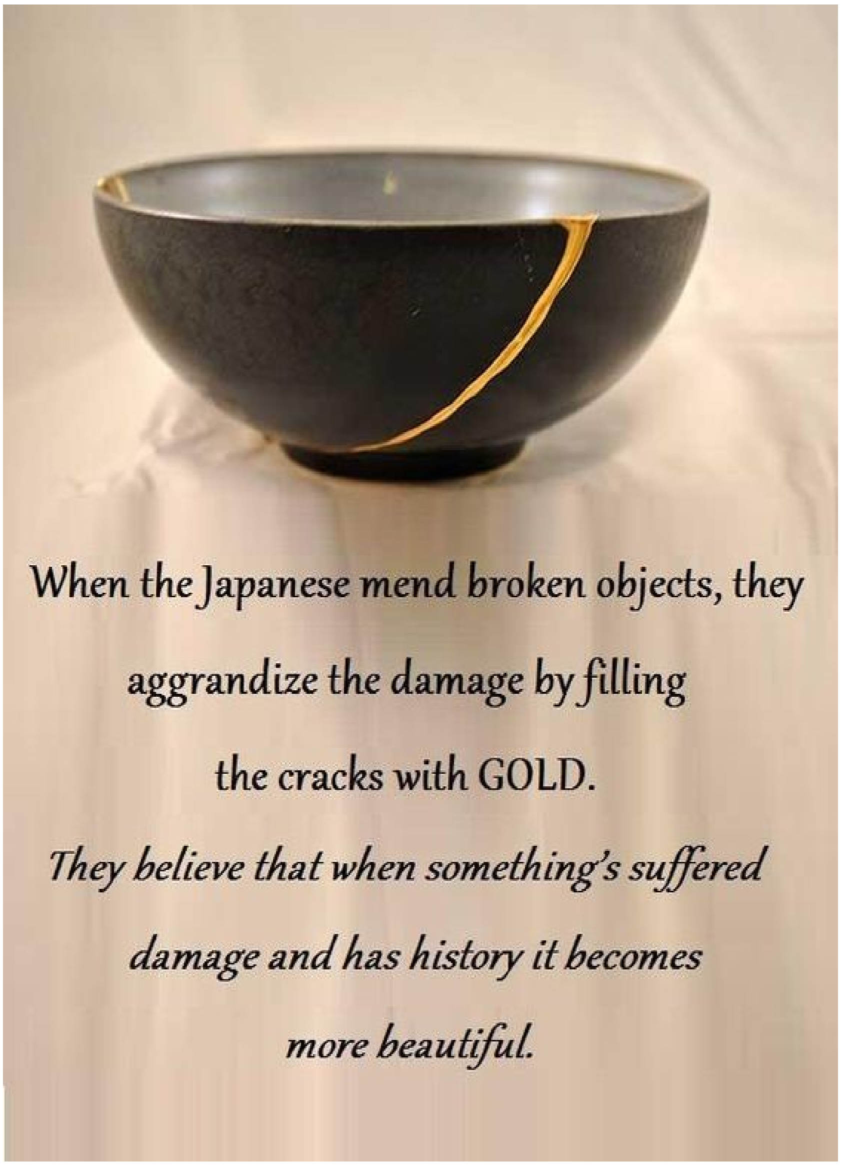
2021

What are the barriers to implementing hydrogen in Dichterswijk Utrecht



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Abstract

This thesis aims to focus on the barriers to the implementation of hydrogen in neighbourhood Dichterswijk Utrecht. In the climate agreement of the Netherlands, one of the sub-sectors in which carbon emissions should be reduced is the built environment. Natural gas is used in the residential areas for heat provision and sometimes also for cooking. Therefore, 38% of all the total carbon emissions in the Netherlands result from the built environment's produced carbon. An alternative for natural gas can be hydrogen, which is almost carbon-neutral if made from a renewable energy source. However, before such a technology can be implemented in Dichterswijk, there are, according to this study, three significant barriers that prevent this transition.

First of all, hydrogen recognizes technical defects that threaten this technology for upscaling and result in high production costs, therefore, losing credibility as an alternative for gas. These technological impediments ensure that political support on a regional scale is unfeasible. Secondly, local actors such as grid and energy corporates seek other options than hydrogen to be possibly used in the built environment. Thirdly, the social support base of this technology is becoming an increasing factor as the demand for hydrogen is becoming a hype in the Netherlands. Yet, local ownership plays a pivotal role as the upcoming transition happens behind the residents' front door. This entails that the residents are willing to switch to hydrogen if it proves that this technology is, in fact, the best solution.

The chance of hydrogen to be implemented in Dichterswijk is highly unfeasible as the costs do not outweigh the possible mitigative effects on the environment. Thus, at this moment, the potential of this energy carrier lies elsewhere, even though inhabitants might favour the technology.

Acknowledgement

Before you lies my thesis, it results from a very long journey that sometimes was quite challenging. During this period, I have worked with great pleasure on the thesis. This thesis was constructed from January till July and is the result of my graduation from the MSc. Environmental and Energy management at the University of Twente in 20/21.

Therefore I want to express my sincere thanks to dr. E.J.Aukes and dr. F.H.J.M. Coenen, who were my thesis supervisors and guided me through this process with utmost patience and showed understanding of the situation where both students as lectures were situated during the COVID-19 pandemic. I have greatly benefited from their professional knowledge and high academic standards. I am very thankful for the continuous support I received and will take it as a lesson for the future to be just and resilient with others.

Furthermore, I would like to thank friends and family who have helped me construct the survey and always backed my endeavours and encouraged me to reach my goals.

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List of Abbreviations

MLP	Multi-level perspective
RES	Regional Energy strategy
STUW	(Dutch=Stichting Utrechtse Woningbouwcorporaties) Building corporations in Utrecht
PAW	(Dutch=Programma Aardgasvrije wijken) Programme of gas free residentials
IRENA	International Renewable Energy Agency
IEA	International Energy Agency
CBS	Central bureau of statistics
Ministerie EZK	(Dutch= Ministerie van Enconmische Zaken en Klimaat) Ministry of Economic affairs and climate
PBL	(Dutch=Planbureau voor de Leefomgeving) Dutch Environmental Assessment Agency
TNO	(Dutch= Nederlands organisation voor toegepast natuurwetenschappelijk onderzoek) The Dutch organisation for applied Scientific research
Gemeente Utrecht	Municipality of Utrecht
PV	Photovoltaic
GHG	Greenhouse gasses

Introduction

''Kintsugi arose as a way to not merely fix a broken object
but to transform it into something beautiful.
Use something beautiful on something damaged to
create something even more beautiful than it was before,
even if that object was once broken''(Santini, 2018).

Concern for climate has received a lot of attention recently; more specifically, the situation aggravates with every year passing by. This is because our energy consumption and the discrepancy between energy availability have emerged as a global phenome, where the reliability of energy is a daily burden. Fossil fuels are the most dominant form of energy, whereas fossil fuels are not sustainable energy sources (IRENA, 2019; PBL, 2020b). In 2019, the IEA (2019b) predicted that the peak oil supply will reach its maximum in less than two decades. As a result of the expected finite fossil fuels, innumerable collective action problems arise, such as energy poverty, resource scarcity and warfare in the regions of production (Van Den Graaf & Sovacol, 2020). Therefore, the demand for a new innovative energy technology that does not affect the environment is essential for future progression.

In this regard, the Paris climate agreement was established to mitigate the effects of global energy production. From this international conference of parties, the Dutch climate agreement was conceived to reduce carbon emissions, thus creating demand for a zero-emission energy system. A key contributor to climate change is the built environment in the Netherlands that accounts for one-quarter of the emitted carbon (CBS, 2019). The utilisation of natural gas primarily causes this as the fuelling technology in our residential areas. Consequently, the development of alternatives is becoming of pivotal importance for both climate and economic reasons, hence, the urgent need for natural-gas-free residential areas. One of the goals set for 2030 is to successfully make 1.5 million houses free of natural gas (De Rijksoverheid, 2020) and by 2050, it must be entirely free. However, in the experimental households, this process happens anything but smooth (Van De Knaap, 2020); after just two years only a few hundred of these houses have been made natural gas-free. Hence, the magnitude of the grand renovation is unmistakable significant because in the Netherlands 91% of the households are heated by natural gas, thereby releasing an abundant amount of CO_2 into the atmosphere.

Zooming in to the city of Utrecht, the primary objective is to reduce carbon emissions, thereby investigating every possible alternative for the disengagement of natural gas. Despite the considerable amount of substitutes for lowering the reliability of natural gas, each of these solutions still pollutes the environment (Berenschot, 2018). A potential option for achieving natural gas free neighbourhoods is the preference of using sustainable gasses. This implies on the one hand biogas which is nothing more than natural gas produced more eco-friendly, therefore still emitting carbon into the atmosphere. At the same time, there is hydrogen that is the most abundant element on earth, that does not occur naturally in comparison with oil and gas. Yet, it has to be produced from other materials; therefore, it's an energy carrier instead of an energy source (Fuel Cells and Hydrogen, 2019). More specifically, the possibility of utilising hydrogen as a fuelling technology in the built environment has been recognised (TKI Urban Energy, 2020) and currently gaining momentum (Waterstoflab, 2021). This is because hydrogen has an incredible capability of inducing zero carbon footprint if produced from a renewable energy source. Moreover, hydrogen can be employed as an alternative for natural gas in residential areas due to its high energy capacity (V.Ressen, 2020).

Nevertheless, several issues with hydrogen have surfaced being the availability, transport and implementation procedures (PAW, 2021d). First of all, hydrogen is not available on a large scale at this moment due to high production costs; therefore, it must first experience a price drop along the supply chain to be an attractive solution (Global, 2019). Secondly, responsible authorities must recognise the three layers and the implementation program (CE Delft, 2020). The application of hydrogen in the built environment is a new topic that raises many questions by the national and regional authorities, companies involved with the energy supply and civilians. Overall, along with the socio-technical transition in which hydrogen becomes the replacement of the dominant fossil fuel regime in our homes. One thing plays a vital role in the actual implementation process and that's local ownership (PAW, 2021b). In the end, if hydrogen as a niche can penetrate the market and become the new way of heating our residential areas, it occurs behind the front door (PAW, 2021a). This change suggests that the individuals that own a particular house will determine which technique they will allow into their homes. It stands to reason that suggestions from the local authorities are presumably the options that are fit to be considered. Nonetheless, by implication, the planned system change can only be driven by the acceptance of the local inhabitants. Hence, the ambitious task ahead for convincing the local owners for allowing radical innovation into their beloved homes.

An ''all-electric'' heat pump is considered to be a realistic option as it only uses electricity. However, the electricity consumption increases drastically, whereby the electrical consumption can sometimes quadruple (Vattenfall, 2020). Besides, this option will not solve the issue of carbon emissions. However, it will only move the problem due to the share of natural gas still used in the energy production of the Netherlands, in particular Utrecht, in which natural gas accounts for 75% of the total (Eneco, 2019). Overall, the ‘’all-electric’’ option might serve its cause in the long term battle for reducing carbon emissions, be that as it may, the first reference moment is in 2030. In this line of reasoning, the heat pumps have the potential for the future. Yet, as our electrical production still relies on natural gas, this option loses the capability of reducing carbon emissions by fifty percent before 2030.

A second alternative for the disentanglement of natural gas in the built environment is district heating. This is an option whereby water is heated at a central point and distributed further into a residential area. Considering that the water is heated with an energy source that diminishes the carbon emissions, this technique emerges as sustainable heating for residential spaces. However, the municipality in Utrecht recently has constructed a biomass incineration plant that will deliver the required heat for district heating (Eneco, 2020a). Yet, a recent study (NOS, 2019) concluded that biomass plants still produce carbon during incineration. Furthermore, the produced carbon even increases, thereby exacerbating the environmental harm from generating energy for district heating (Wang et al., 2019). More specifically, the controversial aspect of using biomass as an alternative energy source is also something that emerges on a national scale. The former minister of economic affairs and climate took the initiative to integrate biomass as a part of a consistent framework for the Dutch climate agreement (Ministerie EZK, 2019). Thereby acknowledging the potential of biomass procedures to be carbon neutral instead of accepting that this contradictory carbon-emitting technique (PBL, 2020a) will not win the war for the Netherlands.

Overall, the built environment accounts for 38% of the total gas consumption and the Netherlands is the fourth-largest gas consumer in Europe (IEA, 2019a). This entails that the Netherlands is a suitable place to evaluate the transition towards renewable energy sources. More specifically, the Netherlands must increase its commitment to more serious CO_2 emission reductions set by the EU for its member states. According to the United Nations climate change Secretariat (2018), the Netherlands incurs 90% of its greenhouse gasses to CO_2, in which the built environment accounts for 38%. Therefore, the Netherlands and more zoomed in on Utrecht are facing as described by (PAW, 2021c) one of the biggest national challenges. The scenario in Utrecht is where approximately 75% of households rely on natural gas (Eneco, 2019). In other words, the extrication of the natural gas regime has been engaged by the municipality of Utrecht.

1.1 Research objective

With this intention, the possible transition to hydrogen in the Netherlands in particular Utrecht faces as described by Geels (2019) several mechanism in which the dominant fossil fuel regime is locked into the current system. In order to shift to a more renewable fuelling system a heat pump or district heating option will not give the credibility of achieving the climate goals. The objective of the thesis is to identify the impediments towards the implementation of hydrogen as a fuel for the residential area in Dichterswijk in Utrecht. Hydrogen can be seen as one of the many technologies which might be the answer to solving this complex puzzle (Consortium Waterstofwijk Hoogeveen, 2020). However, this technology lacks the political, economic and social support. Although, there is an abundant amount of support in politics for the other technologies. Provided, that this technology will be used in the energy transition (De Rijksoverheid, 2019a), this research will help to determine the political, technical and societal barriers which come at hand and will formulate the probability of implementation in Dichterswijk in Utrecht. The specific objective of this research are threefold:

1) To describe the current elements of hydrogen as a fuel in residential areas in terms of actors, problems, goals, strategies, instruments, technologies, responsibilities and resources.
2) To explain the socio-technical impediments towards implementing hydrogen in Dichterswijk.
3) To determine the social acceptability in Dichterswijk for allowing hydrogen to be used as a fuelling technology

1.2 Research questions

What are the barriers for hydrogen as a fuelling technology in Dichterswijk in Utrecht towards the natural gas free neighbourhoods?

- How does the current regime look like regarding heating of the residential areas in Dichterswijk?
- What are the socio-technical impediments which hinder the further implementation of hydrogen in Dichterswijk?

Conceptual framework

This chapter will define and elaborate on the conceptual framework of this thesis. Thereby investigating previous work of academia on transitions and provide insight on possible impediments that the future transition in the built environment can experience. Furthermore, the conceptual framework will be developed in order to provide the researcher with a systematic analysis on the research objective of this thesis.

2.1 MLP

Research and innovations are programs that emerge within the context of sustainability transitions (Geels, 2002). These sustainability transitions are needed for realising social and technological change to reduce the harmful impacts of our polluted systems. In the Netherlands, these ongoing transitions are part of the climate agreement of 2015. All these transitions are happening because of the global shift from fossil fuels to renewables. The normative goal of this research and innovations programs is improving the social necessities like the desire for versatility and energy, where social advancement could be characterised as development. Thereby limiting negative socials impacts and improvements around issues like the typical weight of these issues on the environment (Bakhuis, 2020). In theory there are three models that have the capacity to describe transitions in general, specifically Transition Management and Strategic Niche Management. The first model describes transitions as significant shifts in 'socio-technical regimes,' or the dominant direction by which social needs such as energy supply and heating are met, from their pre-development phase to the sustainable stage (Loorbach, 2007; Loorbach et al., 2017). This all comes together as the analytical perspective that describes the society as a diverse and complex system that evolves and ultimately undergoes a dynamic and structural change. At the same time, the latter describes transitions as the consciously regulating niche formations processes that will develop through real-world experiments (Raven et al., 2010).

Having said that, the last model that enables the researcher to acquire the research objective of this thesis is the MLP framework. This is a model capable of providing an analytical framework to view the situation from an academic perspective and critically assess a potentially upcoming transition (Geels, 2011). Furthermore, this model has been created through several contextual analyses on previous transitions to understand long-term socio-technical change and recognises three analytical concepts: niches, landscape and regimes (Roberts & Geels, 2019)(see figure 1). The main idea of MLP is the regime that is regularly associated as the reason to clarify why new advancements do not break through the rules and institutional barriers and guides the regime actors into blindness for alternatives. On the complete opposite, there is the concept of niches which represent the radical innovation or the promise of improvement. The niche is the innovative solution often presented in the contextual framework of the regime and will radically change the current system (Geels & Schot, 2007). The last concept of MLP is the landscape which is a metaphor for the alignment of developments that determine once the shift occurs (Geels, 2012). Changes at the landscape level, for instance, put pressure on the regime and create openings for new technologies.

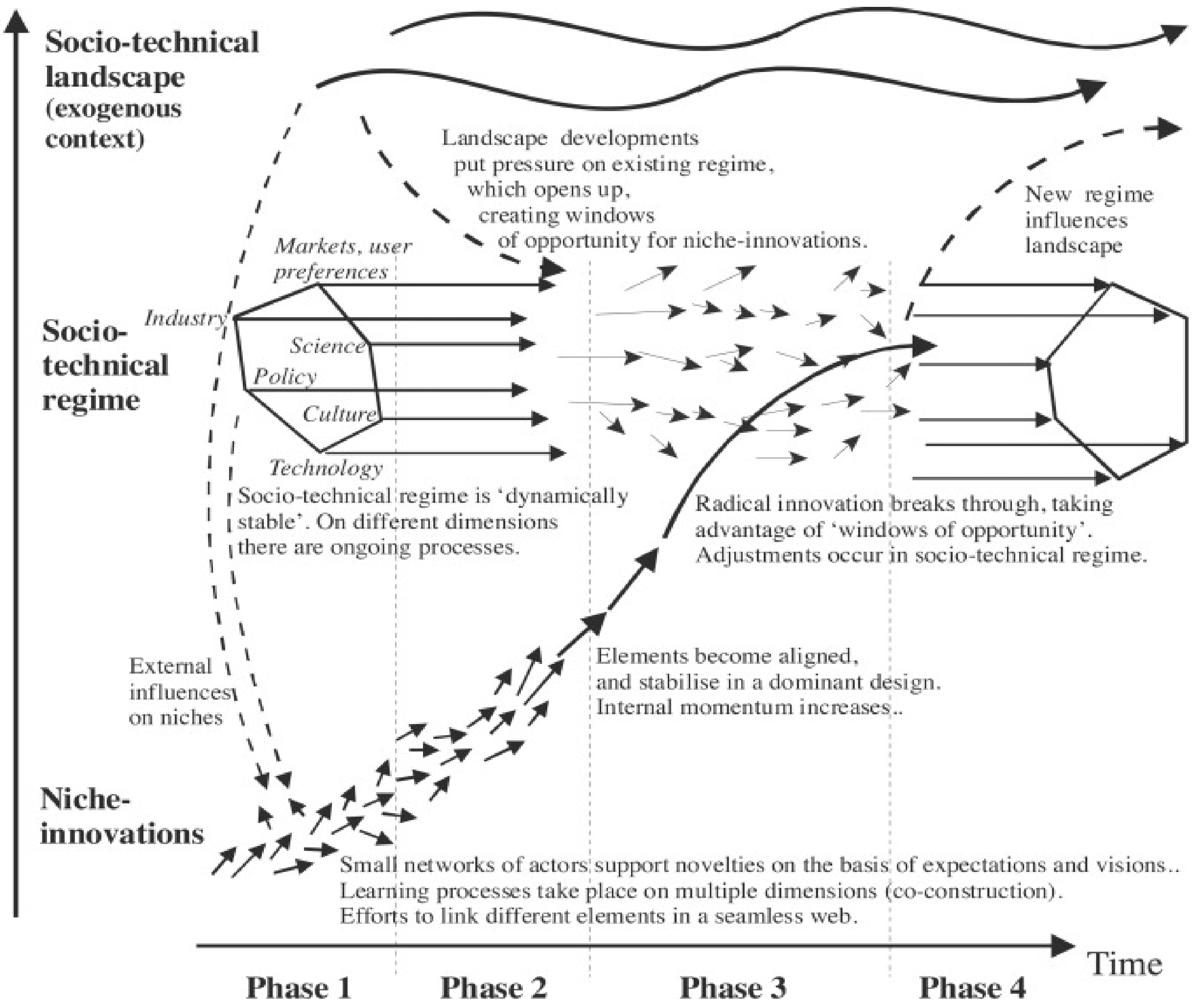

Figure 1: The MLP (F.W.Geels, 2002)

2.1.1 Motive for MLP

With this in mind, the role of MLP on socio-technical transitions in the built environment offers a broad perspective thus allowing the researcher to identify the socio-technical impediments for bringing about the intended change. This is important as environmental, economic yet also social problems are associated with a carbon lock-in as Unruh (2000) illustrates. In this regard, the MLP framework does well at characterising incumbent actors and relevant organisations at the regime- and niche level. Concretely, the MLP distinguishes on the three levels thereby, creating a clear scope for the project serving as a just demarcation for this research's problem statement. For example, identifying green hydrogen as the niche allowed the researcher to classify related actors and organisations thus to have a clear distinction between niche and regime.

A second motive for a choice on MLP could be the combination of drawing on lessons from historical lessons on previously done case-studies therefore developing diverging paths which can lead to a new establishment of the contemporary regime. Moreover, the role of the MLP on these socio-technical transitions in this thesis can serve as an investigative tool of the position of hydrogen in the built environment. Furthermore, this determination can provide a comparison framework with the fossil fuels where both situations are depending on the national and European developments regarding hydrogen. Therefore, the application of MLP as Geels (2018) describes can offer an overarching framework where the socio-technical transition involves the struggle between the emerging niche innovation and the existing socio-technical system. This all in the context of the landscape developments in which there is a re-alignment towards the niche innovation. Using MLP in this regard suggests that incumbent policy-makers defection is crucial within these socio-technical transitions, yet is a very under-studied mechanism for political acceleration of transitions (Meadowcroft, 2009). More specifically, the switch in allegiance to destabilize the socio-technical regime increases the drivers of niche-momentum and their influence on policy-makers (Turnheim & Geels, 2013).

2.2 Scientific overview of MLP on transitions in the built environment

The Netherlands faces an incredible task formulated through the climate agreement. This incredible task entails the five sub-sectors to be decarbonized: mobility, industry, built environment, agriculture and land and electricity (PBL, 2020c). In the face of the worldwide peril of climate change, the demand for possible pathways to make the sub-sectors more sustainable has rapidly increased in the past years. In the Netherlands, there is a widespread agreement for a more viable built environment that will require a significant socio-technical transition (Thuesen et al., 2016). Yet this transition will not happen as new technologies present themselves as possible alternatives for the dominant fossil fuel regime. Subsequently, the incumbent system that paralyzes the new technologies shown in niches is supported by pre-existing mechanisms. These path-dependent tools can be vested interest, sunk investments, and user practices as cognitive routines that make the existing system blind to change (Geels, 2012). Moreover, institutional parties play a pivotal role in these ongoing transitions where politics and power can change the playing field. However, in the earlier transition studies, politics wasn't explicitly enough present in the analysis (Geels, 2002). The discussion in these works focused on historical research and socio-technical transitions. The socio- was there, and the technical element, yet the explicitly political, was not there so much. However, to a large extent, that has been overcome as researchers have contributed pieces that more and more have put politics as a critical component in the processes of change (Roberts & Geels, 2019).

Initially, essential transition scholars such as Kemp and Geels (2005) never applied their management ideas to the field of the built environment. Early on, a transition study by Kemp and Loorbach in which they blamed current Dutch politicians for being too fragmented on technological fixes and a comprehensible future vision. Later on, transition studies have been done by independent research institutes (TNO, 2021), thereby investigating every opportunity for making the built environment more efficient and climate neutral. Moreover, these academia and research institutes acknowledged the necessity for a solid policy framework within this research. Thereby highlighting that the progress made within the built environment was beginning to stagnate. Therefore, in line with the path-dependent tools described by Geels (2019) academic interest lies in identifying the policy and politics behind the transition. This vital factor is recognized by Bögel et al. (2019) as part of an organizational change in which the fossil fuel policy regime is resistant to change.

In addition to the help of MLP is supposed to contribute to articulate the complex challenges involved transitioning away from current practices and technologies within the built environment sector. The socio-technical transition perspective offers the help of explaining the current situation with the hydrogen fuelling technology used in the built environment. Thereby offering a comprehensive framework in which the incumbent actors, policy strategies, yet institutional capabilities and knowledge are of pivotal importance for obtaining a widespread consensus on the implementation process of hydrogen in the built environment. Furthermore, various mechanisms of the current fossil fuel regime suggests that incumbent policy-makers tend to be locked-in and are generally supportive of the existing system. In line with the jargon of the MLP framework, thereby elaborating on the big picture and understanding innumerable actions in which these socio-technical barriers aid the dominant system to be resistant to radical innovation. This will contribute to sharing new insights into the socio-technical impediments for increasing the niche momentum in the built environment (PAW, 2021a).

Furthermore, public and regional authority interaction is crucial for processing signals from the residential area to the corresponding organizations, hence, the importance of reaching a consensus with the local owners (PAW, 2021c). In addition to these developments, the social support base for accomplishing a more sustainable built environment is brought within the light of this transition through acknowledging the social support base as a potential barrier for the implementation. In this line of reasoning, regional authorities have determined the social support base as the new challenge in the grand renovation of the Netherlands. This entails that the social support base might be seen as the biggest socio-technical impediment to overcome in the transition towards hydrogen in Dichterswijk.

In other words, in this research to offer an overarching framework and to explore the research objective of this thesis MLP will be applied in the built environment. In this settlement green hydrogen is interpreted as the niche, the regime level is confided as the natural gas system that is currently used in Dichterswijk. Finally, the landscape will serve as a background to both niche and regime and will be elaborated on in the section (4.1 current position of hydrogen in Dichterswijk).

Methodology

This chapter will explain the methodology used in this thesis, thereby elaborating on the techniques of data collecting. Moreover, there will also be a description of how the data will processed to answer the research questions. Lastly, this chapter contains the methodology behind the survey questions and on which social indicators the different survey questions consists of.

3.1 Dichterswijk

The current sample used within this research is the Dichterswijk community which can be interpreted as a typical case as described by Patton (2001). Why the Dichterswijk community is a typical case will be argued as follows. First of all, the community is architectural significant diverse containing different sorts of houses which could be identified as an adequate illustration of urban areas in the Netherland. Secondly, Dichterswijk contains people from multiple different cultural background thereby serving as an average example of the Dutch society which is also growing to be multicultural. Moreover, the combination of rental and owner-occupied homes in Dichterswijk is truly representative of the average Dutch residential areas. Although, the number (Gemeente Utrecht, 2020a) of young adults (25-44) is relatively high compared to the Dutch average this could also serve as adequate illustration on what the future's generation perception is about hydrogen and the potential for the future. Therefore, the Dichterswijk can be seen as a true typical and representative sample for the Dutch residential areas which is a kind of neighbourhood that can be found in other big urban areas in the Netherlands such as Amsterdam and Rotterdam. In line with this reasoning the results of this research might be applied to other residential areas in the Netherlands who share a mutual design and because Dichterswijk is interpreted as a typical case sample.

3.2 Data generation

This research uses more than one method, it involves the use of multiple types of qualitative data collection. Where on the one hand desk research is used (scientific literature and governmental reports and using fieldnotes from attended congresses and seminars) along with empirical research from the survey. The motive of this approach is based on the belief that by applying multiple methods and data collection procedures, the research will obtain a comprehensive picture of the situation. This applies especially while studying socio-technical issues such as sustainable heating and the energy transition in general. In other words, this may improve the validity of the study by using multiple methodological tools, such as surveys and desk research. Therefore, as described by Verschuren & Doorenwaard (2010), the combination of desk research and empirical research, allows for a better understanding of the research context. In line with this reasoning, triangulation will serve as a check on biases and deceptions that one source of data may have.

3.2.1 Primary data

In this research, the data gathered via the survey will be formulated by developing an in-depth literature review on social acceptability. Based on this study, the questions asked in this survey will be formulated in such a manner that the questions represent social indicators. The questions will directly be asked to the people living in Dichterswijk. This process might take some time, but in this research, there will be total control over the relational and attribute data gathered.

The survey will be distributed through a Facebook group called ''Dichterswijk''. This allows the researcher to obtain all the data required to answer sub-question 2, without having all the personal data such as e-mail addresses. If during this process it seems that the number of respondents is insufficient, an alternative process will be used. This method will require the researcher to make a round through the neighbourhood whereby the possible respondents are asked if they would like to be part of this research. To make sure the personal data of the participants is not given to the researcher, a printed paper with the link to the survey will be arranged. This way if the possible participant has agreed to participate in this research. He/she can directly go to the survey, therefore allowing the research to not obtain any personal data which can be linked to the participant.

3.2.2 Survey

The first indicator to be discussed is macro-social performance. This is an indicators that measures the acceptance of economic and environmental measures by the general public in the predefined criteria of the PAW (2021a). The survey questions are conceived in such a manner that the respondents can formulate their willingness towards the social indicators. Furthermore, one of the methods used to determine the willingness to contribute to a certain social indicator on the introduction of hydrogen is the Likert scale. This technique asks the respondents to indicate their willingness to a certain statement that is formulated in the survey. The used extremes of this method indicate the acceptance or rejection of the formulated statements. In some questions, the respondents are asked to indicate their willingness to a certain statement in the form of a linear scale. The motive for applying one of the methods for a particular question was based on the researcher's perception of which method was the best to optimize the results to determine the social support base. Finally, for the last survey question the respondents were asked to rank criteria that are important for realising the transition towards hydrogen in residential areas. These criteria were defined by the researcher throughout the study and were obtained through the webinar of the waterstofnet (2021).

Table 1: Extremes used with the survey questions

Extremes Likert	Extremes linear	Definition
Fully agree	10	The respondent indicates to fully accepting the information in the statement.
Partially agree	6-9	The respondent indicates to partially accept with the statement, thereby indicating a certain condition.
Neutral	5	The respondent cannot formulate an accepting or rejecting attitude towards the statement.
Partially disagree	2-4	The respondent indicates to partially disagree with the statement, thereby indicating a certain condition.
Fully disagree	1	The respondent fully disagrees with the statement, thereby rejecting all the information in the statement.

The second aspect to determine the social acceptability of hydrogen are the internal human resources. This includes the effects of the possible implementation of hydrogen in the form of policies. This entails, policies from the local authorities to realize the transition. Furthermore, this aspects deals with effects on health and safety of the end-consumers.

Table 2: Macro-social performance indicators

Aspect	Indicator	Definition	Measurement
1. Macro-social performance	1.1 Socio-economic performance	External economic impacts caused by the introduction of an innovative form of heating residential areas.	Willingness to financially contribute to innovation in the heating of residential areas.
	1.2 Alternative heating	Effect caused by the introduction of an alternative form of heating.	Willingness to contribute to innovation heating (production/utilization).
	1.3 Socio-environmental performance	Contribution to the introduction of innovative heating solutions that reduces harmful impacts on the environment.	Willingness to the contribution of innovation that reduce environmental load.

The final aspect External population analyses the social acceptance of community-related indicators. These indicators take into account both environmental as cultural factors that are influenced by the introduction of hydrogen. These social indicators are important because the community cannot be affected in a disproportionate way by innovation. Lastly, the different indicators which were used for every question are shown in table 5. Based on the results of the survey the social acceptability can be determined for the implementation of hydrogen in Dichterswijk.

Table 3: Internal human resources indicators

Aspect	Indicator	Definition	Measurement
2. Internal human resources	2.1 Consumer health and safety	Health and safety impacts of innovation regarding heating.	Respondent's perception on the health and safety impacts of innovative forms of heating.
	2.2 Level of commitment	Level of commitment to alternative forms of heating	Willingness to commit to general effects caused by the introduction of innovative heating.
	2.3 Environmental commitment	Level of commitment to alternative forms of heating that reduce environmental impact	Willingness to commit to alternative heating that reduce environmental load.
	2.4 Self-Environmental-Awareness	Level of awareness to innovative technologies used in residential areas that reduce environmental impact	Willingness to invest time and knowledge into innovative forms of heating that have an positive effect on the climate.
	2.5 Consumer impacts	New practices/impacts that come at hand while introducing innovation	Willingness to contribute to new practices/impacts
	2.6 Forced Impacts	Level of compliance to new practices and law	Willingness to contribute to forced practices and impacts

Table 4: External population indicators

Aspect	Indicator	Definition	Measurement
3. External population	3.1 Community acceptance	The degree of acceptance of new business by the local community	Willingness to contribute to new businesses
	3.2 Community resources	The atmosphere created by the local community including culture and social cohesion	Evaluated by the public
	3.3 Community Landscape	Aesthetics of the landscape/community	Evaluated by the public

Table 5: Survey questions and indicators

Content of the question from the survey	Indicators
1. Awareness of hydrogen	1.2, 2.4
2. Safety regarding hydrogen	1.2, 2.1
3. Environmental load of production	1.2, 1.3
4. Adjustment of the household	2.2, 2.3, 2.5
5. Electrical cooking	2.3, 2.4, 2.5, 2.6
6. Aiding and Investing	1.1, 1.2, 2.3, 2.6
7. Collectivity of the transition	1.3, 2.2, 2.4, 3.1
8. Guidance in the process	1.2, 2.2, 3.2
9. Type of policy	1.1, 1.3, 2.5, 3.1, 3.2
10. Local/central production/storage	3.1, 3.2, 3.3
11. Infrastructure	1.2, 2.2, 2.6, 3.1, 3.2
12. Ranking	All

3.2.3 Secondary data

In the case of this thesis, a research framework has been outlined that is defined around the concept of the MLP. The qualitative data will be gathered from scientific articles, existing databases, relevant policy documents, governmental reports/documentation and reports from independent research institutes such as the PBL. The use of the MLP framework functions as an in-depth analytical tool of the areas of interest. Thereby investigating the current trends within the field of hydrogen and the possible application in the built environment. Throughout the literature review the relevant governmental institutions, incumbent actors in Utrecht Dichterswijk were identified and were included in the full length of the research. As part of the desk research, an analysis through the literature has been performed by utilising keywords such as hydrogen, built environment, (energy) transition etc.

More specifically, journal and reports were identified based on a check on their purpose through which the similar research interest could be examined. Moreover, if certain reports or journals explicitly mentioned or presented a similar research interest and provided the researcher with further literature that was relevant to the topic, these journals and reports were also identified as crucial for answering the corresponding research questions. Lastly, the use of independent research institutes that were allocated to research for the municipality of Utrecht for constructing policy regarding the transition of the residential areas were taken into the research. These institutes such as TNO and Greenvis provided the municipality and researcher with data that was used for creating the presently used policy on the transition. The intended result of doing such broad research is attaining a comprehensive understanding of the existing literature. Moreover, this broad overview of existing governmental reports as other planned reading material will give the researcher an extensive view of the transition of hydrogen and the natural gas neighbourhoods.

3.3 Data analysis

The survey in this research will determine what the public's perception is on the possible implementation of hydrogen as a fuelling technology In Dichterswijk. This technology is gaining more momentum on the potential of heating the residential areas in the Netherlands. Therefore it has been recognized by the PAW as an alternative for the liberation of natural gas. After studying the relevant literature on this technology the possible implementation of hydrogen into residential areas rest on some fundamental criteria which have to be met in order to be identified as an alternative for natural gas. These core principles of this innovative technique can be translated into measures that are required to be socially accepted by the possible new owners. In order to measure the social acceptability of hydrogen into Dichterswijk, a survey was conducted. The survey aims is to examine and identify the social support base for hydrogen. As stated before, the social acceptability was demarcated into several aspects, thereby structuring the aspects into social indicators. Within this section, the social indicators will be defined and elaborated on how to measure the performance. Moreover, the social indicators were identified by studying literature (Shiau & Chuen-Yu, 2016) on the social acceptability of innovation.

Lastly, the survey was conceived through external validity as described by (Boeije, 2010) this is a technique that obtains empirical information through the survey and that can represent the studied population through the theory. In other words, this means that criteria for the possible implementation of the technology hydrogen are predefined through the PAW. More specifically, these pre-defined criteria are transformed into questions in the survey. Whereas, the respondents provide the researcher with acknowledgement on these aspects in the questions. The Researcher can conclude that the fuelling technology hydrogen has higher feasibility in terms of the possible implementation in Dichterswijk. To achieve external validity through the survey the total number of respondents should be between 80-100 according Boeije (2010) this is because of the total population in Dichterswijk (5335) (Gemeente Utrecht, 2020c). After the survey was constructed, the researcher used the pilot approach in which the survey was sent to 5 candidates. These candidates objectively filled in the survey and provided the researcher with additional information; which questions required an adjustment in order for the future respondents to better comprehend the questions. This entailed the adjustment of grammar errors to some minor modifications to questions. This technique prevented issues such as when the actual survey was sent out any possible barriers for the future respondents not to understand questions or would run into problems regarding filling in the survey were eliminated.

3.4 Method of reflection

This thesis was written during the COVID-19 pandemic which implied to follow the social and physical restrictions. This entailed, that alternative ways were applied to distribute the survey among the possible respondents of the survey. The researcher’s method for the distribution of the survey was therefore through social media platforms such as Facebook groups (Dichterswijk, 030-Dichterswijk). The first difficulty was identified through a weak number of respondents after multiple attempts through the Facebook groups to acquire the appropriate number of respondents. This can be explained through the none personal approach of using the Facebook platform. A second method to acquire the right number of respondents was through two Whatsapp groups one of the Dichterswijk community and the other through the researcher personal street. Furthermore, the researcher used his own network to distribute the survey among the inhabitants of Dichterswijk. Reflecting one the more personal method turned out to be a more effective approach in comparison to the Facebook method to acquire more respondents, however; not enough to reach the intended goal. The last method used to distribute the survey among the inhabitants of Dichterswijk was using a flyer. The survey could be accessed through a self-generated QR-code (appendix section 2). During the distribution of the survey some new respondents had difficulty accessing the survey because the respondents did not have a smartphone and were therefore unable to access the survey.

In the end, the distribution of the survey was experienced as difficult to achieve the intended number of respondents for this research. This can be explained by making possible respondents enthusiastic about the research and therefore incentivising them to fill in the survey. This was also one of the encountered difficulties during the distribution of the survey. Many of respondents either knew nothing about hydrogen or wanted to know more about hydrogen before willing to participation within this research. Therefore, the recommendations for future surveys might be to inform possible respondents about this kind of research. This entails a more detailed information provision thereby taking into account the ethic restrictions of data collection with regard to personal information.

Results

This chapter will elaborate on the current situation of hydrogen used in Dichterswijk. Thereby describing the current regime of natural gas. Furthermore, the socio-technical impediments will be defined and explained that hinder the further implementation. Therefore, this chapter will provide a comprehensive overview of the relevant stakeholders, national and regional processes and on the possibility of hydrogen to be implemented in Dichterswijk. Lastly, this chapter will contain the results done via the survey which was distributed in Dichterswijk. The survey was established to determine the social support base for hydrogen to be implemented in Dichterswijk.

4.1 The current position of hydrogen in Dichterswijk

The enormous task ahead is straightforward unlocking the Dutch residential areas from the dominant fossil fuel grip. While the load of the assignment is visible, the responsible authorities strive to construct an entire decarbonized built environment that contributes to the global efforts to limit climate change to the highest extent (The EU, 2021). The carbon emissions (including mobility and industry) in Utrecht are caused by one-third of the built environment (Stedin, 2020c). Within the built environment, gas is used with heating our homes. For the municipality of Utrecht to achieve its climate goal, thereby making the transition towards a sustainable heat provision requires a wide range of objectives to be met. This entails finding an alternative for the natural gas used in our residential areas where at this moment, the reliability is almost 100%. The alternatives for natural gas as an energy carrier for heat provision in residential areas can be categorized threefold (Stedin, 2020b). Furthermore, the demand for alternative niche drivers that have emerged can reshape the built environment towards a more sustainable direction (El Azzeh et al., 2011). A Logical step in this process is selecting a method that drastically cuts the CO_2 emissions and creates a future vision about the climate agreement.

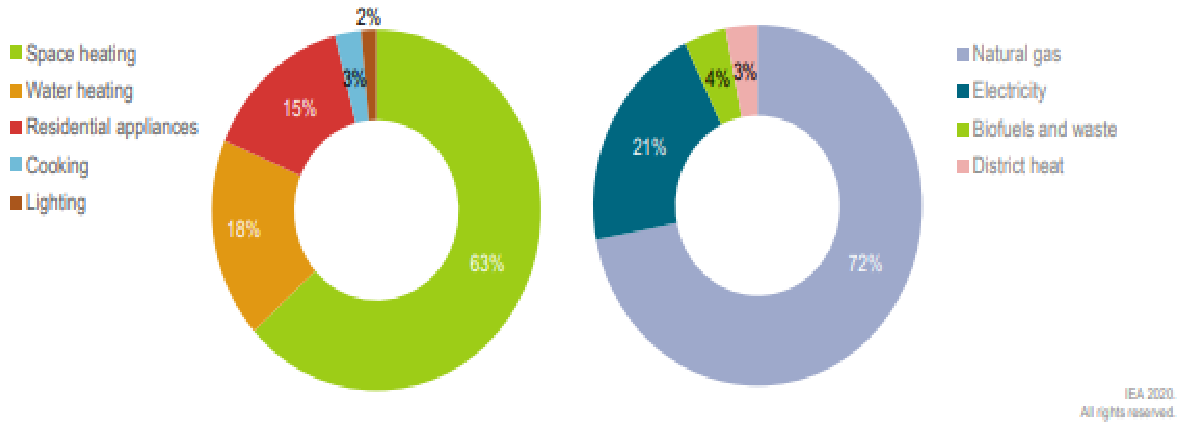

Figure 2: Residential energy consumption by use and fuel in the Netherlands, 2019 (IEA, 2020)

While the alternatives for diversifying the heating provisions in our households all have their pros and cons, consequently, the utilisation of an innovative technique to increase the zero-emission Dichterswijk is still assumed to be unfeasible and not realistic for hydrogen. What is crucial is the role of the fuelling technology hydrogen will play for it being recognised for its potential for decarbonising our energy systems (Brandon & Kurban, 2017). In that regard, the first-ever residential area in the Netherlands, Haringvliet, demonstrates the possibility of providing entirely emission-free households compared to traditional fossil fuel houses. The main advantage of hydrogen-based heating in homes is that only water is created during the process, making it a desirable alternative for natural gas, especially in the Netherlands as the securer of heat provision of urban areas. Yet also delivers a wide range of uncertainties that come at hand (Straver & V.Staalduine, 2020); in particular, hydrogen has yet to attract the same levels of attention as fossil fuels (De Rijksoverheid, 2019a). This makes the acknowledgement of the formation of the hydrogen market with its regulations, social awareness and its corresponding crucial role in developing this transition far from stable.

The Dutch Ministry of Home Affairs (2018) recognizes the transition to a more sustainable built environment as a necessary national policy shift. An early attempt by the responsible authorities led to the establishment of the RES, in which the programme of natural gas free neighbourhoods was conceived (PAW, 2019). During the formation of the programme, society and knowledge are brought together. This innovative bearing contributes to collaboratively sharing knowledge through recognizing the socio aspect as important compared to the technical and financial- of the built environment transition.

In line with the MLP framework on socio-technical changes, green hydrogen is interpreted as the new emerging niche, which supports the transition as the opposition to the dominant fossil fuel regime. The regime level is recognized as the natural gas system that supplies our current homes with heat. The importance of the MLP is that a new technology is not governed by the processes in the niche. Thus, also by developments at the level of the existing regime and socio-technical landscape. The socio-technical landscape is the background of both the niche and regime (Twomey & Gaziulusoy, 2014). Within this landscape, the national and provincial developments regarding the energy transition occur; regulations, societal trends targets and the technology hydrogen in general. Therefore, the landscape, as Geels ((2002); V.Bree, 2010) describes, is the reasonably resolute or gradually changing constructions to the socio-technical regime where such outer designs are the macro-economic developments, social changes or expansive political or ecological changes (Geels, 2019). It is the alignment of these developments that determines if the shift occurs. Changes at the landscape level for instance put pressure on the regime and create openings for new technologies. Therefore, if hydrogen is to be considered a realistic option, some pivotal conditions in the regime and landscape have to be met to induce changes in the overall transition.

In contrast, the current heating provision in Utrecht is stabilized by the arrangements between policies, user preference, technologies, shared beliefs and societal organizational practices. These discourses have been developed in the past, in which the incumbent actors such as policymakers, end-consumers, grid management companies, yet also building corporations have incrementally enhanced the system elements for natural gas. Thereby, forming the socio-technical regime that is described by academia such as Geels (2014). The director’s table of the energy transition in Utrecht is managed by directors and the ones responsible for the result with the mandate of five different organisations: Regional authorities, housing corporation STUW, Eneco, Stedin and Energie-U (Gemeente Utrecht, 2019b). All different actors are only licensed to make decisions in their organisation. The collaboration will handle long-term queries and encountered difficulties will be discussed to accelerate the transition. However, when analysing the system the actors involved with the fossil fuels are still at the centre of the contemporary built environment regime. In other words, the incumbent actors have a lasting position and are defined as vested due to the arrangements in the previously established regime.

This encompasses, that regulations, policies and infrastructure is still lacking enforcing features for radical innovation such as hydrogen to penetrate the market (Buttner et al., 2017). In that sense, reciprocal action between the incumbent socio-technical regime and the hydrogen niche are formed in the broader context of the socio-technical landscape that Geels (2002) characterizes. In addition to these developments, this landscape described by Geels (2002) for the built environment in Utrecht is influenced by several factors: user preference, local regulations and -policy, the community's position, regional and national developments regarding renewable energy and climate change (De Rijksoverheid, 2019b). Consequently, the landscape in Utrecht is altered through co-evolutionary processes by people and technology, that will perform pressure on the regime (Parlev, 2019). Yet, these processes have occurred and incumbent policymakers and actors framed hydrogen with provisions that contain energy conservation with regard to a more sustainable built environment (TKI Urban Energy, 2020).

In accordance, the landscape determines the position of hydrogen within the broader context of the built environment in Utrecht. Therefore, the role of the landscape is important in the scenario of implementing hydrogen. These developments in the landscape regarding hydrogen require an enormous investment of the including stakeholders. This entails, a structured programme from the national and regional authorities that will complete several decades (TKI Urban Energy, 2018). More specifically, the agenda will ultimately consist of a vision that is transformed into a solid policy, that will explore the possibilities for realising this transition. Thereby, seeking the functions of hydrogen to fulfil the necessary policy support and market organization. More importantly, these preconditions within the landscape can be decisive whether hydrogen has the appropriate future prosperity of providing the supportive and flanking activities for the socio-technical impediments (Ministerie EZK, 2020a). These preconditions can be accelerated or hindered trough institutionalised parties by creating space in legislation and regulations and in neighbourhood-oriented approaches for pilots and demos in the coming years (Gemeente Utrecht, 2020d).

However, as these aspects characterize the emerging market for hydrogen for its current position in Dichterswijk is still in the first phase as described by Barker (2012). Based on Barker (2012), the progression towards a hydrogen economy can be in specific phases of development and he classifies four different stages (see figure 3). Furthermore, in each phase there are different obstacles that the technology hydrogen endures before it can reach the next phase. Thereby, highlighting the essential part to identify the specific phase for the hydrogen niche to understand the socio-technical impediments that can be encountered.

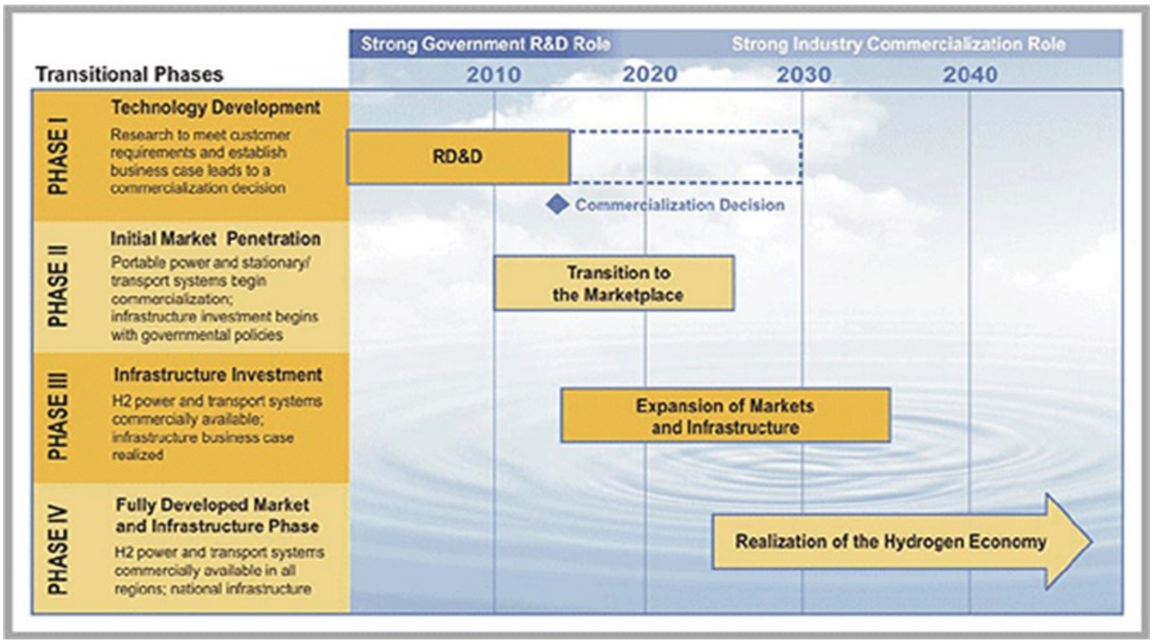

Figure 3: Phases of transition towards a hydrogen economy

At this moment, hydrogen is still in the first phase in which it will encounter an innovative ecosystem that will grant the possibility of system integration. In other words, this means that hydrogen will deal with issues for vision development on the possible implementation. Yet, at this moment is hindered through mechanism from the dominant regime. The combination of preventive measures from the incumbent system is found in the niche and landscape layers of the MLP framework. On the assumption, that hydrogen will successfully penetrate the market and has the possibility of becoming the new regime depends on the opportunities that will occur in both niche and landscape. As for this moment, the position of hydrogen in Dichterswijk is blocked by social-technical impediments.

4.2 Political acceleration or deceleration in Dichterswijk

The authorities are entwined with all transitions and this means the role the national or regional state takes. Historically, academia and politicians tell society that most shifts were driven by markets in which investors wanted to benefit financially. Yet, climate change is different due to the environment being the issue; this entails not a privately motivated driver for profit. Subsequently, the Dutch government has to be the key mover and introduce a policy that will move society into a low-carbon direction (Meadowcroft, 2011). When the RES was introduced in the Netherlands, every regional authority, including Utrecht, was given the power to execute the central mission; finding an alternative for gas. This significant policy change is difficult and quite rare because policymakers are locked into policy regimes (Meadowcroft, 2021). Policy regimes consist of the policy networks, so not just the policymakers but also those invited to provide their input to the policymaking process; this is often associated with business interest. Considering the change to hydrogen that needs to happen in Dichterswijk, the local politicians will play a critical role in shaping this socio-technical transition. When analysing this case study, an important aspect is the clarification of what drives these policymakers into the intended position.

The first point is that of economic development in which the local authorities thrive on the implementation of hydrogen. In the ideal situation, hydrogen will be used for the heat provision in Dichterswijk, where the availability is not limited. However, Greenvis (2020), a local actor that played a pivotal role in the policymaking process in Utrecht, provided input that was not favourable for hydrogen about the upcoming transition. The independent research institution was licensed to provide feedback to the local authorities on the possible renewable energy sources available. The overall conclusion was that hydrogen was never to play a crucial role in a future scenario of heating homes in Dichterswijk due to the considerable uncertainty of being available. Thereby suggests that the city of Utrecht contains numerous alternative renewable energy sources that can change the transition; logically, the regional authorities are following a more rational energy planning and always go for the option that provides the most economic development. This entails that the grand renovation of Utrecht induces a financial investment. Where at this moment, the politicians have decided on a district heating option for Dichterswijk (Gemeente Utrecht, 2020b).

The other concern for the municipality of Utrecht to consider is that of technological supremacy. At this moment, Utrecht is the second most competitive region of the EU and this is based on the indicators associated with innovation (Gemeente Utrecht, 2019a). In this case, the fuelling technology hydrogen can prove valuable in the ongoing battle with upcoming transitions and for Utrecht to maintain its position about competitiveness. The municipality would gain a technological advantage concerning efficiency yet also driven by cost reduction as it is often seen that technological supremacy and economic development emerge hand in hand (Mondschein et al., 2021). However, on the assumption that the independent research institute acted objectively in providing insight concerning policymaking. Local authorities will only include the technology hydrogen in a future heat provision of Dichterswijk if it proves to be financially feasible. This encompasses that the technology should receive a financial boost from the national state to acquire this position. The national government does recognise the importance of hydrogen and the potential for the climate agreement. Yet, it also acknowledges the enormous investment it requires to be used on a large scale, therefore to be implemented in Utrecht (Ministerie EZK, 2020b). While the ministry of Economic Affairs and Climate is currently investigating the potential of what hydrogen can have on the future scenario of the Netherlands; also depending on the necessity to build a hydrogen network. This entails a legal framework in which affordable, safety and security of supply are crucial for the inhabitants (TKI Urban Energy, 2020). The authorities are responsible for creating the right preconditions, making it affordable by allowing costs to be socialised across all gas network users, supervising safety, and forcing the market. Without these preconditions, practical projects will not get off the ground, therefore, making upscaling in Dichterswijk unfeasible.

Another motive has to do with competing interest in which all sorts of new arrangements emerge that competing interest reach into the state and use it to slow down change further. First of all, the Dutch electoral system consists of a time period of four years where a new political party is chosen to lead society. The result of a system that changes every four year leads to political short term thinking (Klok, 2021). Furthermore, this kind of democratic system shows that the political will that creates stability and continuity in sustainability transitions is the typical swing between the two systems (Johnstone & Stirling, 2020). In line with these historical developments regarding sustainability transitions, it gets interesting with the case study in Dichterswijk. In the previous elections, Groenlinks was the biggest party in Utrecht for both the regional as national elections. (Gemeente Utrecht, 2021). Yet, the recent national polls showed that the VVD became the biggest party in Utrecht, given rise to the historical development where new parties might swipe the previously established policy of Groenlinks away from the directing table. On the other side, the results from the previous elections do not indicate a potential shift from political parties in Utrecht as it was the national instead of the regional elections. Yet, introducing new technologies such as hydrogen always brings a certain risk of these typical democratic shifts; where policy about governing sustainability transitions is completely wiped off the table.

When analysing the case study in Dichterswijk, the fuelling technology hydrogen is not recognised by local politicians in the upcoming transition. Regional actors such as Greenvis (2020) point out that at this moment, hydrogen will not play the intended role of heat provision in Dichterswijk. The technology hydrogen has incredible potential for the Dutch energy transition (Ministerie EZK, 2020a); however, for Dichterswijk and the built environment requires some vital financial preconditions to be met for it to be utilised. Currently, the availability and costs outweigh the possible advantages that hydrogen brings about. Therefore, at this moment, the politicians can be seen as a barrier towards possible implementation. Yet what drives local politicians in their judgement is often based on their perception of what is best for society, thereby reducing costs and environmental load. For technologies such as hydrogen to be substantial in the transition, it requires the technology to transform systems to societal needs (Gemeente Utrecht, 2018). More specifically, this is a better, equitable and more convenient system for it to be decarbonised. Therefore, the politics in shaping the socio-technical transition in Dichterswijk lies behind the policy. Local politicians will support the implementation of hydrogen when there is a mutual strategic interest for both societies as institutionalised parties. This political will in practice is there as long as it serves a rational energy planning model. Yet as it seems, the only thing that Dichterswijk requires for a pull into the hydrogen direction might come from the community itself.

4.3 Technical aspects of the development of hydrogen in Dichterswijk

In recent times, the Netherlands has aspired its ambition in becoming a climate forerunner and to utilize every possible opportunity in reducing carbon and GHG (Ministerie EZK, 2020a). Logically, the developments with the use of innovative technologies such as hydrogen have seen more and more implementation in the different sub-sectors (IEA, 2020). Within recent decades, this technology has progressed significantly with regard to overcoming technological obstacles in the industry. In particular, within the existence and application of the hydrogen technology several impediments such as transport through pipelines and purification of hydrogen mixtures have been resolved to a large extent (Hu et al., 2020). Yet as it stands, the developments regarding hydrogen in the built environment have been stagnating especially in Utrecht as it has been recognised for the potential but not have been included in the vision of the transition (Gemeente Utrecht, 2020d). Instead of evolving why has the progression stopped in the built environment, what technological barriers are there that prevent this important technology in proving its worth to the climate crisis in Utrecht.

First of all, hydrogen is not available on a large scale and is therefore characterized as an uncertain factor that could be negatively affect the forward marching Utrecht. Research of Accenture (2019) predicted an enormous demand for hydrogen in the future built environment of Europe thereby highlighting the Netherlands (see figure 4). Their research revealed that if hydrogen was to be implemented in the built environment it has to be securable for this future demand. TNO (2020) acknowledged this reflection that green hydrogen suffered scale-up difficulties. At this moment, its financially not feasible to produce hydrogen on a large scale and therefore to be implemented in the built environment. Similar results were reported by the authorities in Utrecht (Gemeente Utrecht, 2020b) containing data about the pace of national policy and legislation being decisive on the realisation of achievable business cases for this transition. In other words, the potential of this energy carrier lies elsewhere.

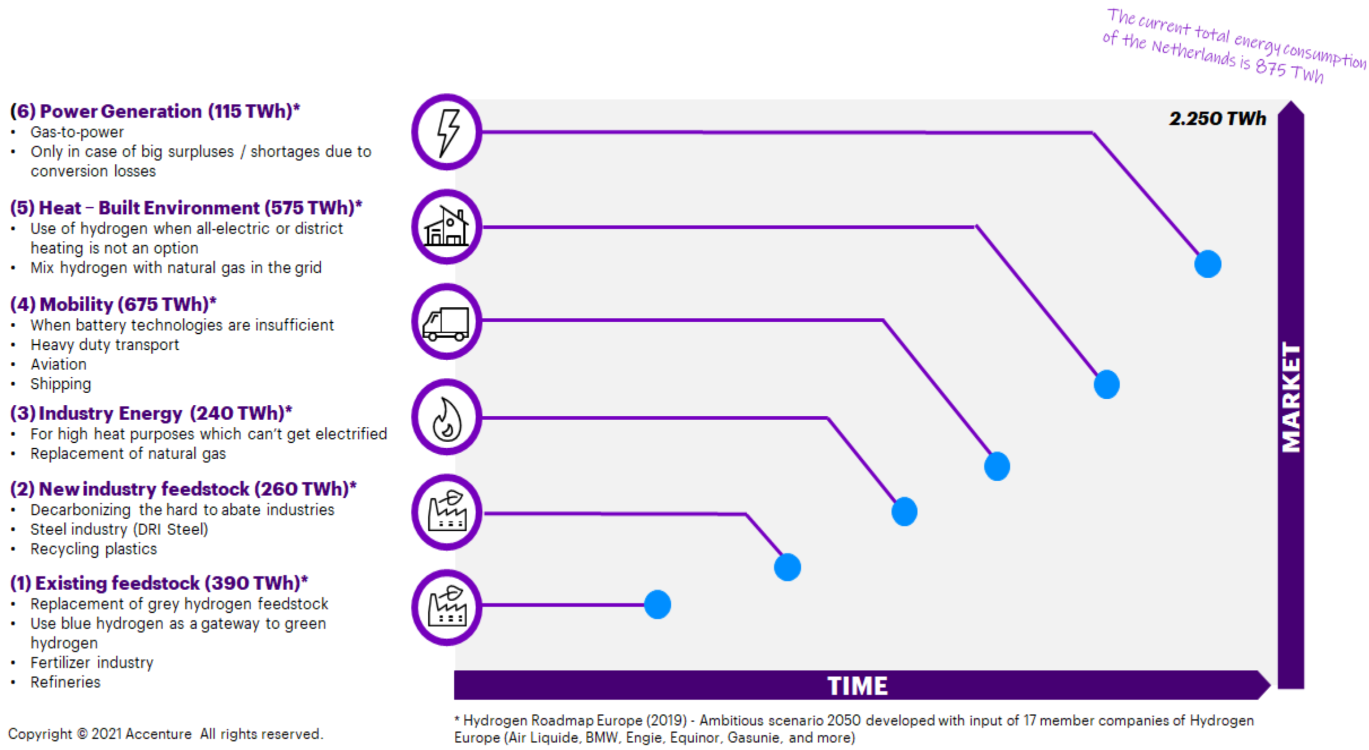

Figure 4: Hydrogen roadmap for the Netherlands in the different sub-sectors

On the other hand, organisation such as the Gasunie and Tennet are investigating the possible transformation of gas infrastructure into a national hydrogen backbone (De Gasunie & Tennet Holding BV, 2020). This also happens on a smaller scale in which Stedin that is involved in Utrecht is determining the position of the grid with regard to the transformation to the hydrogen backbone (Stedin, 2020b). However, what interest lies in the transition towards a hydrogen backbone when the supply of hydrogen is uncertain. Logically, when analysing the different case-studies Rozenburg, 't Haringvliet and Hoogeveen (TKI Urban Energy, 2019) in which the application went to 100% hydrogen infused system. The supply of hydrogen was a decentralised system consisting of a local production plant. More specifically, because of the issues that emerge with security of supply but also the affordability, the authorities decided to engage a decentralised system. Furthermore, this entailed a distribution system that took place via a local part of the network that has been adapted for hydrogen and which was cut off from the natural network. Controversially, based from a case-study done by TNO (2020) and substituted in Dichterswijk. Depending on the selection of a centralised or decentralised system, the option that at this moment will generate the most favourable situation regarding finances is a centralised system. This is a system where the hydrogen is produced on the shore of the Netherlands and further distributed into the Netherlands via the hydrogen backbone (CE Delft, 2011).

Table 6: Case-study Dichterswijk with 2264 households (Appendix 1 for calculations)

Situation	**Type of heating**	**Installed power [MW] from renewable energy sources**		
		Solar-PV	Wind on land	Wind on sea
Demand for heating with gas 1340 m^3/year	100% H_2-boiler	46.8	16	10.4
Demand for insulation with gas 1000 m^3/year	100% H_2-boiler	34.8	12	7.6

If hydrogen were to be produced locally from solar PV every household in Dichterswijk requires the energy from 222 solar panels to generate enough renewable energy to produce green hydrogen. These numbers are incredibly adverse and proof only that with the current technology of PV and hydrogen the transition towards a particular system outlines a significant technological barrier. As with regards to hydrogen production and distribution this option identifies the hefty demand for knowledge concerning new developments. In fact, there is only one actor that has the capability of tilting the playing field by overcoming the technological barrier and that is the central government. As for this moment, local authorities have decided not to engage with hydrogen for the large bottlenecks of production costs and hydrogen security. In the ongoing debate on what drives innovation governments have the capacity to respond to a demand-pull. This is where the market determines the formation and introduction of new technological possibilities. Broadly speaking, incumbent actors such as the grid management corporates like the Gasunie and Stedin are articulating a desirable future for hydrogen. At the same time, the niche hydrogen requires a functionality and performance advancement that will convince authorities to invest. This tension between highly specific versus policy interventions requires careful consideration. While governments at national and local levels play a crucial role in the shaping of technologies. The alignment of visions and market actors can bring in the necessary competences to induce new money and actors into the project and therefore respond to a demand-pull from the market.

4.4 The organisation in Dichterswijk

The current plans for the inevitable transition in Utrecht are controlled by an organisation described in the vision of the transition (Gemeente Utrecht, 2020d). According to recent scenarios, the decarbonization seems to imply the collaboration of these actors. In terms of the built environment, every organisation will deliver or is responsible for aspects of the upcoming transition. By the time, the pawns on the playing field will exert their pressure on the implementation of hydrogen thereby, questioning what role every contestant delivers.

Table 7: The organisation with the different actors at the directing table in Dichterswijk

Actor	Role
Stedin	Grid management company
Eneco	Energy production
STUW	The housing corporation in Utrecht
Municipality of Utrecht	The local authorities in Utrecht
Energie-U	The initiative of inhabitants to influence this transition

Firstly, Stedin is the incumbent organisation that has managed the grid for many decades. As discussed earlier, Stedin envisioned a novel grid that relies on the production and transmission of hydrogen. Thereby highlighting affordability due the utilization of the current grid infrastructure that might need minor modifications (Stedin, 2021). Yet as it seems from the investing document the technology hydrogen is labelled as a stranded asset. This entails, that there is a large uncertainty surrounding hydrogen within this transition and therefore only offers a strategic risk (Stedin, 2020a). Furthermore, Stedin invalidates their own vision on the future transformation of the grid towards a hydrogen backbone. In line with these development, academia such as Geels (2014) have described the difficulty of green incumbent re-orientations as risky that often fails. The problem with green growth is the uncertainty of the market and this is due to the reliance on policy and policy can be fickle as is seen in the UK (D'Arcy, 2017). Furthermore, green growth is dependent on consumers and these can be reluctant. Only a few of the majority have the tendency to pay more for innovation that can be cost-intensive.

In the case of STUW and Eneco, large sums of capital, labour and effort are ''sunk'' into other investments than hydrogen. According to Eneco offshore wind power is the new natural gas. Elmer de Boer a financial expert of Eneco (2020b) follows all the innovations in the renewable energy sectors and is convinced that offshore wind power will integrate a renewable energy system of the future (see figure 5). At the same time, believes that before 2030 hydrogen will not play a part within this transition due to the costs. A similar scenario occurs with STUW (2020), the housing corporation in Utrecht has placed their bet on solar PV in combination with district heating. In line with these developments the reorientation of these incumbent firms are likely to be resistant towards hydrogen. Logically, they will try to protect their sunk investments and milk their assets to slow down the transition.

On the one hand, these developments offer a perspective on a future transition towards hydrogen as these companies follow a rational energy planning model. This entails, that both organisation have not yet rejected a hydrogen infused energy system. On the contrary, both organisations have reached the consensus that green power enables a sustainable community. Thereby acknowledging that the transition towards a renewable energy system recognises an integral role for hydrogen as was predicted by other research institutes (PBL, 2021). On top of that, the pair only follows an energy pathway that is technically and financially feasible. In other words, there is a strong growing tension between the climate-change imperative of decarbonization and the affordability dimension of this matter.

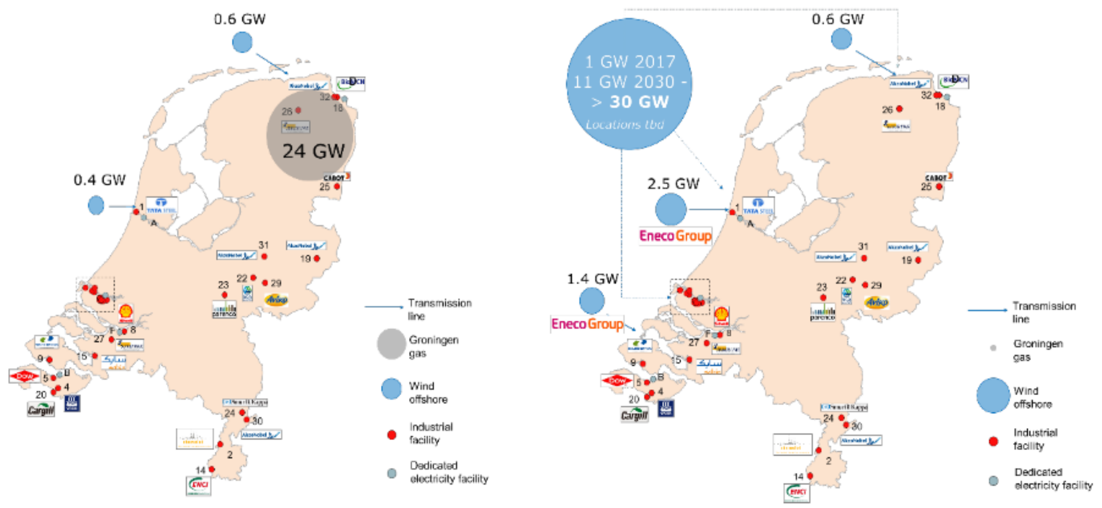

Figure 5: Offshore wind power is the new gas (Eneco, 2020b)

At the same time, the position of the integral role for hydrogen in the built environment does lack some vital requirements for the technology to be feasible. At this moment, there is an incredible loss of energy that comes in two-fold when converting renewable energy to hydrogen and finally heating water In the boiler (Shell, 2017). The potential of this energy carrier is therefore not recognized in the transition vision of the municipality of Utrecht. In addition to these developments the report of Greenvis (2020) acknowledges the enormous potential of other renewable energy sources being available in Utrecht. This entails, that organisations such as STUW are sceptical on the design of a hydrogen infused built environment. More specifically, in Dichterswijk the largest train station Jaarbeurs is close-by making it a potential source of residual heat. In other words, making Jaarbeurs a possible source for the district heating in Dichterswijk.

The normative campaign in the Netherlands has urged investors and authorities to withdraw their financial investments from fossil fuel bonds and to reinvest in more green alternatives. There is an inevitable policy initiative behind this and that's the liberation of natural gas. As is seen in Dichterswijk the push for developing a more sustainable built environment is not constructed around hydrogen. Instead incumbent actors have made their decision known on other green alternatives such as district heating. Importantly, just consideration is the key component of the governance of the energy transition. As such, linking affordability and energy together emphasizes the necessity of a rational energy model. Seen from this perspective, the challenge of decarbonization thus requires an adequate business model on neighbourhood scale. A large part of this solution provides that innovation represents a radical disjuncture that changes the very nature of the efficiency in the built environment. As of this moment, based on the disruptive efficiency in the supply chain hydrogen is not included by organisations in the future of Dichterswijk.

4.5 The social support base for hydrogen in Dichterswijk

In the upcoming transition, local ownership plays a pivotal role in determining an appropriate alternative for gas. The position becomes visible because the actual change will happen behind the front door of the inhabitants of Dichterswijk, thereby highlighting the necessity for proper support for a chosen substitute for gas. This social support base is demarcated into 12 aspects that characterize the possible implementation of hydrogen in Dichterswijk. Furthermore, the 12 aspects are categorized in three underlying themes that will be discussed in this section.

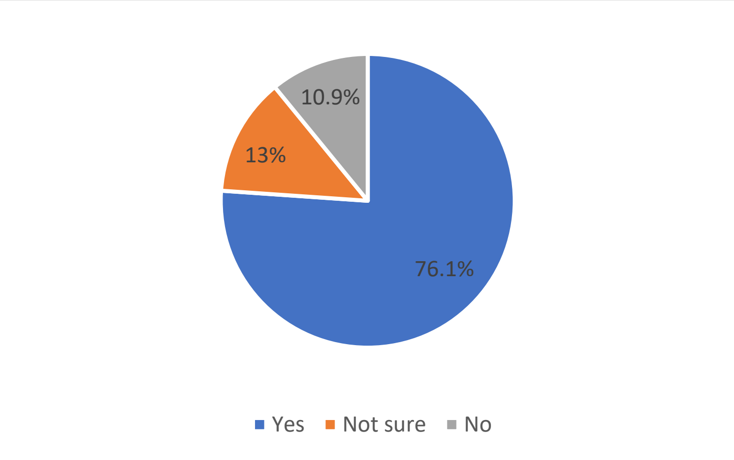

Figure 6: Knowledge of hydrogen; Do you know what hydrogen is?

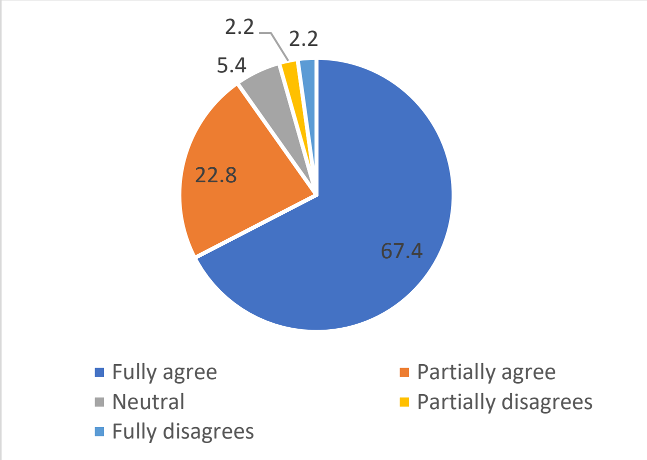

Figure 7: Willingness for switching to electrical cooking

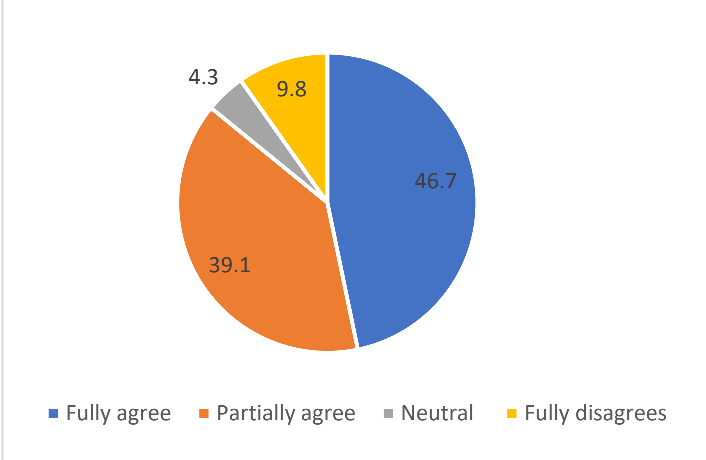

Figure 8:Willingness to adjust household for hydrogen

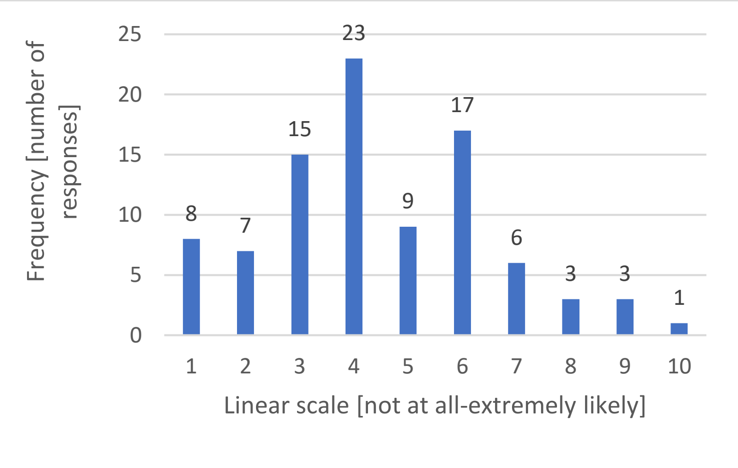

Figure 9: Unsafe association with hydrogen

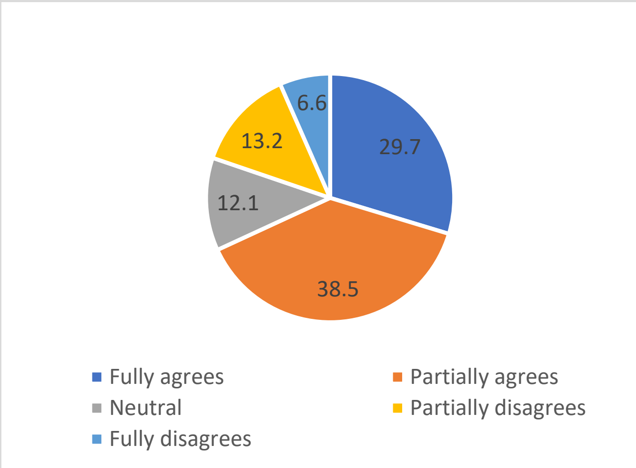

Figure 10: Willingness for infrastructure in the immediate surroundings related to hydrogen production

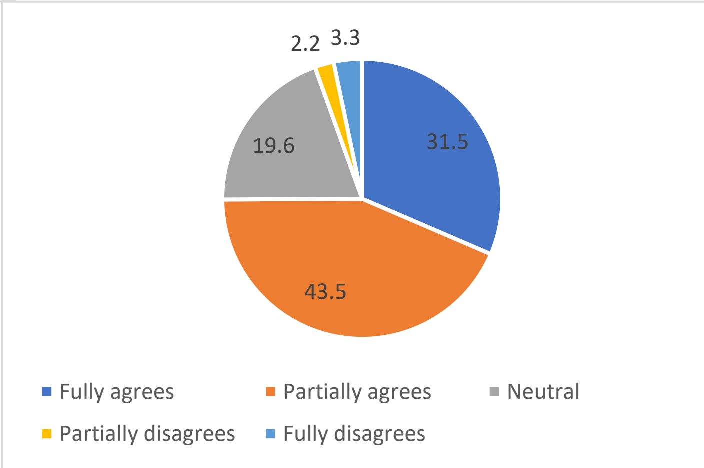

Figure 11: Willingness to do this transition if properly guided

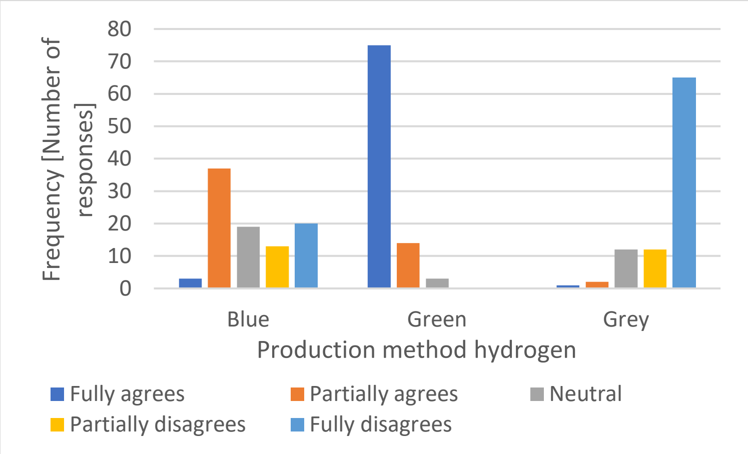

Figure 12: Preference for the hydrogen method of production

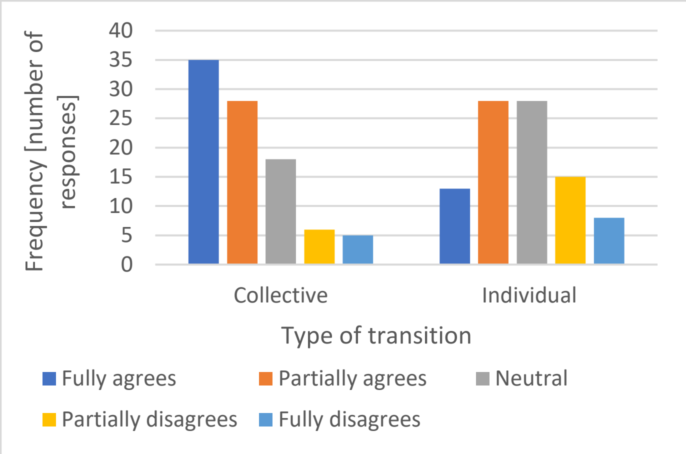

Figure 13:Preference for the type of transition

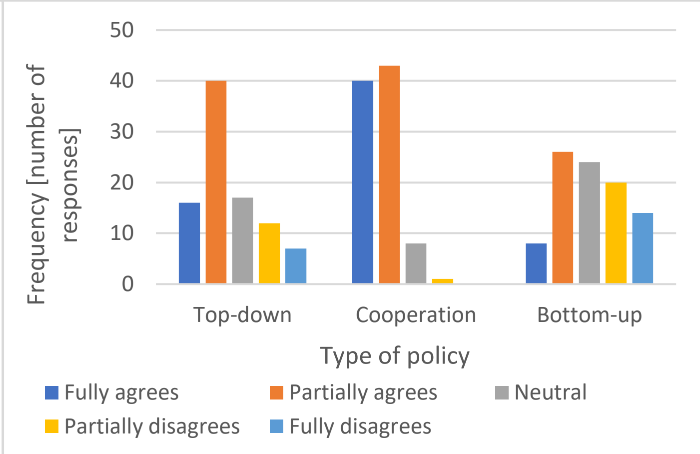

Figure 14: Preference for the type of policy from the municipality

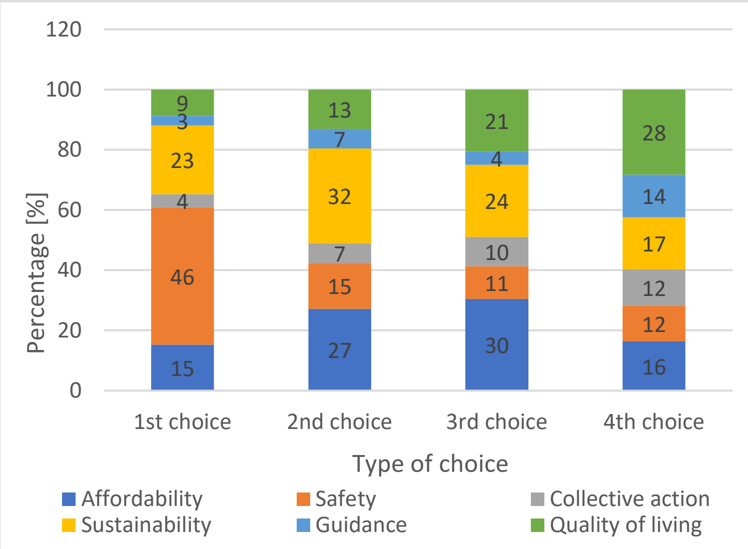

Figure 15: Ranking of the different aspects of hydrogen

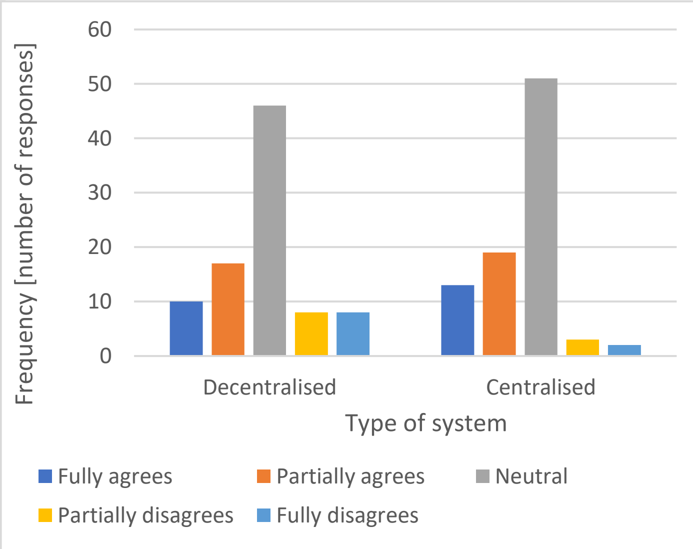

Figure 16: Preference for the type of hydrogen production system

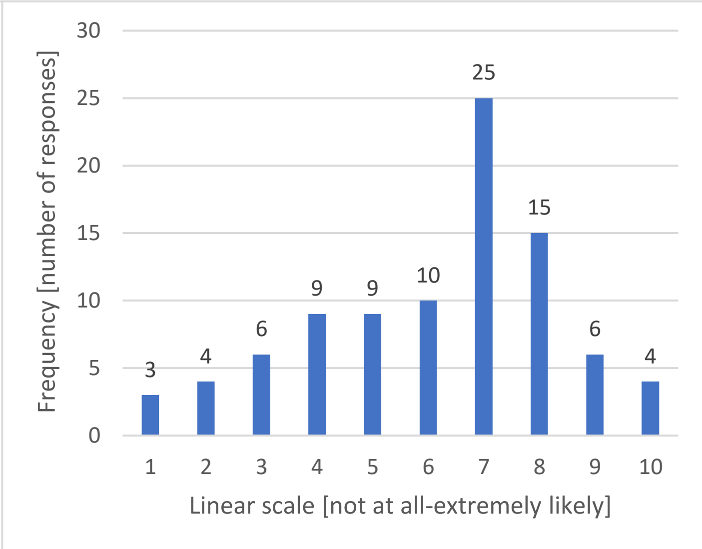

Figure 17: Willingness to financially support the municipality for the transition towards hydrogen (unforeseen costs and electrical cooking)

4.5.1 Information provision in the transition

In Dichterswijk, most people indicated to have basic knowledge about what hydrogen is and its purposes (figure 6). This ranges from the understanding as an alternative for fossil fuels to “I have heard about it”. Yet, the importance of this notion is that people are well-informed about a new energy carrier in their homes. This is because the provision of information is contingent on a broad social consensus. On the assumption that hydrogen is to be implemented in Dichterswijk, every inhabitant wants to comprehend what hydrogen means for them thoroughly. Before the inhabitants of Dichterswijk accept hydrogen, more support can be gained through the distribution of knowledge, thereby assuring that as much as possible of all the inhabitants know of hydrogen and all the aspects it brings about.

The spread of information can also guarantee safety when novel technologies are introduced to inhabitants. In Dichterswijk, this sentiment is present with its inhabitants; however, some did indicate specific conditions (figure 9). One of these conditions was that hydrogen brings a comparable amount of safety issues as gas if adequately installed by skilled workers, highlighting the essential part of a proper information provision. When it comes to safety, most of the inhabitants in Dichterswijk are willing to cooperate within the transition towards hydrogen if their questions and doubts are taken away, especially with innovative technologies where there has not been any spread of information. Also, some of the inhabitants are indicating they do have an unsafe feeling with hydrogen, trust can be gained through adequate information distribution. It is a cultural thing to raise questions if new technologies are introduced, above all when applied in their homes. However, suppose the technology hydrogen is used in residential areas due to previous studied work and industrial utilisation possible safety bottlenecks are identified and due to an adequate information provision, doubts and questions can be taken away.

Another safety aspect hydrogen brings about is the smaller particle size compared to natural gas. This brings forward a specific risk that hydrogen might escape the pipes before being used in the new boiler. In line with these developments, the willingness of the inhabitants must be in favour of possible adjustments (figure 8). Logically the municipality of Utrecht pays for the connection (pipes and boiler) of a potential new heating source with taxes. Therefore in Dichterswijk, residents are willing to adjust their household as long as they are adequately educated about the safety aspects of hydrogen. This indicates that people are eager to commit to an alternative form of heating if adequately informed about their future scenario. An alteration to a household brings a period of tension and uproar; these impacts have to be carefully considered and requires the owner to be convinced of the green cause. An important driver for people in the possible transition is the liberation of financial restrictions to this adjustment. This support mechanism enhances the chance that inhabitants will support a possible change towards hydrogen in Dichterswijk. Another essential factor to be considered is that not everyone supports the idea of hydrogen and a possible adjustment to their home. These are people that have switched to an alternative already or don’t believe in the concept of hydrogen in Dichterswijk. The transition happening in households entails that people are willing to invest their own time into this matter, thereby formulating a specific opinion about the options for realising a sustainable home. When it comes to finding a proper solution, local authorities should have the power and workforce to talk to its inhabitants and acknowledge constructive support for whatever alternative this might entail. This involvement is an ongoing process to realise a successful transition in Dichterswijk.

The aspect of switching to electrical cooking is perhaps the inevitable feature of this transition. Whatever option is applied in residential areas in the Netherlands/Utrecht electrical cooking will be part of this. Nevertheless, this is a condition that requires support from the inhabitants to be accepted in Dichterswijk. In Dichterswijk, this sentiment can be detected in most households in which people are willing to cooperate or have done it already (figure 7). Yet, an essential factor often forgotten is that the family must finance the switch to electrical cooking themselves. This can be formulated as a barrier towards hydrogen because socio-economic performance is crucial when it comes to unexpected costs that have to be covered by the inhabitants. Furthermore, some people have grown an unbreakable connection with cooking on gas. They might experience the switch to electrical as an uncertain factor of achieving the intended results. Therefore, the attractiveness of electrical cooking has to be promoted through the cooperation of local authorities and inhabitants to convince residents to contribute to this cause.

4.5.2 Collaboration of citizen and municipality

An important aspect that can help reaching a broad social consensus is receiving information and guidance in this transition. This could be in the form of an energy coach or a municipality representative to answer questions and handle potential troubles along the road towards hydrogen. Yet, some pivotal conditions were mentioned that the affordability and information dimensions are more important than the actual guidance in the process. Importantly, this gathering between the socio-economic and the social dialogue creates stability in the community's acceptance of hydrogen. What people want in this transition is not an energy coach that tells them what or when, yet prefers the municipality not to exert pressure at the expenses of the inhabitants (figure 11). Therefore, they want a just transition; a just transition could deliver the mitigation of these impacts for the inhabitants in Dichterswijk, serving as a check for the concurrence of circumstance and, therefore, the guidance in this transition. This inclusive and participatory approach will enhance the community's attitude robustness and stimulate cooperation between authority and resident.

The case study of Hoogeveen (2020) proves one essential thing that collective action in this transition towards hydrogen is of pivotal importance. If just one of the households does not want to participate in the shift towards hydrogen, the application becomes unfeasible. This entails that the change towards hydrogen can only happen when the whole neighbourhood is supporting the ideals. The reasoning behind this is that the utilisation of the gas network has to be of one kind, so only hydrogen or biogas. If one of the households does not support this idea, the probability reduces, and the only option left is an all-electric. Consider this information, the collaboration of citizens and municipality becomes essential due to two effects that occur while doing a collective configuration. The first effect can be described as the technology effect; if hydrogen is to be implemented in an early stage in Dichterswijk, the problems that emerge can be detected and adjusted in order to reduce costs in a later stage. The second effect is the scale effect; if hydrogen is to be implemented for the whole of Dichterswijk, the effect will reduce the costs associated with hydrogen because of the advantages that emerge with respect to scale. These two factors will enhance the probability of implementation in Dichterswijk as it creates a mutual reduction of the expenses for both institution and inhabitants. Yet, the preference of the residents is widely spread on this type of system (figure 13). This proves only one thing: before a possible transition towards hydrogen happens in Dichterswijk, a broad social consensus must be reached and this involves the cooperation of citizens and municipality.

So far, this transition proves a critical factor that cooperation is essential for a smooth progression of the transition. The strength of a mix between the two conventional (top-down and bottom-up) policy types emphasises an inclusive and participatory approach for both planning and policymaking. Yet If the inhabitants are directing the transition, this will create chaos as the complexity and vagueness of higher-level participation mandates for the local actors. Furthermore, inexperience about a participatory mechanism will result in divergent perception about the expected outcomes. At the same time, from a normative perspective, public participation is necessary for the better function of democracies in Dichterswijk. This entails incorporating values, beliefs and knowledge of inhabitants is being essential for the sustainable and equitable management of this transition. The governance of this transition should be transparent policymaking. The residents of Dichterswijk can provide their input to the policy; however, the municipality sets the structure and rules as the proper exercise of authority (Gemeente Utrecht, 2020c). The inhabitants of Dichterswijk have indicated that a configuration in which authorities allocate the rights and resources will encourage the most support (figure 14). This encompasses that input from the inhabitants is not viewed as an obstacle but an instrumental aspect of the transition in Dichterswijk.

An essential aspect of this transition is local commitment from inhabitants of Dichterswijk that have to accept an alternative form of heating. Yet a shift also delivers a wide range of new costs both foreseen as unforeseen, thus requires financial contribution. This socio-economic effect of the transition is often a process in which people state certain conditions before willing to accept (figure 17). An important feature is that the costs are affordable, yet this is also a dimension that is difficult to predict as it differs from person to person. On the one hand, this implies that most of the expenses are covered by the authorities and the inhabitants only aid within this process. At the same time, there is a limit to what people are willing to contribute. Yet, a transition that requires financial assistance of the inhabitants always brings a risk of people not wanting to support this cause. This is primarily due to the uncertainty associated with the costs of new products. This entails that inhabitants are not likely to adopt low-carbon technologies and practices that are not cost-competitive without supporting policies and incentives. Thus, the attractiveness of new green solutions that need financial support has to be promoted as a mutual convenience to both climate and people. The community acceptance towards innovation such as hydrogen will be enhanced if local authorities can incentivise them. This can be in the form of constructive policies that can provide broad societal benefits and therefore increase overall socio-economic commitment towards hydrogen. As long as people know why they should invest, the uncertainty associated with this investment is taken away.

4.5.3 Method of production

One crucial factor when hydrogen is applied in Dichterswijk is whether the production is a centralised- or decentralised system. This entails locally produced hydrogen or hydrogen production at a large production facility such as along the shore and further distributed through the gas infrastructure. In Dichterswijk, the respondents do not have a particular preference for a production method as long as it is the most sustainable option (figure 16). The result should be the consideration that employs an energy system that contributes to the concepts of parsimony and redundancy; make it as simple as possible, thereby taking all the relevant aspects into account. At this moment, a centralised system formulates the most favourable solution as hydrogen can be produced at a location fit for it and distributed via the hydrogen backbone (section 4.3). The current knowledge regarding decentralised systems offers a wide range of uncertainties ranging from production to spatial planning. Therefore, the utilisation of a centralised system is preferable in a process in which we are transitioning towards increasing efficiency within the built environment. In the upcoming transition both politicians and residents in Dichterswijk are generally interconnected in generating a reliable and efficient standard for the heat provision. In addition to the flexibility of a system that must deliver what is demanded, at this moment an insufficient decentral system is considered invalid for Dichterswijk taking into account both efficiency and costs.

Whether the choice is a decentralised- or centralised system, what type of hydrogen that will be used is also an essential factor. At this moment, there are three types of hydrogen (see appendix section 3) and the people in Dichterswijk have indicated that green hydrogen upholds their preference. This suggests that these people are only willing to allow hydrogen in their homes if produced sustainably. The importance of this matter becomes visible as the green solution alone can drastically reduce both carbon emissions and the reliability of natural gas. A significant disadvantage of the green method is the availability on a large scale, making the implementation unfeasible. As it stands, both blue and grey do offer this critical factor; however, it is not preferred by the inhabitants of Dichterswijk (figure 12). With the growing urgency of liberating Dichterswijk of its gas before 2050, the local authorities can carefully consider switching to a grey or blue option, yet this reduces support by its inhabitants. On the other hand, there is the hold-up for innovation for the green solution concerning upscaling. A possible explanation could first cover both the grey or blue method and switching to the green solution once it has reached its full potential. Yet, the socio-environmental performance of the inhabitants prevails if the transition is made to an alternative for natural gas that it must be a sustainable source that contributes to reducing harmful impacts on the environment. Otherwise, a switch will not be decisive in the climate agreement.

In line with the production of green hydrogen, the possible implementation will require infrastructure in the immediate neighbourhood. While the introduction of renewable energy infrastructure is also an inevitable feature of this transition, the inhabitants could only allow the introduction of solar PV as some have already done or are planning on doing. Yet, the one problem with solar PV is the amount of renewable energy that is required to produce decentralised hydrogen. This option is highly unfeasible and in this regard wind power does offer a future perspective, the inhabitants of Dichterswijk do not favour the application of wind power as this is not common in urban areas. The allowance of infrastructure related to hydrogen production follows the ‘’not in my backyard principle’’; this entails wind power is not likely to be accepted by Dichterswijk. The option of solar PV is not in line with the principle of the energy transition in which we want to increase efficiency with both energy consumption and production. In this line of reasoning, why would renewable energy from solar PV be converted to hydrogen if you require a lot of it?

Rational energy planning would suggest the direct utilisation of the generated power for household purposes. In one way or another, a decentralised system requiring locally generated renewable energy is not likely to be used for hydrogen in Dichterswijk.

4.5.4 Ranking the preference

The introduction of hydrogen offers new aspects to inhabitants of Dichterswijk, yet whatever the future transition entails for Dichterswijk, the guarantee that this happens safely is prioritized (figure 15). Another essential feature is the sustainability aspect of this transition is ranked as second. This means the residents of Dichterswijk want an alternative for gas that has proven worth in reducing carbon emissions. This might be explained because the transition towards a new heating source in their homes requires a period of adjusting the household causing disruption in the daily habit of living. Therefore, they want this alternative to be a solid contribution to the energy transition of the built environment. Another point to be considered is the affordability dimension of this transition. Although the municipality of Utrecht finances a large sum of the upcoming transition, there are still unforeseen expenses that must be paid by the resident. Logically, they want this to be affordable so that the advantages of a more sustainable household outweighs the possible expenses. The last point to be discussed is that whatever option will be applied the respondents have indicated that an information campaign will ensure the right selection of choices. This interaction between resident and municipality facilitates a safe and affordable possible future for the heat provision in Dichterswijk.

Discussion

In this chapter, the empirical research findings will be discussed concerning the conceptual framework and previous research. Although the focus of this thesis is on a single area, the conclusions must be viewed in the context of broader transitional and academic discussions. This study aimed to understand the socio-technical impediments for implementing hydrogen in the built environment. To do so, it drew on research from previous studies on transitions to conceptualize the built environment as an extensive socio-technical system. The most significant barriers identified included poor performance or inefficiency along with the supply and utilization of hydrogen, the lack of subsidies and a regulatory framework at a local scale and differing objectives among incumbent actors. In the end, some remarks will be given on how the findings should be interpreted and some suggestions for future research.

The results align Dichterswijk with the literature on socio-technical transition studies in which the challenges associated with the re-orientation of the regime are both organizational and technological. Academia such as Geels (2018) illustrated that technical barriers for the niche can create specific path dependencies that will induce ''technological momentum,'' which is tough to overpower when establishing a new system. The differences among an aligned vision on the technology were also observed as an obstacle. These organizational issues among policymakers and incumbent actors coalesce to make the shift towards hydrogen quite challenging. Bögel et al. (2019) already emphasized the necessity to examine organisational barriers that hamper innovation and destabilize the current regime. However, focussing on the interaction between possible solutions and organizational barriers often follows specific logical reasoning. A rational response of critics of the technology is the possibility of direct application of the generated renewable energy. The underlying goal is to increase efficiency in the energy transition. When a niche such as hydrogen cannot yet deliver these expectations, technical infeasibility becomes a significant organizational barrier towards implementation. Considering the dynamics between niche and regime, the actual destabilization of the regime is inevitable because of the imperative of decarbonization. Yet, at this moment, most of the resistance comes from the hydrogen niche itself as it is not substantiated to incumbent actors and therefore, to expectations.

The conceptual framework of MLP describes the results on technological and organizational barriers towards innovation. Within this study, this framework therefore, fitted well on the illustration of the scenery on socio-technical transitions. However, the built environment delivers new insight with regard to the MLP framework, which is public participation. The MLP framework provides a more general view of the situation. Therefore, public participation is not described yet; the reciprocity of innovation and public participation is judged as crucial to inducing system innovation in the built environment. The location of this transition best discloses the powerful feature of this transition and incorporates a concept that is local ownership. Therefore, this shift requires a new aspect that incorporates the values, beliefs and knowledge of the public members which is essential for the equitable, sustainable development of the built environment. The application of good governance of this transition thereby highlights the distribution of a transparent policy that is accountable for allocating the proper rights and resources to the public.

Within this research, external validity was used to reflect on the Dichterswijk community towards the implementation of hydrogen. However, reflecting on the sample population, some aspects need clarification for the means of this research. Consider the socio-economic status of the inhabitants of Dichterswijk; this entails, the educational level and income that all play a crucial role in the critical interpretation of aspects of hydrogen. This causal relation entails a particular sentiment in the community and that can be in the form of a bias for alternatives. Yet, this is also a dimension that is difficult to generalize among other neighbourhoods in Utrecht or the rest of the Netherlands, as this differs from community to community. Perhaps this is also one of the aspects of this transition that makes it the most challenging transition of the climate agreement as every urban or rural area in the Netherlands is different from each other therefore, confirming the diversity of this transition. In other words, the one problem with the transition in the built environment is the lack of a panacea kind of method, in which there is an universal remedy for every neighbourhood in the Netherlands.

5.1 Future research and limitations

There are some ideas for further research that could be of interest. The findings of this thesis are primarily based on the combination of governmental reports, scientific articles, until data from a survey. However, what was not included was an interview with representatives from companies or residents. For future research, additional in-depth information on the topic can be gathered through structured interviews to understand the upcoming transition comprehensively. Another future research could investigate the application in the sub-sectors in which hydrogen has an incredible potential of decarbonizing. There is some case in which hydrogen is the most realistic option for heating our homes; future research could discover what kind of residential areas fit this idea.

Limitations of the research can be found in the generalization of the Dichterswijk community towards the built environment as a general. Therefore, the findings of this thesis must be cautiously interpreted. Another limitation of the research could be the respondent bias on specific topics or suggested solutions to some survey questions. Therefore, the survey outcome was significant positive what could mean that the sample population was very willing to introduce hydrogen in Dichterswijk. This could be the lack of potential in-depth information of the survey in which the survey’s proposed solutions, therefore, influenced respondents. Another explanation is a limitation of a survey. That is the unconscientious method that could result in respondents quickly scrolling through the survey as they would not have felt the urgency of fully participating in this research. Finally, although the final number of respondents was 92, the total number of people living in Dichterswijk is around 5500, suggesting that the sampling population’s external validity was not a truly representative sample Dichterswijk. Thus, for future research, more research could be invested into finding suitable ways for reaching out to the sample population or with structured interviews.

Conclusion

The current built environment is on the verge of an inevitable transition towards a green alternative for gas. This research focussed on the alternative hydrogen and aimed to identify the current position of hydrogen and the socio-technical impediments that hinder the possible implementation in Dichterswijk Utrecht. Based on the analysis of the social acceptability aspect of the transition in the built environment, it can be concluded that the interaction of citizens and municipalities shapes the upcoming transition. This cooperation of actors is demarcated into three aspects; First of all, the spread of information provides the solutions to both foreseen as unforeseen problems. Secondly, this interchange is essential for the just governance of this transition and goes hand in hand with public participation. Finally, if hydrogen or another alternative is selected as the promising substitute, this must be the most sustainable option as inhabitants favour the most mitigative solution.

These observations generate several thoughts about the social acceptability and the intended hydrogen market of this particular socio-technical change. Besides the municipality, there are multiple other actors such as grid management, building corporates and local initiatives active within a neighbourhood. These stakeholders all have their ideas, interests and planning regarding the transition. Sometimes these aspects have an overlapping appearance and sometimes not. Yet, what plays a crucial role is the commitment and active participation of local owners as they want a contributing attitude in shaping this transition. Therefore, it is essential to work together where possible concerning communication and involvement. Thereby, reducing conflicting action and messages to residents that can disrupt the process. Moreover, if the municipality and different stakeholders work together, they can achieve synergies that ensures the just governance of hydrogen in the built environment.

As of this moment, with the functioning hydrogen market in the built environment, the availability for heat provision is determined through several factors. These factors range from physical possibilities and limits; however, economic, political and cultural considerations are of pivotal importance. The initiation of the production of hydrogen will be enabled when investment costs have a return of investment. In the energy transition, this means coordination issues that need to be solved, such as covering the flooding risks of capital-intensive networks. The current mechanisms for the allocation of hydrogen production are not yet suitable for the production increase that is technically possible and considered desirable from a policy point of view. New rules are needed to allow hydrogen production and distribution to grow together with long-term consistent government policy and many subsidies for the time being. This must be done before determining whether hydrogen is an attractive alternative in the built environment. Going back to the philosophy of Kintsugi, in which broken ceramic is repaired with gold. This Japanese technique tells us; it is not the fracture that counts but the quality of the reparation. If we acknowledge hydrogen as the gold, hydrogen might serve as the best alternative for achieving the climate agreement. For now, hydrogen might be the gold that will help us in repairing our built environment and making it more sustainable.

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Appendix

Section 1: Calculations

An average household in the Netherlands (Utrecht) uses 2340 m^3 natural gas per year for heating and insulation (TNO, 2020).

There are 2264 households in Dichterswijk, so the total number of gas that's required:

$$2264 * 2340 = 5{,}297{,}760\ m^3$$

The density of natural gas is 0.833 $\frac{Kg}{m^3}$ (The Engineering Toolbox, n.d.)

This entails, $5297760 * 0.833 = 4{,}413{,}034.08$ Kg natural gas

The energy density of natural gas is 45 MJ/Kg within modern boilers and an efficiency of at least 100% (Bouw-energie, n.d.)

$$4{,}413{,}034.08 * 45 = 198{,}586{,}533.6\ MJ$$

The energy density of hydrogen is 120 MJ/Kg with an efficiency of 85% in modern boilers (Vakblad warmtepompen, n.d.).

This means that the total number of hydrogen required for heating Dichterswijk is:

$$\frac{198{,}586{,}533.6\ MJ}{(120 * 0.85)} = 1{,}946{,}926.8\ Kg\ hydrogen$$

For a modern electrolyser to produce hydrogen the required renewable energy is 39 KWh/Kg with an efficiency of 60% (Vakblad warmtepompen, n.d.)

This means the number of KWh required is:

$$1{,}946{,}926.8 * (39 * 1.4) = 106{,}302{,}203.3\ KWh/year$$

An average PV-panel delivers a minimum of 212 KWh (CBS, 2020)

The total number of PV-panels required to produce enough renewable energy for the production of hydrogen that is needed for heating and insulation is:

$$\frac{106{,}302{,}203.3}{212} = 501{,}426\ solar\ panels$$

This means that the average PV panels per household is

$$\frac{501{,}426}{2264} = 222\ solars\ panels$$

Section 2: Flyer Dichterswijk

Duurzame Dichterswijk

Laat ik mijzelf eerst even voorstellen: Ik ben Coen Drukker student aan de Universiteit van Twente, wonende op de Coornhertstraat. Voor het afstuderen van mijn studie: Environmental and Energy management doe ik een onderzoek naar de mogelijke overstap van aardgas naar waterstof in de Dichterswijk Utrecht. Op het moment wordt aardgas gebruikt om de woningen in Utrecht te voorzien van warmte en kan het gebruikt worden om mee te koken. Één van de speerpunten van mijn onderzoek (en binnen de mogelijke transitie) is het sociale draagvlak of te wel de acceptatie van waterstof in de Dichterswijk. Door deelname aan deze enquête kunnen jullie hieraan bijdragen, verder is de deelname volledig anoniem en zal met alle informatie vertrouwelijk worden omgegaan. De tijd voor het invullen bedraagt ca. 5 minuten.

Scan de QR-code met je telefoon door naar je camera te gaan en de code te scannen

SCAN ME

Section 3: Types of hydrogen production

At this moment there are five options (green, blue, grey, pink and yellow) to produce hydrogen, each option will be elaborated on in the section underneath (Petrofac, 2019).

Green

The most sustainable form of producing hydrogen is called green hydrogen.
This is the technique in which renewable energy in the form of wind is transformed into hydrogen. The reaction is called electrolysis and is in simple terms two metal plates are placed into freshwater and during this process the plates are connected to a electrical source. During this process water is split into two products each occurring at one of the two plates. At the one plate hydrogen (H_2) is formed and at the other plate oxygen (O_2) is formed. The chemical reaction is shown in equation 1.

(1) $$Electricity + 2H_2O = 2H_2 + O_2$$

Blue

The option of blue hydrogen is the reformation of natural gas (CH_4) in hydrogen and carbon dioxide (CO_2). This happens on a large industrial scale and is still dependent on fossil fuels (natural gas). During this process carbon dioxide is captured and can be used for purposes such as industrial growing of crops. The reaction can be seen in equation 2.

(2) $$CH_4 + H_2O = 3H_2 + CO$$

$$CO + H_2O = CO_2 + H_2$$

Grey

This is the same production process as blue, the only thing that differs is that carbon dioxide is not captured but released in the atmosphere.

Pink

This is the same technique as green only in this case nuclear energy is used as renewable energy source.

Yellow

This is the same technique as green only in this case solar power is used as renewable energy source.

Section 4: The survey

1. Do you know what hydrogen is?

- ◯ Yes
- ◯ No
- ◯ Not sure

2. Do you associate hydrogen with an unsafe feeling if it is applied into your home?

	1	2	3	4	5	6	7	8	9	10	
Not at all	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Extremely likely

3. What kind of production method of hydrogen do you prefer? *

	Fully agree	Partially agree	Neutral	Partially disagr...	Fully disagree
Blue	◯	◯	◯	◯	◯
Green	◯	◯	◯	◯	◯
Grey	◯	◯	◯	◯	◯

4. Are you prepared to adjust your household in order to utilise hydrogen? (boiler and pipes)

- ◯ Fully agree
- ◯ Partially agree
- ◯ Neutral
- ◯ Partially disagree
- ◯ Fully disagree

5. Are you prepared to switch to electrical cooking?

- ◯ Fully agree
- ◯ Partially agree
- ◯ Neutral
- ◯ Partially disagree
- ◯ Fully disagree

6. Are you prepared to financially aid the municipality if needed (kitchen + unforeseen costs) as long as it stays affordable

	1	2	3	4	5	6	7	8	9	10	
Not at all	○	○	○	○	○	○	○	○	○	○	Extremely likely

7. I only want to make the transition towards hydrogen if I can do it as () *

	Fully agree	Partially agree	Neutral	Partially disagr...	Fully disagree
Collectivity (wh...	○	○	○	○	○
Individual hous...	○	○	○	○	○

8. I'm willing to make the transition towards hydrogen if i'm properly guided during this process

- ○ Fully agree
- ○ Partially agree
- ○ Neutral
- ○ Partially disagree
- ○ Fully disagree

9. The transition will work the best in this policy configuration *

	Fully agree	Partially agree	Neutral	Partially disagr...	Fully disagree
Top-down	○	○	○	○	○
Cooperation	○	○	○	○	○
Bottom-up	○	○	○	○	○

10. If the transition has been realised I would like hydrogen to be produced accordingly

	Fully agree	Partially agree	Neutral	Partially disagr...	Fully disagree
Local (in the n...	○	○	○	○	○
Central (along t...	○	○	○	○	○

11. Are you willing to allow more infrastructure in the immediate surroundings (wind power, or PV)?

- Fully agree
- Partially agree
- Neutral
- Partially disagree
- Fully disagree

12. Finally, what aspects do you think are important in the upcoming transition (ranking) *

	Affordability	Safety	Collective ...	Sustainabil...	Guidance	Quality of l...	Other
1st choice	○	○	○	○	○	○	○
2nd choice	○	○	○	○	○	○	○
3rd choice	○	○	○	○	○	○	○
4th choice	○	○	○	○	○	○	○

Do you want to elaborate (optional)?

Long answer text