen, het gaat niet om de vraag óf deze leiding hier komt, sterker nog, we weten al waar 'ie komt en hoe diep 'ie komt te liggen. De vraag is: hoe kunnen we zorgen dat de impact op de omgeving wordt verminderd? (...) Maar het beeld wordt vaak geschetst bij participatie: oh, dan hebben we nog maximale invloed op wat er nog zou kunnen komen. En dat leidt dus duidelijk tot teleurstelling." (interview 15)

Page 43:

"Dus: participatie heeft in mijn ogen alleen zin als er daadwerkelijk een vraag voorligt waar mensen wat mee kunnen. Anders is het gewoon communicatie wat mij betreft. Dan ga je vertellen wat er gaat gebeuren en hoe het eruit ziet en dan mogen mensen alleen nog aangeven: houd rekening met dit of dat. Dus participatie gaat er echt vanuit dat je ook echt mee kunt denken en beslissen in zekere zin. Mee kunt sturen." (interview 15)

"We moeten er inderdaad voor uitkijken, als mensen het niet allemaal snappen, dat ze ertegen gaan protesteren. We moeten een duidelijk PR-verhaal hebben waarin we de risico's duidelijk uitleggen. Ik zit misschien een beetje te chargeren, maar het moet wel in Jip-en-Janneketaal. Ik denk dat de gemiddelde Nederlander nog nooit van een QRA heeft gehoord en dat soort zaken en daar dan een eigen gewicht en mening over gaat geven waar je helemaal niks aan hebt. Dus we moeten dat heel gecoördineerd en heel zorgvuldig met z'n allen gaan doen." (interview 12)

Page 46:

"Daarbij is het van belang dat je die visiestroken van de Structuurvisie Buisleidingen ook daadwerkelijk kunt gebruiken. Dus niet dat de stroken gereserveerd zijn, maar dat er lokaal toch andere gedachten over zijn. Dat is toch nog wel een spanningsveld in de steeds verdergaande decentralisering van de ruimtelijke ordening. Er is een Rijksoverheidsvisie, maar er zijn lokale belangen die ook spelen. Het is belangrijk dat die nationale plannen gevolgd worden, ook in lokale bestemmingsplannen. Dat gebeurt in de praktijk helaas niet altijd" (interview 9)

"Vroeger konden we dan met het Ministerie van EZK gaan praten, het energie-ministerie, en met BZK voor de ruimtelijke ordening. En dan konden we zaken gaan regelen. Straks kunnen we met 24 gemeenten op de Veluwe gaan discussiëren over de aanleg van een leiding." (interview 12).

Page 47:

"Het is een beetje het kip-ei-verhaal: je moet een afnemer hebben voor datgene wat je door je buis vervoert. Ga je eerst buisleidingen aanleggen zonder afnemer, dan heb je een grote kostenpost, waarbij je niet weet of je je waterstof aan de man krijgt." (interview 13)

"Dat is natuurlijk altijd een beetje een lastig spel: je weet de elektriciteitsprijzen niet over tien jaar, je weet de groene waterstof prijs niet, je weet de beschikbaarheid niet, de leveringszekerheid weet je niet." (interview 14).

Page 48:

"We hebben een soort "Steve Jobs"-achtige moed nodig om te investeren in de grootschalige ontwikkeling van waterstofinfrastructuur" (interview 9).

Page 49:

"Maar we zien met name ook wel bedreigingen voor vertraging als het gaat om stikstof en PFAS en dat soort zaken. Dat zijn zaken die wel naar voren komen, waar we natuurlijk ook niet alles voor opgetuigd hebben. Dat zien we als een bedreiging." (interview 2)

Page 51:

"Maar de grote slag die moet nog komen. En die grote slag is naar mijn idee veel meer afhankelijk van de betaalbaarheid, dus de subsidiestructuur, dan van ruimtelijke processen." (interview 4)

"Waterstof valt een beetje tussen wal en het schip. Het is te groot voor de demo's of de innovatiesteun, maar kan toch nog niet concurreren in de SDE++ met andere CO2-reducerende technologieën die veel volwassener zijn. En voor waterstof heb je eigenlijk nog iets daartussen nodig." (interview 14).

Page 52:

"Het zijn inderdaad nog alleen maar plannen, maar als straks duidelijk is wie de landelijke beheerder wordt van het waterstofsysteem, dan heeft die partij ook het mandaat om aan de gang te gaan met zo'n waterstofinfrastructuur. Dat genereert dan ook weer vanzelf de markt. Dan zien bedrijven ook wel dat er iets ontstaat. Dan ontstaat een stukje enthousiasme. Maar dan ziet men ook dat waterstof er écht aan zit te komen. Dan krijg je vanzelf wel een kentering." (interview 6).