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SCHOOL OF BUSINESS, ECONOMICS AND LAW

Navigating the unknown – the only certainty is that there will be uncertainties

A single case study of a green hydrogen project in Sweden

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ABSTRACT

Green hydrogen technology can decarbonise energy-intensive industries and contribute to sustainable development globally. The technology itself is so novel that there are currently no large-scale production facilities. The objective of this thesis is therefore to investigate a practical case of a green hydrogen facility project in Alby, Sweden. A green hydrogen project does not come without difficulties and this thesis aims at creating an understanding of uncertainties in the project and how these are navigated by the two key stakeholders, RES and Ånge municipality. Further, this thesis intends to create an understanding of the diffusion of renewable energy technologies and in particular green hydrogen technology. The research areas are met through a qualitative case study based on nine interviews with actors involved in the green hydrogen project; RES and Ånge municipality as key stakeholders and technical experts involved in the project for additional understanding.

The empirical findings are structured around each interviewed group to cover the following areas; project management and technology diffusion. The research conducted for the green hydrogen facility in Alby confirms previous literature which shows that uncertainty in projects stems from common sources and that different uncertainty types call for different actions. When uncertainty is small and predictable, stakeholders can resort to planning. Once it is greater, flexibility is needed and close collaboration between stakeholders is important. Further, the thesis suggests that stakeholders and the roles they take impact uncertainty management; supporting stakeholders will reduce uncertainty and hindering stakeholders will bring more uncertainty. Managing uncertainties is a prerequisite for project completion, and successful project management helps pave the way for future green hydrogen projects. This leads to the second research area of this thesis, where the diffusion of renewable energy technologies is examined. The thesis shows that literature on renewable energy technology diffusion is relevant to explaining the challenges of green hydrogen technology. Local opposition to renewable energy is mentioned extensively in literature and opposition challenges exist also in the Alby project. A non-existent green hydrogen market is considered to have implementations for the project itself and the diffusion of green hydrogen technology. Due to the novelty of green hydrogen, this thesis contributes with theoretical and practical knowledge in a primarily unresearched area.

Keywords: green hydrogen, project management, project uncertainty, stakeholder involvement, diffusion of technology, diffusion of renewable energy technology

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Lisa Halldin *Eric Larsson*

ABBREVIATIONS AND CONCEPTS

CAPEX = Capital Expenditure
Concession = Permit to operate 400 kV and 220 kV grids issued by the Swedish transmission system operator, Svenska Kraftnät
DSO = distribution system operator
Offtaker = buyer of the product(s) produced by a project; in this case, green hydrogen and its by-products (oxygen and heat)
Offtaker agreement = an agreement signed between a seller of a produced commodity and a buyer. In this thesis, it will be mentioned for buyers of green hydrogen and buyers of electricity produced by renewable energy.
OPEX = Operating Expenditure
PPA = power purchase agreement; agreement where one party buys the electricity produced by an energy source
SE1 = Swedish electricity area one, also known as Luleå
SE2 = Swedish electricity area two, also known as Östersund

Translations
Energimyndigheten = The Swedish Energy Agency
Länsstyrelsen = The County Administrative Board

Table of Content

1. Introduction and background

The thesis starts with an introduction to green hydrogen and the case that has been studied. Moreover, the focus of the thesis and a problem discussion of why the case was chosen will be presented. Finally, the purpose and research questions will be displayed followed by limitations and a structure of the thesis' disposition.

1.1 Introduction

The world is in urgent need of a sustainable transformation. To reduce the impact on our planet and future generations, greenhouse emissions need to be reduced. At large, electrification is expected to drive CO2 reductions, but it is not an alternative for most heavily polluting industries (Energimyndigheten, 2021; Lazard, 2021b; IEA, 2019). Instead, green hydrogen is expected to solve the problem of decarbonisation for industries that depend on fossil fuels, such as steel producers, ammonia manufacturers and the heavy transportation industry (Lazard, 2021b). Green hydrogen is created when water is electrolysed by electricity produced by renewable energy (Lazard, 2021b). Together with Ånge municipality, the global renewable energy company RES (Renewable Energy Systems) had signed a letter of intent to start a hydrogen production facility in Alby (SVT, 2021; RES, 2021). The two actors are the key stakeholders of the green hydrogen project. With rising costs of emission rights (Ember, 2022), investing in hydrogen-based manufacturing can help energy-intensive production companies hedge against the future risk of high production costs from fossil operations. Looking from a lifetime perspective, onshore wind power has the lowest cost per MWh of any energy source (Lazard, 2021a; Energiforsk, 2021), making it suitable to pair up with energy-intensive hydrogen projects. Therefore, renewables play an important role in the future industry needs of Sweden as they facilitate green hydrogen production and help ensure that the new energy needs are met. Establishing green hydrogen facilities in the north of Sweden are motivated by electricity prices; Swedish electricity areas SE1 and SE2 have periodically shown considerably lower prices than SE3 and SE4 (Fossilfritt Sverige, 2021). The possibility to establish cheap renewable energy in Sweden gives a unique position to produce low-cost hydrogen (Energimyndigheten, 2021). Green hydrogen projects are therefore best located in proximity to the renewable energy production and low electricity prices of northern Sweden, which explains why the Alby project is located in SE2.

Since green hydrogen is new on an industrial scale, projects come with many uncertainties. Thus, project uncertainty management becomes critical in project development. Uncertainties take different shapes in projects and research illustrates coping strategies. De Meyer, Loch & Pich (2002) argue that greater uncertainty demands greater flexibility. If uncertainty is hard to predetermine, adaptability and flexibility are needed for project success (De Meyer et al., 2002; Böhle, Heidling & Schoper, 2016). Uncertainty gives rise to both opportunities and challenges and when handled correctly it yields economic benefits (Ward & Chapman, 2003; Perminova, Gustafsson & Wikström, 2008). Addressing stakeholders needs is important as it reduces the uncertainties associated with the complexity of having many stakeholders involved in a project (Enevoldsen & Permien, 2018; Hartono, Sulistyo, Praftiwi & Hasmoro, 2014; Böhle et al., 2016). Stakeholders can affect the outcome of a project negatively or positively (Ruggiero, Onkila, & Kuittinen, 2014; Phillips, Freeman & Wicks, 2003) and they play a vital role in accomplishing project success (Ruggiero et al., 2014; Odabashian, HassabElnaby & Manoukian, 2019). Thus, stakeholder collaboration affects project management and the outcome of the project. Since the green hydrogen project in Alby is one of the first of its kind, looking at technology diffusion aspects becomes important. Renewable energy diffusion literature has shown many common barriers: local opposition (Enevoldsen & Permien, 2018; Khan 2003; Seetharaman, Moorthy, Krishna, Nitin Patwa, and Yash Gupta, 2019; Painuly, 2003), lack of standards (Painuly, 2001; Seetharaman et al., 2019), high investment costs (Rao & Kishore, 2010; Painuly, 2001; Seetharaman et al., 2019) and lack of infrastructure (Painuly, 2001; Seetharaman et al., 2019). Green hydrogen is dependent on renewable energy and shares diffusion barriers with renewable energy. For instance, lack of infrastructure and standards are challenging barriers to green hydrogen diffusion (Energimyndigheten, 2021). In some areas green hydrogen faces different barriers than renewable energy; a great concern is high production costs (Seh, Kibsgaard, Dickens, Chorkendorff, Nörskov & Jaramillo, 2017). However, the high costs of hydrogen from water electrolysis can be offset by low production costs for electricity (Turner, 2004), once again emphasising why northern Sweden is an attractive region for green hydrogen production.

1.2 Case description

In December 2021, RES and Ånge municipality signed a letter of intent to produce green hydrogen in the Alby region (RES, 2021). The goal is to create an industrial cluster, a so-called green hub, where energy-intensive industries can establish themselves to access green hydrogen and decarbonise operations. The hub is expected to create a large number of job opportunities for the local community. The Alby site has been chosen for the project due to the large quantities of wind power available from the local sub-station Tovåsen, where a cluster of both operational and planned wind power creates prerequisites for a hub (RES, 2021). Large volumes of energy are not only needed for the hydrogen production facility itself, but also for the industries looking to establish themselves in the region. In the first phase of the project, a 20MW green hydrogen facility will be built and connected to the local grid (RES, 2021). For this phase, the current local energy production is considered to be enough, but as the facility is planned to expand continuously, there is a need for more energy production and a new grid connection will be made. Considering the need for new energy, the local opposition to wind power is a potential problem for the Alby project. Hopefully, the project will clarify that there is a symbiosis between wind power, green hydrogen and local industrial development.

1.3 Problem discussion and purpose

A vast amount of renewable energy and low electricity prices in the north of Sweden opens up for ground-breaking green hydrogen projects that can decarbonise energy-intensive industries. Green hydrogen can replace coal in many energy-intensive industries, but production demands large amounts of renewable energy. The municipality of Ånge is therefore well located for such a project. In this thesis, we looked at a project in Alby, which is a small community in the

Swedish electricity area called SE2. Commercialising a green hydrogen project does not come without difficulties and the aim of this thesis is firstly to create an understanding of the uncertainties that are faced and navigated in the green hydrogen project in Alby and secondly how these affect the diffusion of green hydrogen technology. Until today, no large-scale production plants have been established, which explains why this thesis looks at how two key stakeholders navigate project uncertainty in the development of a green hydrogen facility in Sweden. Emphasis has been put on the relationship between RES and Ånge municipality, as the key stakeholders of the project. Stakeholder involvement aspects are therefore seen from the perspective of the two main stakeholders as they are responsible for carrying out the project, in contrast to other stakeholders. Project uncertainty, as well as stakeholder theory, were used to explain the specific problems that have to be managed in the project. While these are project-specific, the technology diffusion perspective takes a broader view and looks at the bigger picture of impact.

1.4 Research questions

With the discussion of the problem and purpose in mind, the research concentrates on a specific case; the Alby project. Project management includes project uncertainty and stakeholder theory that is specific to the project, while technology diffusion takes a broader perspective.

How do key stakeholders navigate project uncertainty in the development of a green hydrogen facility in Sweden?

- *How do different stakeholders affect project uncertainty?*

What project factors affect the diffusion of technology?

The first research question and sub-research question aim to study the specific case on a project level. The sub-research question debates how different stakeholders affect project uncertainty, in turn impacting which uncertainties the key stakeholders should navigate. This helps to answer the first main research question of how key stakeholders navigate project uncertainty in the development of a green hydrogen facility in Sweden. The second research question aims to study the bigger impact on a technology level. The research questions were formulated in this order since navigating uncertainty and accomplishing a successful project in a novel technology area can positively affect how the technology becomes widespread.

1.5 Data needs connected to purpose and research design

Bryman and Bell (2011) argue that one thing that stands out with qualitative research is that it often aims at understanding the social world through interpretations made by those involved in it. In this regard, a qualitative study on individuals involved in a project related to green hydrogen can help create an understanding of uncertainties in the project and the collaboration around these. The focus of this thesis was therefore placed on interviewing technical experts, business representatives and officials from the municipality. A primary expectation was that 9-

12 interviews had to be conducted to reach saturation which is dependent on the respondent's answers. While it was likely that the respondents have some differences in their goals for such projects, it was also likely that they share some common goals. It was therefore too early to estimate exactly how many interviews had to be conducted, as this depended on the respondents' answers. As an abductive approach to research is somewhat exploratory (Dubois & Gadde, 2002), it made sense not to have the number of respondents written in stone.

1.6 Delimitations

The Alby project presented is the case in the focus of this thesis. Therefore, the scope is limited to a single green hydrogen facility case. This gives less ability to generalise the conclusions outside of the scope of this thesis. The conclusions will benefit the involved stakeholders in the specific project, mainly RES and Ånge municipality since their relationship was in focus. On the other hand, since green hydrogen is an area that will grow, there could be possibilities for upcoming projects to be inspired and to learn from the findings of this thesis. Another limitation is the stakeholders involved. There are actors of the Alby project that aren't official yet, so the scope is limited to the official stakeholders involved in the project; RES, Ånge municipality and technical experts. The latter takes a smaller role by providing technical knowledge. The industry actor that will buy the green hydrogen facility, or the offtakers of green hydrogen or by-products are not a part of the thesis scope. The aim is thus to create an understanding of how project uncertainty and stakeholders affect the potential for project success and the diffusion of green hydrogen technology, focusing especially on the relationship between RES and Ånge municipality. Another aspect is that the Alby project will not be finished within the time horizon of this research. With this in mind, the scope does logically not include implementation and the result of the project.

1.7 Disposition of thesis

The thesis includes six main chapters. The first chapter, the *introduction*, presents the background of the subject and further describes the specific case. This also contains the purpose of the thesis followed by displaying the research questions and delimitations. The second chapter, the *methodology*, highlights the choices regarding research strategy and design. Additional research methods are specified and motivated. Research quality is also discussed to ensure trustworthy research. Chapter three, the *setting the context*, aims to capture the prerequisites and create an understanding of the complex subject of the thesis. The fourth chapter, the *literature review*, presents the chosen literature concepts and the theoretical framework, which lays the foundation for the analysis. The chosen order aims to first present the background and then the methodology to decide on how to investigate the Alby project and what literature to search. This order is required since the area of green hydrogen is so new that one cannot start with literature without having a plan on what to include and exclude. Afterwards, creating an understanding of the novel subject where literature might not exist or be up to date through setting the context and finally introducing a literature review to display theories for the later analysis. This forms a natural order when investigating a practical case where few sources of literature exist. Thus, the methods on how to perform the research must first be clear. Chapter five, the *empirical findings*, focuses on the collected primary data, gathered from interviews with RES, Ånge municipality, and technical experts. The sixth chapter, the *analysis*, provides an examination where theory is applied to the collected data. Chapter seven, the *conclusion*, outlines the findings and further states an answer to the research questions. Suggestions for future research are also presented. *The disposition is displayed below in Figure 1.*

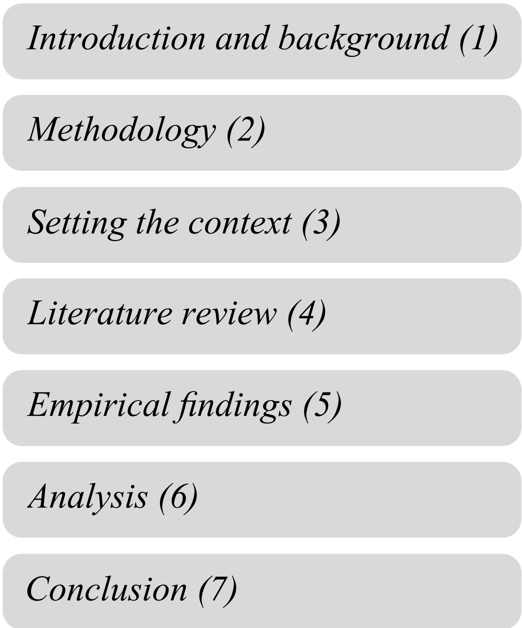

Figure 1 – Disposition of thesis.

2. Methodology

In this section, the chosen research methodology and approaches will first be presented. The chapter continues by discussing the primary and secondary data collection, followed by how the literature review was gathered. Besides, the section discusses the thematic analysis and research quality of the thesis. Lastly, ethical aspects will be taken into consideration and reviewed.

2.1 Research methodology

2.1.1 Chosen research strategy

The chosen research strategy for this study was the qualitative method, which was believed to be the best option for answering the formulated research questions. As these involve a *"how"* and *"what"*, it shows that the most suitable strategy was a qualitative one, where the focus lies on exploring and interpreting individuals' views of the specific phenomena (Bryman & Bell, 2011). Here, project developers, technical experts and people working in the municipality shared their views on how to navigate project uncertainty for a green hydrogen facility and how it affects project success and diffusion of technology. The interviews aimed to clarify how different stakeholders affect project uncertainty and project success, with the main focus on the relationship between RES and Ånge municipality. Connotations and words were important to create an understanding of the underlying motives and incentives to answer the research questions properly. This is in line with what a qualitative research strategy emphasises (Bryman & Bell, 2011).

Exploring research questions implies that a qualitative research strategy is more suitable than a quantitative one where existing theories are tested and generalised (Bryman & Bell, 2011). The former, qualitative, takes an inductive-, and the latter, quantitative, a deductive approach according to Bryman and Bell (2011). The research questions were formulated in a more exploratory way with *"how"* and *"what",* aiming to investigate a specific phenomenon, which supports using an inductive approach as it is exploratory according to Bryman and Bell (2011). Further, the inductive approach aims to generate theories from the research conducted (Bryman & Bell, 2011). For this thesis, theories and research has been found, examined, and included in a literature review. Simultaneously, data has been collected from interviews. There was a parallel development where theory was gathered, and interpretations was made alongside. This is referred to as systematic combining and an abductive approach to case studies (Dubois & Gadde, 2002), which therefore was seen as a more accurate fit for this thesis than an inductive approach. Dubois and Gadde (2002) describe systematic combining as being closer to the inductive approach rather than the deductive one, which goes well with the exploratory research questions. An abductive approach focuses on theory development, in the form of refining existing theories (Dubois & Gadde, 2002). This goes in line with the fact that the most noticeable difference from the other approaches is the theoretical framework, which in this thesis was changed corresponding to collected empirical findings and new theoretical insights. Dubois and Gadde (2002) argue that researchers will develop new combinations of the existing theories and new theories consistent with the empirical findings from reality. They further highlight that an abductive approach allows a greater understanding which was harmonious to the purpose of this thesis. Dubois and Gadde (2002) also argue that an abductive approach is a better fit for a case study which was in line with the chosen research design, discussed in the upcoming paragraph *"Chosen research design"*. Taking these arguments into consideration, the abductive approach was decided to be the most suitable.

2.1.2 Chosen research design

Bryman and Bell (2011) discuss research design methods to follow when conducting the research, gathering and analysing the data. One of them is the case study design, which Eisenhardt and Graebner (2007) portray as arguably popular. Goffin, Åhlström, Bianchi and Richtnér (2019) criticise the method by describing that research through case studies has a somewhat low quality and often does not highlight why a case study was the appropriate research method to use. They argue that to reach a high level of quality when performing a case study, the sampling method is vital. In addition to the former critique, Siggelkow (2007) emphasises that the case study perspective is often seen as too narrow a sample or even biased. Flyvberg (2006) on the other hand, argues that case studies provide rich information by reflecting the real world, taking a narrow but detailed perspective. Rowley (2002) and Bryman and Bell (2011) present arguments in line with Flyvberg (2006), by saying that a case study aims at analysing a specific case deeply, investigating *why* or *how*. In this thesis, the researchers deeply studied the case of a project in Ånge municipality, focusing on how key stakeholders navigate project uncertainty for a green hydrogen facility, and how it affects the diffusion of technology. Besides, how stakeholders affect project uncertainty, concentrating on RES and Ånge municipality, and project success of the specific project. To gain deep knowledge and create an understanding of *how*, a detailed single case study was an appropriate research design, in accordance with Rowley (2002) and Bryman and Bell (2011).

Case studies are very broad and can cover almost any kind of research. Somewhat of a distinction is thus needed and is usually taken through two different approaches (Bryman & Bell, 2011). The one presented as an idiographic approach aims to recognise features that are unique in a specific case. The nomothetic approach, in contrast, aims to discover findings that apply no matter the context (Bryman & Bell, 2011). The idiographic approach was the most suitable for this thesis since the research aimed to study a specific case at the current moment. Namely, how stakeholders navigate project uncertainty and how it affects the diffusion of technology for a green hydrogen facility in Ånge municipality. The chosen research design was also strengthened by the fact that literature is missing regarding the phenomenon of navigating project uncertainty, accompanied by stakeholder involvement from a green hydrogen perspective. A case study is seen as a suitable method to deeply investigate a topic where theory is almost non-existing according to Rowley (2002).

2.2 Collection of data

To conduct comprehensive research, both primary and secondary data were used. In addition, a literature review was written. The collection of data strived to answer the formulated research questions properly, as stated earlier:

How do key stakeholders navigate project uncertainty in the development of a green hydrogen facility in Sweden?

- *How do different stakeholders affect project uncertainty?*

What project factors affect the diffusion of technology?

2.2.1 Primary data

Primary data collection is important to answer the stated research questions focusing on a single case study. Bryman and Bell (2011) describe the main research methods for gathering primary data; ethnography/observation, focus groups, and interviews. The first is highly time-consuming and one should be involved in activities for a longer period. Focus groups instead centre on the interaction in the group. The last alternative, interviews, was chosen as the method for primary data collection to focus on meanings and people's interpretation of the specific phenomena studied (Bryman & Bell, 2011). This was both a suitable and standard choice when conducting qualitative research (Bryman & Bell, 2011). Meanings and words were important to achieve the purpose of the thesis; creating an understanding of how stakeholders navigate the uncertainties that the green hydrogen project in Alby is facing and how these affect the diffusion of green hydrogen technology.

2.2.1.1 Qualitative research method – semi-structured interviews

Bryman and Bell (2011) stress that the purpose of conducting interviews is to gather rich data, in other words, to get detailed answers. They argue that the way to collect data through interviews can vary, and describe the unstructured and semi-structured interview approach. Unstructured interviews allow the respondents to talk freely about a specific subject, seen more like a conversation. Semi-structured interviews cover areas that the researchers have listed in what is called an interview guide. This approach allows some flexibility, such as asking supplementary questions according to Bryman and Bell (2011). Besides, semi-structured interviews ensure comparability, while unstructured interviews carry the risk of not collecting appropriate data or not generating enough data (Bryman & Bell, 2011). The ability to have a structure with an interview guide and ensure comparability, while providing the flexibility to add questions during the interviews, made the semi-structured interview approach suitable for this thesis. This allowed the researchers to create an understanding of project uncertainty and its impact on project success for a green hydrogen facility. Moreover, the semi-structured interviews helped to study how different stakeholders affect project uncertainty and project success on a deeper level.

2.2.1.2 Interview guide

When conducting semi-structured interviews, an interview guide was essential. Bryman and Bell (2011) emphasise that the purpose of an interview guide is to make sure areas needed to be explored are covered accordingly. This doesn't mean that the interview guide is only written words or a list of questions, but rather that it includes a brief list of areas needed to be covered (Bryman & Bell, 2011). The interview guide acted as the basis during the interviews for this thesis, as well as enabling the flexibility to ask complementary questions. The questions asked needed to be planned so the respondents could reflect and express their views. At the same time, contribute to an answer to the research questions which is emphasised as important by Bryman and Bell (2011). Closed or leading questions were avoided to prevent biasing of the respondents' answers. This is framed as a risk with closed questions according to Bryman and Bell (2011). They further argue that asking questions of a general and demographic kind is important to create a context of the persons and their answers. The interview guide *(see interview guides in Appendix 1, 2, 3)* was therefore composed of two main parts to firstly create a context of the respondents and secondly contribute to answering the research questions.

1. Background
- Presentation of the topic and the researchers
- Demographic questions of the respondents

2. Questions related to navigating project uncertainty and how it affects project success and diffusion of technology. In addition, how different stakeholders affect project uncertainty.
- The respondents' views and interpretations

There were introducing questions in the first part which, according to Kvale (1996; through Bryman & Bell, 2011) is an important step. The introducing questions aimed to let the respondents describe their background and their role in the project. They thus helped to create a context of the respondents which eases the understanding and interpretation of their thoughts.

The second and largest part entailed the questions related to navigating project uncertainty and how it affects the diffusion of technology. This part also addressed how different stakeholders affect project uncertainty and project success. The second section of questions thus covered the main research topics of this thesis. These questions aimed at letting the respondents express their views and how they experience the project in Alby, hence a mix of indirect- and direct questions was applied, as suggested by Kvale (1996, through Bryman & Bell, 2011). He describes that indirect questions aim at making the respondent express their thoughts, while the direct questions are formulated in a more concrete way to get more concrete answers. Direct questions could bias the respondent by pointing out a particular way more clearly according to Kvale (1996; through Bryman & Bell, 2011), so he stresses that direct questions should be asked in the final stage of the interview to avoid the eventual influence. The authors thought about the advice when formulating the interview guide and during the interviews.

Finally, follow-up questions are used to clarify something or explore areas further (Kvale, 1996; through Bryman & Bell, 2011). Such questions were asked during the interviews when the researchers felt the respondent could elaborate their answer more, or when clarification of an answer was needed. These questions varied for each interview since certain topics or questions needed clarification or further elaboration depending on the respondent's answers.

2.2.1.3 Conducting interviews

Bryman and Bell (2011) stress that flexibility in how to interview is critical. In this thesis, interviews were conducted face to face if possible. Otherwise facial expressions and body language are missed out, which are two disadvantages since these are vital for the interpretations of the respondents' words and meanings (Bryman & Bell, 2011). When it wasn't possible or reasonable to conduct the interview face to face, as with the people working in Ånge municipality (due to the long distance), online interviews were held. In those cases, the researchers emphasised the importance of having the camera on to increase mutual connection and trust. The aim was to record the interviews and respondents were asked for approval accordingly. To record interviews is positively emphasised by Bryman and Bell (2011). They argue that it ensures a correct and detailed analysis since phrases can be lost when just taking notes. Therefore, all interviews were recorded and transcribed after approval. Bryman and Bell (2011) stress that this facilitates the analysis, making it easier to recognise and compare similarities and differences. The downside of transcribing interviews is the time consumption (Bryman & Bell, 2011). However, the advantages outweighed the drawbacks and the researchers transcribed the interviews as soon as possible after they were performed, which further eases the analysis according to Bryman and Bell (2011). Likewise, it increases the dependability of the research because of comprehensive transparency (Bryman & Bell, 2011).

2.2.1.4 Language

Interviews were held in Swedish or English, depending on the native language of the respondent. The researchers considered having all interviews in English but used the native language for each interview session. The decision was taken to make the respondents feel comfortable so they could express themselves. It was further strengthened by the fact that some did not have English as their work language and the researchers wanted to avoid that respondents felt restricted by language during the interviews, since words and meanings are of high importance for a qualitative single case study. The recorded interviews were transcribed in the same language as they were held. A translation was so needed for the analysis and quotes. This presents an increased risk of misinterpretation and misunderstandings. Xian (2008) argues that there are three types of risk with translation; linguistics, cultural and methodological. The first relates to specific national words that do not have an English equivalent word, the second to cultural differences and contextual understanding, and the last to the translation process. Researchers carry a big responsibility since they interpret words and meanings (Xian, 2008), which arguably is important for qualitative research (Bryman & Bell, 2011). Xian (2008) argues that the researchers need to recognise the risks and differences that may occur because of translation. Both authors of this thesis were aware of the risks discussed by Xian (2008). Still, the decision was to use the native language for the respondents to make it easier for them to express their thoughts. To mitigate the potential problems that could arise, the researchers went through the transcriptions individually and later together to discuss content and decide how to translate words and meanings into English in the best possible way.

2.2.1.5 Choice of respondents

As discussed in the paragraph *"Chosen research design",* the sampling is vital to secure a great quality of a case study (Goffin et al., 2019). Goffin et al. (2019) further discuss that opportunistic sampling should be avoided since it brings a risk of lower quality, so the sampling needs to be based on appropriateness for the case and theoretical reasons. With a single case study, this becomes increasingly vital for achieving trustworthy research (Goffin et al., 2019), which is why a thought-through purposive sampling was the best fit. The respondents were strategically chosen because of their knowledge and relevance to the green hydrogen project in Alby. This did increase the risk of bias since the researchers chose the respondents, although the choice is a standard in qualitative research according to Etikan, Musa and Alkassim (2016). When taking the risk of a low quality and the need for relevant data into account, a purposive sampling was considered the best fit for this case study. Since the research was conducted with some help from RES, a snowball sampling method was also applied, besides the purposive sampling. An interview was held with a respondent selected through purposive sampling, where the selected respondent recommended another person for an interview, which is called snowball sampling (Bryman & Bell, 2011).

2.2.1.6 Sampling criteria

Solely individuals that are involved in the green hydrogen project Alby have been of interest for this case study which was the first sampling criteria of the study. Most respondents were chosen strategically, as mentioned in the paragraph *"Choice of respondents",* while some were recommended by a person who was chosen purposefully. There are several actors involved in the project and to avoid missing out on details and to get the big picture, all actors were of interest since they have different views of the project. However, only official stakeholders could be a part of the sample. These actors include individuals that work within RES that are developing the project, local people within the municipality of Ånge and technical experts. One of the technical experts is an in-house expert at RES and one is a technical consultant. These persons were chosen since they contribute to the Alby project with technological knowledge and thus impact technological choices. The people working within Ånge municipality are officials, working directly with project-based questions but they do not have a mandate for wider decision-making. To clarify, they are not local politicians with decision-making mandates. To include all in the sample was vital to ensure a comprehensive understanding of navigating project uncertainty and how it affects the diffusion of technology, and in turn how this is affected by the different stakeholders. However, some actors were confidential even for the researchers which in turn affects the trustworthiness of the study which is something to have in mind, but as many actors as possible were included in the sample. The focus was on RES and Ånge municipality since they are key stakeholders involved in the Alby project. *Details regarding the interviews are provided in the three tables below (Table 1, 2 and 3), one for RES, one for Ånge municipality and one for the Technical experts.*

Table 1 – Respondents at RES.

RES

Name	Location	Date	Duration	Pages
Respondent A	RES Nordic's Office in Gothenburg	2022-03-08	1 hour and 15 minutes	12,5
Respondent B	RES Nordic's Office in Gothenburg	2022-03-14	1 hour and 8 minutes	12,5
Respondent C	Microsoft Teams	2022-03-30	46 minutes	8

Note: Transcription, number of pages in MS word - Times New Roman 12, single space lining

Table 2 – Respondents at Ånge municipality.

Ånge municipality

Name	Location	Date	Duration	Pages
Respondent A	Microsoft Teams	2022-03-09	1 hour and 19 minutes	12,5
Respondent B	Zoom	2022-03-16	53 minutes	11
Respondent C	Zoom	2022-03-21	54 minutes	11
Respondent D	Zoom	2022-03-22	51 minutes	8,5

Note: Transcription, number of pages in MS word - Times New Roman 12, single space lining

Table 3 – Technical experts.

Technical experts

Name	Location	Date	Duration	Pages
Respondent A	Microsoft Teams	2022-03-10	55 minutes	9,5
Respondent B	Zoom	2022-03-24	1 hour and 11 minutes	11

Note: Transcription, number of pages in MS word - Times New Roman 12, single space lining

2.2.2 Secondary data

Secondary data was used to present the facts in *"Setting the context"* which involved different industry reports and news articles related to the subject of the thesis. These reports and articles were gathered through agencies and corporations that work intensively with energy and green hydrogen, for instance, The Swedish Energy Agency and "Energimyndigheten". To ensure a high quality of facts about green hydrogen, the information was gathered from official agencies and intelligence consultants. The decision to use industry reports and articles were strengthened by that the subject is continuously developing and newly released reports were needed to present an accurate picture of the current situation of green hydrogen in areas where literature might not be up to date. A distinction was needed between industry reports and scientific research, which is why both *"setting the context"* and a *"literature review"* were developed.

2.2.3 Literature review

Previous research was used to find information and gain insights into important topics and develop a theoretical framework. The outcome of earlier research is of special interest if the study is conducted in a set environment, as this thesis was. The literature was gathered from articles found through GU Library, Scopus and Google Scholar. To secure high quality and legitimacy, the literature used was primarily peer-reviewed. Higher cited articles were favoured, but since the topic is continuously developing, newer articles with fewer citations were needed to find relevant information. The literature found was framed through a literature review and a theoretical framework that helped to analyse and further answer the research questions. The following keywords have been used to search for literature; *project uncertainty*, *stakeholder theory*, *project uncertainty renewable energy projects*, *stakeholders renewable energy projects*, *diffusion of technology*, *diffusion of renewable energy, diffusion energy systems, green hydrogen project uncertainty* and *green hydrogen projects*.

2.2.3.1 Inclusion and exclusion criteria

Before writing a literature review, the researchers needed to decide upon what to include and exclude. This is explained by Bryman and Bell (2011) as inclusion and exclusion criteria, creating the basis for what the literature review is built upon. This research included English and Swedish literature while literature in other languages was excluded. In this thesis, it was interesting to include theories such as the potential for green hydrogen solutions to be established. The diffusion of technology is an interesting aspect that brings up challenges for the deployment of renewable energy solutions from a green hydrogen perspective. This was an important area since the focus of the research lies on navigating project uncertainty and how it affects project success and the diffusion of technology. Literature on the diffusion of technology was included since a successful project in Ånge might in the long-term contribute to a well-spread technology. On the other hand, literature with a deep dive into very technical aspects of technology diffusion was excluded to avoid an angle that was far-fetched from the research questions. A subject that was partially excluded is the science of how electricity is traded since many aspects are outside the scope of this thesis. However, the authors of this thesis acknowledge that the energy produced in a certain place doesn't necessarily end up being consumed in the nearby region and that the shifting electricity demand in Europe affects the way electricity is exported, imported and used. Some phenomenon of the electricity market was therefore included in the thesis. Project uncertainty was an important area for this research and was included when searching for literature. Both general project uncertainty and project uncertainty in renewable energy projects were included, but literature focusing on project uncertainty in a different sector was excluded. The same method applied to stakeholder literature, which was of interest since the thesis investigated how different stakeholders affect project uncertainty. Thus, literature related to renewable energy projects was included, while articles focusing on non-relevant energy sectors were excluded. *The inclusion and exclusion criteria can be seen in Table 4 below.*

Table 4 – Inclusion and Exclusion criteria.

Inclusion	**Exclusion**
English and Swedish literature	Other languages than English and Swedish
Peer-reviewed and cited literature	Literature that isn't peer-reviewed
Focus on general diffusion of technology	Deep-dive into specific areas of diffusion of technology
Market aspects of the electricity market	Detailed electricity market theory
Focus on general project uncertainty and project uncertainty in renewable energy projects	Project uncertainty focusing specifically on a completely different sector

Focus on general stakeholder literature accompanied with specific to renewable energy projects	Stakeholder literature focusing specifically on a non-relevant energy sectors

2.3 Analysing the data – thematic analysis

The collected data needed to be analysed to hopefully refine theories and answer the formulated research questions accurately while generating conclusions. Therefore, the collected data was processed to compare and further recognise if any similarities or differences were seen. Qualitative research often yields large amounts of data that need to be analysed, creating a struggle to perform an analysis in a structured way according to Bryman and Bell (2011). In other words, to manage to capture the bigger picture and not only get stuck in the detailed information (Bryman & Bell, 2011). To perform a qualitative analysis in a systemised way, although having large amounts of data, is often done through finding codes and common themes. According to Bryman and Bell (2011) and Braun and Clarke (2012), this is referred to as thematic analysis and the method allows the researcher to find patterns and meanings in a simplified manner when going through the conducted data. The thematic analysis gives insights into patterns and focuses on meanings across a data set, hence finding common meanings and experiences to answer the research questions (Bryman & Bell, 2011; Braun & Clarke, 2012). The thematic analysis was consequently chosen to perform the analysis, navigate the rich collected primary data in an organised manner, and identify dissimilarities and similarities. This was needed to create an understanding of the uncertainties faced, how to navigate project uncertainty and how it is affected by the involved stakeholders, in turn impacting the diffusion of technology.

A thematic analysis comes with the risk of giving research that is indistinct and with unclear results because of the large flexibility the method gives (Bryman & Bell, 2011), even though flexibility is also seen as one advantage (Bryman & Bell, 2011; Braun & Clarke, 2012). Bryman and Bell (2011) emphasise that when coding a large amount of data with high richness, losing the context is a present risk. Braun and Clarke (2012), on the other hand, discuss the risk poor analysis, for instance putting asked questions as an identified theme, which weakens the analysis. To prevent this, both authors went through the conducted material individually to get familiar with it, find codes and themes, and reviewed the results together. According to Braun and Clarke (2012), this way of working is beneficial to get a comprehensive analysis. The presented disadvantages were also discussed and taken into consideration, but the thematic analysis was still seen as the most suitable method for performing analysis for this conducted research.

When processing the collected data, open coding allows the researcher to break down the gathered data into concepts and later on group them into themes according to Bryman and Bell (2011). This allows comparisons and scrutinises the collected data in a structured manner

(Bryman & Bell, 2011; Braun & Clarke, 2012). Bryman and Bell (2011) suggest that coding should be executed as closely as possible to the data being collected to create a severe understanding. They also argue that one might drown in the amount of data gathered if an analysis of the whole material is started at the end. The conducted data was therefore analysed continuously alongside the new interviews being held in this single case study. The process of analysing the data involved repetition and reviewing the concepts and themes, to first get familiar with the collected data and later on find key aspects of the research questions. This is emphasised as a beneficial way of working when performing a thematic analysis (Bryman & Bell, 2011; Braun & Clarke, 2012). Consequently, coding and finding themes were firstly done individually in Excel and then the authors went through it together. Afterwards, finding coding and themes was done once again but in a program called NVivo. This method was beneficial to reaching a thorough analysis in an organised way. *An example of thematic analysis can be seen in Appendix 4.*

2.4 Research quality

A big area of potential concern was related to research quality. Because of the dynamic nature of the world, the external reliability of a qualitative study is low (LeCompte and Goetz, 1982, through Bryman and Bell, 2011). In this thesis, we investigated an area where technological development and political decisions have the potential to change the environment surrounding the study, making it hard to apply the results of the study in other future scenarios. If a study in a similar municipality was conducted in parallel with this thesis, for example, local political opinions could have yielded much different results, showing the problems of the dynamic environment for external reliability, both in terms of geography and time. According to LeCompte and Goetz (1982, through Bryman and Bell, 2011), internal reliability will be affected by how similarly two (or more) researchers interpret the same observations. It is therefore a sign of high internal reliability if the two authors of this thesis interpret observations similarly. In line with this, having two authors for the thesis is seen as a strength. Internal validity is based on the match between researchers' observations and the theories they create (Bryman & Bell, 2011). This thesis aimed for a high internal validity through careful analysis of interview data and discussions between the authors. Since the analysis was made first in excel and the second time with a program called NVivo, it enabled a comprehensive analysis and clear overview of the respondents' views. Thus, increasing the internal validity and contributing to reaching a high validity. LeCompte and Goetz (1982, through Bryman and Bell, 2011) argue that external validity is an issue for qualitative research because of the nature of case studies. In the case of this article, however, there might be some potential for generalisability as other future projects could face similar problems in similar environments. As a result of the criticism that validity and reliability in qualitative research have received, Guba and Lincoln (1994) have argued for better fitting criteria, whereas four of them address trustworthiness and one authenticity.

Credibility (similar to internal validity) is equal to internal validity dependent on following good practices and having other researchers validate the research (Bryman & Bell, 2011). In this thesis, credibility was ensured as both researchers gave their interpretations of the data.

However, respondent validity was not reached as this calls for respondents to go through the entire material, which is time-consuming and rarely used in business research (Bryman & Bell, 2011). This was also the case for this thesis as most respondents were busy. Transferability is similar to external validity. Through what Geertz (1973, through Bryman and Bell, 2011) calls “thick description”, problems of transferability can be solved to some extent by explaining a culture and its related findings in detail. This allows other researchers to see how the culture works and gives them the ability to try the same approach on other subjects of environments. For this thesis, it meant that similar studies in hydrogen and renewable energy could be completed in other sparsely populated municipalities using a similar approach. The thesis is thus conducted so that phenomena were explained clearly and detailed to promote transferability and open the door for more research in the same area. Dependability is comparable to reliability and has emerged as a qualitative alternative to what reliability is for quantitative research, and the main concept of dependability is keeping track of everything that has been conducted throughout the research (Guba & Lincoln, 1994). This allows other researchers to audit the research during or after it has been conducted. It does, however, mean that those auditing have to go through great amounts of data, which has resulted in it being sparsely used in business research. In this thesis, dependability was high as everything was written down carefully. Some degree of auditing occurred as both researchers went through all primary data, but no peers went through it. Conformability shares similarities with objectivity and means making sure that the study has been conducted in good faith (Bryman & Bell, 2011). In the case of good faith, there was one obstacle for this thesis, as one of the authors of this article has worked for the company that has initiated the project in Ånge, which is one of the main actors of the study for this thesis. To avoid bias and potentially bad faith, it was beneficial to have two researchers, as this greatly reduced the risk of bad faith.

The authenticity measures as presented by Bryman and Bell (2011) had to be considered when writing this thesis. Problems with fairness could emerge if only one stakeholder was interviewed. However, in this study, members from all official stakeholders were interviewed and involved directly, which lessened the problem. This thesis aimed to help members to understand more about the relationship they are in, which should benefit the thesis’ ontological authenticity. Educative authenticity was also high as knowledge about all actors emerged, opening up an opportunity to learn about each other. Hopefully, it created a mutual understanding of problems. The members of the study were also provided with information on how to change their situation to some extent, making catalytic authenticity high. One should know that it might be hard to change one’s situation in certain cases, for instance, if one or all parties involved are held back by government actions. Tactical authenticity was moderately high. If the thesis helped members change their situations, it is also likely that it gave some guidance on what the path forward should look like. For instance, if the government was the main concern, the way forward might be lobbying.

2.5 Ethics

When conducting research and writing a thesis report, ethical principles are a crucial part. By being aware of ethical issues, the researchers can manage them and further understand the implications of these choices (Bryman & Bell, 2011). According to Diener and Crandall (1978; through Bryman & Bell, 2011), one of the most identified ethical principles concerns confidentiality and anonymity. This area is emphasised as being particularly apparent for qualitative research according to Bryman and Bell (2011). They stress the risk of uncovering a specific organisation, a local place or even an employee, especially when the research is conducted in a specialised area accompanied by a small sample. The same applies if a secondary analysis later would be performed since transcribed interviews and notes might expose sensitive details (Bryman & Bell, 2011). Thus, respondents needed to be informed about the risk of losing confidentiality and anonymity at the start of a performed interview, and the ability to withdraw accordingly (Bryman & Bell, 2011). These ethical issues needed to be taken into consideration when writing the thesis. First, the communication towards respondents had to be transparent, where they were asked to take part and for approval to record the interviews. This is emphasised as vital by Bryman and Bell (2011). It was also of high importance to ensure anonymity if the respondents would like to be framed accordingly, which is something that was communicated to potential respondents. It was particularly important for this thesis since the case focused on a sparsely populated community and a few actors. Hence, a specialised area and a small sample increased the risk of exploiting an organisation, a place or an employee according to Bryman and Bell (2011). It was therefore decided to remove the names and roles of the respondents in this thesis, only presenting the actor they work for.

The aspects discussed regarding confidentiality and anonymity were significant to ensure correct ethical research with a high level of trustworthiness. However, to ensure trustworthy research and transparency towards potential readers (Bryman & Bell, 2011), the interview guides were a part of the appendix. Different interviews had diverse follow-up questions because of the semi-structure, which a reader should have in mind. One should likewise have in mind that interviews contained questions regarding collaboration among actors. The answers from people within Ånge municipality could therefore be thoughtful since they knew the researchers had a close connection to RES. The researchers tried to create a trust to the respondents by being neutral during the interviews and by offering the possibility of being anonymous.

3. Setting the context

This section aims to create a deeper understanding of a complex area. Here, green hydrogen is discussed more thoroughly to give the reader an understanding before moving into scientific research. The green hydrogen industry is constantly developing and this section presents market information which is not yet available in scientific articles to give the reader a better understanding of green hydrogen.

Green hydrogen is a type of hydrogen created by the electrolysis of water, where electricity stems from renewable energy (Lazard, 2021b). Cheap renewable energy is a prerequisite for green hydrogen production and the most well-suited sites of production are therefore in areas with an abundance of cheap renewable energy (Lazard, 2021b), such as Sweden. Green hydrogen is on the rise as a prominent solution for decarbonisation, but the hydrogen market is currently dominated by hydrogen created by fossil fuels (Lazard, 2021b). Hydrogen produced by fossil fuels is called grey hydrogen if produced by methane/natural gas (Lazard, 2021b; IEA, 2019; IRENA, 2022), brown or black if created by coal gasification (IEA, 2019), yellow when produced by nuclear energy (Lazard, 2021b) and blue when the hydrogen comes from fossil fuels but carbon emissions are captured and stored (IEA, 2019; IRENA, 2022; Lazard, 2021b). The focus of this thesis is on green hydrogen.

While renewable energy and electrification are driving CO2 reductions at large, electrification is not viable in many heavy polluting industries (Energimyndigheten, 2021; Lazard, 2021b; IEA, 2019). The most notable industries are the steel manufacturing industry, the chemical industry (particularly creating ammonia) and the transportation industry (IEA, 2019; Lazard, 2021; IRENA, 2022). As of now, green hydrogen is not considered to be cost-effective in comparison to conventional fuels for vehicles (Lazard, 2021b). Lazard (2021b) also reports that green hydrogen production is more expensive than conventional methods of hydrogen production. Nonetheless, prices of green hydrogen are expected to drop with the establishment of more renewable energy as well as cheaper and more efficient electrolysis as the technology matures (Lazard, 2021b). According to Bloomberg NEF (2020, through Energimyndigheten, 2021), the cost of Swedish green hydrogen by 2030 might even be low enough to compete with natural gas. Due to large fossil-free energy production and notable renewable energy potential, Sweco (2022a) argues that Sweden possesses the required prerequisites to lead a green hydrogen development.

Although hydrogen offers a wide variety of benefits in terms of decarbonisation, the technology is facing serious barriers. Effectiveness is a big concern as there are losses in the green hydrogen production process; first when electricity is converted to hydrogen and secondly in manufacturing processes or reconversion processes. (Energimyndigheten, 2021). Energy losses from converting electricity to hydrogen explain why electrolyser efficiency is important and reconversion losses in conversion processes from hydrogen back to electricity hint at the difficulties of using hydrogen for transport or energy storage. The development of electrolysers in terms of efficiency and cost will affect the commercial viability of green hydrogen (Energimyndigheten, 2021). Another commercial concern of green hydrogen is the novelty of green hydrogen as a commodity, which brings concerns of lack of infrastructure, non-existent standards, technological immaturity and lack of policies (Energimyndigheten, 2021). A carrot and stick approach can be taken to policies where examples of the former are economic support for investments or risk reductions, and an example of the latter is carbon prices (Lazard, 2021b).

To support the commercialisation of green hydrogen, the EU is looking at creating incentives for greener investments. In a proposal for an amendment of Directive 2018/2001, Regulation 2018/1999 and Directive 98/70/EC of the European Parliament and the Council, the following information can be found (European Union, 2021, pt. 21):

> *"Industrial investment decisions today will determine the future industrial processes and energy options that can be considered by industry, so it is important that those investment decisions are future-proof. Therefore, benchmarks should be put in place to incentivise industry to switch to renewables-based production processes that not only are fueled by renewable energy but also use renewable-based raw materials such as renewable hydrogen"*

Although no regulation or directive is in place yet, indications from the EU show that green hydrogen is expected to decarbonise industries and the EU is willing to take measures to promote a switch to renewable energy and renewable raw materials. In the REPowerEU Plan (European Union, 2022b), the EU Commission has stated that they will take efforts to endorse renewable hydrogen[1] to reduce dependency on Russian fossil fuels. An example of an action is to increase investments in hydrogen valleys. The commission also calls upon the industry to set hydrogen production, infrastructure and end-use standards. In the REPowerEU Plan, the EU Commission has upped previous goals of producing 5,6 million tonnes of renewable hydrogen by 2030, to 10 million tonnes (European Union, 2022b).

Like in most places, decarbonisation is driving the green hydrogen establishment in Sweden. Sweden have many heavily polluting industries that cannot be decarbonised by electrification, making green hydrogen the most prominent solution to reduce carbon footprints (Energimyndigheten, 2021). However, green hydrogen does not only serve as a source of decarbonisation for different manufacturing industries but also provides an option to balance the national energy grid through energy storage solutions (Energimyndigheten, 2021; IEA, 2020). In times of overproduction, the energy that would otherwise have been curtailed can be absorbed through hydrogen production (Lazard, 2021b). This will in turn promote the establishment of more renewable energy as days of high renewable energy production will not disbalance the energy grid. Thus, a virtuous circle is created since renewable energy problems can be reduced by green hydrogen. An argument can be made that green hydrogen benefits from a greater establishment of renewable energy as well: since renewable energy lowers the cost of electricity (Sweco, 2014; Sweco, 2022b), a greater establishment of renewable energy can push down the price of green hydrogen and make it more competitive. Therefore, an

[1] The EU use renewable hydrogen synonymously with green hydrogen https://energy.ec.europa.eu/topics/energy-system-integration/hydrogen_en

expansion of green hydrogen and renewable energy is mutually beneficial. Wind power presents the lowest electricity production costs of all energy types (Fossilfritt Sverige, 2021), which helps explain why its establishment is often mentioned together with green hydrogen.

Compared to other countries, Sweden has its own set of benefits and drawbacks. According to Fossilfritt Sverige (2021), Sweden has vast areas of land that can be exploited for wind power, which improves green hydrogen opportunities. Unfortunately, permit processes are slow and there is uncertainty regarding the future development of both onshore and offshore wind as few permits are given even though applications are large in number. Uncertainties increase after 2025, up to which SVK has performed a short term market analysis (Fossilfritt Sverige, 2021). There is therefore a clear link between wind power and the future of Swedish hydrogen. Another challenge in Sweden brought up in Fossilfritt Sveriges (2021) hydrogen strategy report is the absence of hydrogen infrastructure. While other countries have natural gas pipes that can be converted to hydrogen pipes, Sweden only has a limited amount of pipes that could be converted, and the biggest piping system is planned to be used for biogas.

On a more positive note, the country has a relatively stable grid and electricity market. On top of this, two of the country's electric zones, SE1 and SE2, have very low electricity prices and high energy production (Fossilfritt Sverige, 2021), which gives these regions a comparative advantage over other regions in Europe and the world. Energy-intensive industries in the other two regions, SE3 and SE4, are already struggling to access the required quantities of electricity and are in periods facing significantly higher electricity prices (Fossilfritt Sverige, 2021). For the future of green hydrogen in Sweden, several criteria have to be fulfilled. There has to be a collaboration between utilities, industries, technology providers, end-users and authorities (Fossilfritt Sverige, 2021). In other words, different stakeholders have to come together to discuss how the future of hydrogen should look. Fossilfritt Sverige (2021) also states that permit processing time needs to be improved for hydrogen facilities and wind power. Currently, processes are long for actors wanting to switch from fossil hydrogen to green hydrogen production and the same can be said for wind power permits. Looking at the production facilities, new environmental permits are needed to shift the facility from producing fossil (primarily grey) hydrogen to fossil-free (green) hydrogen production, although a better option would be to allow the industrial actors to apply for an extension on the existing permit for the electrolyser (Fossilfritt Sverige, 2021). This would facilitate a quicker establishment of green hydrogen on the market.

To sum up, the development of green hydrogen can help decarbonise many industries where other options are suboptimal. It can also help balance grids where renewable energy sources are dominant and avoid curtailing as well as energy shortages. However, green hydrogen faces many common problems. The technology itself needs to become cheaper and more efficient, renewable energy needs to become more widespread, common regulations and standards needs to be created and policies that support green hydrogen are required.

4. Literature review

This section will present literature within two different areas that together form the basis for the upcoming analysis. These two areas are; project management and technology diffusion. Project management focuses on project-specific theories, examining project uncertainty and stakeholder theory. Technology diffusion takes a broader perspective, examining the diffusion of technology and commercialisation barriers. Since the main focus of this thesis is on project aspects, project-specific theories are mentioned first and technology diffusion literature is presented after. The areas will be presented individually, while the relationship between the two areas is clarified in a literature review synthesis at the end of this section.

4.1 Project management

4.1.1 Project Uncertainty

4.1.1.1 Definition of project uncertainty

Project uncertainty is a subject that has been researched from different angles. A large field of research is called risk management, where 'risk' can be perceived as either positive or negative since it is divided into two categories, namely "upside risk" and "downside risk" (Ward & Chapman, 2003). Perminova et al. (2008) agree and claim that risk has both positive and negative effects on time, cost, scope or quality of projects. In project management, the word risk has no distinct difference from uncertainty but there are important differences (Ward & Chapman, 2003, p. 98):

> "*Uncertainty management is not just about managing perceived threats, opportunities and their implications. It is about identifying and managing all the many sources of uncertainty which give rise to and shape our perceptions of threats and opportunities.*".

To distinguish uncertainty from risk, Ward & Chapman (2003), have come up with some areas that define uncertainty. First, there is uncertainty related to the scope of the project; the time, cost and quality of each activity. Activities are sub-targets in a project. The authors argue that uncertainties can be a result of lack of specifications, lack of experience in a certain field, complexity due to a large number of influencing factors, limited analysis of processes or of the occurrence of happenings that have an unpredictable effect on the activity. Secondly, there is uncertainty in that different actors can have different views on uncertainty and the costs associated with it. The third source of uncertainty is based on which role each actor will take in the project, which costs they will bear and how different stages of the project will be completed. A lot of uncertainty can be removed by deciding conditions for the project in its early phases. However, not all can be planned for and much of this uncertainty will remain during later stages of the project life cycle. The fourth basis of uncertainty is objectives and priorities, where Ward and Chapman (2003) stress the importance of clarifying objectives and priorities and taking into account different stakeholders' perspectives. Examples of relationship-related uncertainties given by Ward and Chapman (2003) are ambiguity, perception of roles and responsibilities, capabilities of the actors, contracts and control mechanisms. To handle all this uncertainty, Ward and Chapman (2003), promote and refer to a "six Ws" framework created by themselves. The framework means asking the following six questions (Chapman & Ward, 2003, p. 10):

> *1. Who are the parties ultimately involved? (parties); 2. What do the parties want to achieve? (motives); 3. What is it the parties are interested in? (design); 4. How is it to be done? (activities); 5. What resources are required? (resources); 6. When does it have to be done? (timetable)*

The expectation is that answering these questions will help with uncertainty management. While Ward & Chapman (2003) encourage the use of the word 'uncertainty' before 'risk' due to the double-sided nature of the latter, Perminova et al. (2008) argue that also the use of the term 'uncertainty' is problematic due to the lack of a common definition of it. Perminova et al. (2008, p. 78) therefore suggest establishing a common definition of the word 'uncertainty' and argue that the core elements of project uncertainty management are "*reflective learning and sensemaking*" as facilitators of quick and flexible decision-making in uncertain situations.

4.1.1.2 Handling project uncertainty

De Meyer et al. (2002) claim that uncertainty should be dealt with in different ways depending on the type of uncertainty that is faced in the project. All projects face uncertainty to some extent and the type of uncertainty varies between projects. De Meyer et al. (2002) argue that there are distinct kinds of uncertainty that all call for different actions from managers: variation, foreseen uncertainty, unforeseen uncertainty and chaos. Variation comes with the smallest degree of uncertainty and the one that is most easily planned for. One way to adapt to a project with extensive variation is to include time buffers in the project schedule in areas of uncertainty, which means that there will be time dedicated to working on these uncertainties if needed. Getting some flexibility towards stakeholders is beneficial. The second type of variation, foreseen uncertainty, calls for the use of contingency plans for different possible scenarios. Therefore, stakeholders will have to be informed about potential risks for them to be ready to cope with the changes. The third type of uncertainty is called unforeseen uncertainty. Uncertainty of this kind cannot be predicted but finding areas where uncertainties are more likely to arise is possible. Therefore, project managers will have to continuously scan the environment to find indications for potential threats or opportunities which means that dealing with this kind of uncertainty calls for more flexibility. When navigating through unforeseen uncertainty, much time will be spent on stakeholder relationships (De Meyer et al., 2002). This type of uncertainty also shares similarities with scenario planning as it stresses the importance of detecting early signs of change. The fourth type of uncertainty, chaos, means not knowing where you are heading or what risks you are facing. Things will change quickly and managers will have to cut losses and be able to change direction quickly (De Meyer et al., 2002). Adaptability is key. As can be seen, relationships with stakeholders are often affected by uncertainties in projects and different kinds of uncertainty affect the relationships to varying degrees; managing projects of much chaos will be easier if interests are aligned and all parties are equally invested so that flexibility comes naturally when the time comes to accept great changes of plans, while relationships between stakeholders can afford to be less flexible in projects dealing with more variability where time aspects are the primary worry.

De Meyer et al. (2002) argue that different approaches in terms of planning are needed for the various types of uncertainty; variability and foreseen uncertainty are more receptive to planning while dealing with unforeseen uncertainty and chaos requires more flexibility. Nonetheless, projects will face all four types of uncertainty to some extent, although the distribution will vary greatly between projects depending on industry and context (De Meyer et al., 2002). Böhle et al. (2016) have also investigated uncertainty, and have similarly found that planning has limited success when dealing with uncertainty. Böhle et al. (2016, p. 1391) explain how uncertainty in projects usually emerges in two parts of projects: first in planning and secondly during the project itself. The former type shares some similarities with De Meyer et al. (2002) 'variability' where planning for buffers can protect against some uncertainties. The two types of uncertainties are created by both technical and social aspects, and handling these correctly can yield innovations that in turn bring economic value. Uncertainty is therefore not all bad; if it is handled correctly it is an opportunity (Ward & Chapman, 2003; Perminova et al., 2008).

To handle uncertain situations, Böhle et al. (2016) promote 'experience-based action' which means responding routinely to critical uncertain situations. Flexibility is therefore a result of the experience created from dealing with uncertainty, explaining why it is important to support 'experience-based action' efforts. In their article on uncertainty management Perminova et al. (2008) promote the idea of reflective learning, where standardised and modularised processes from previous learnings help make decisions in future projects, or further ahead in the same project. The meaning of this is not to create processes just for the sake of it, but to facilitate quick access to learnings from previous challenges. As time moves on, the company and those within it will have access to accumulated knowledge (Perminova et al., 2008). This facilitates flexibility, as decision-making becomes quicker when members of the project team get a feeling of where efforts must be focused and where there is slack in the project (Perminova et al., 2008). Reflective learning in this aspect means constantly finding and evaluating information related to the project, and transforming the information from uncertainty into risks and opportunities, which each is managed in its own way (Perminova et al., 2008). Thus, both Böhle et al. (2016) and Perminova et al. (2008) emphasise the importance of taking advantage of previous knowledge when dealing with uncertainty in projects.

4.1.2 Stakeholder theory in projects

4.1.2.1 Stakeholder theory

Stakeholder theory explains actors who both can affect and be affected by an organisation and its projects. These can be groups or individuals and they are defined as stakeholders by Freeman (1984; through Thornock 2016). Thus, the word stakeholder involves many actors such as customers, capital suppliers, local residents, government and communities that organisations have relationships with (Clarkson 1995). Managing and thriving these relationships and working together efficiently can enhance value creation, according to Hillman and Keim (2001), who researched the area of stakeholder management and shareholder value. These arguments can be seen as pivotal reasons for carefully managing relationships. Through research from another angle, Phillips et al. (2003) argue, in line with Hillman and Keim (2001), that a central part of stakeholder theory is to manage relationships and interests with stakeholders. Phillips et al. (2003) have focused their research on defining what stakeholder theory is and what it is not. Philipps et al. (2003) stress the importance of managing stakeholders since these can either hinder or assist an organisation in reaching its achievements. This is further strengthened by Ruggiero et al. (2014), who have researched stakeholder involvement from a different point of view, focusing on the renewable energy community project perspective. All the former authors outline similar arguments, however, from different angles of research, which further strengthens the conclusion that stakeholders play a fundamental role in all organisations and projects.

Stakeholders can, however, be overlooked when researching and discussing risk and project management. In line with the former authors, Hartono et al. (2014) argue that stakeholders are a vital part of the context, needing to be included when discussing management. This goes in line with Böhle et al. (2016), who emphasise that having several partners involved in a project increases the overall uncertainty. This makes discussions between different actors crucial for project development (Böhle et al., 2016). Ward and Chapman (2003) agree and stress that many parties are involved in projects, thus relationships are often complex, which can lead to uncertainty and ambiguity. As such, stakeholders need to be addressed and roles clarified. Another dimension of complexity surrounding uncertainty is the project environment, since uncertainties can develop from influences in its surroundings according to Böhle et al. (2016). Factors such as technology, the market, regulations, and standards affect and trigger uncertainties (Böhle et al., 2016).

4.1.2.2 Stakeholder involvement

To strive for a successful transition to renewable energy solutions for sustainable development has many requirements, often involving a high level of uncertainty. Thus, it is important to specify the actors involved and clarify which stakeholders that carry the costs and gain the benefits (Ruggiero et al., 2014; Aitken, 2010). Stakeholders are a part of the context and need to be managed (Enevoldsen & Permien, 2018; Hartono et al., 2014; Böhle et al., 2016). Odabashian et al. (2019) take it even further, arguing that projects within renewable energy often need a sound collaboration among stakeholders to just get started. Additionally, Aitken (2010) argues that the relationship between local communities and larger commercial companies is a challenge for renewable energy solutions, but also a prerequisite for successful projects and positive relationships with high levels of trust. A relationship often seen as challenging is the one with local stakeholders, where social opposition may occur (Enevoldsen & Permien, 2018). This is even more common in wind power, which struggles with social acceptance (Khan, 2003; Cass & Walker, 2009; Aitken, 2010), naturally affecting the possibility of project completion negatively. As such, Khan (2003) emphasises that citizen participation is crucial to avoid a negative attitude. Ruggiero et al. (2014) further develop the reasoning and highlight the importance of involving local stakeholders in community renewable energy projects, in the decision-making processes, but also in capturing the benefits. Odabashian et al. (2019) agree, stressing that it is critical to involve stakeholders, which are affected by an implemented project directly or indirectly. Stakeholders can either hinder or help to reach goals (Philipps et al., 2003) which has been confirmed in renewable energy projects where the involvement of stakeholders can have a positive impact in a supportive role, or a negative impact in a hindering role (Ruggiero et al., 2014). Ruggiero et al. (2014) argue that this is corresponding to if stakeholders feel they will benefit from the outcome of the project, or be harmed. Consequently, involving stakeholders and improving the chances for them to be supportive is necessary to reach project completion.

Ruggiero et al. (2014) argue that renewable energy initiatives on a community level are influenced by stakeholders, while the opposite is also true meaning that projects influence stakeholders. According to Ruggiero et al. (2014), this happens on three different levels: the first one is at the macro level, involving stakeholders like the government, commercial companies or other actors as energy suppliers and network operators as the influential stakeholders; the second is the intercommunity level, where the influential stakeholders are intermediaries or communities located nearby; and the third is the local community, which comprises local businesses and individuals living close to a plant/installation who together with local project champions are the most important stakeholders. Odabashian et al. (2019) describe a similar list of stakeholders that influence the outcome of renewable energy projects: national, state and local governments, the local community, owners and suppliers of technology, financiers, project owners and contractors. However, Odabashian et al. (2019) do not explicitly outline the different levels of influence but emphasise the drivers of each stakeholder and the importance of balancing the interests between the different groups.

Stakeholder involvement at macro-level

When looking more closely at the macro level, governments can take a supportive or a hindering role (Ruggiero et al., 2014) . According to Ruggiero et al. (2014), the role is defined by the availability of funding, hence being supportive when this works conveniently, and hindering if easy access is lacking. The authors also argue that non-existent policies is another area that makes governments being viewed as hindering**.** Odabashian et al. (2019), on the other hand, argue that the national government is not directly involved in local projects but it can be seen as somewhat supportive of legislation and incentives to increase the likelihood of private actors' investments and project completion.

Ruggiero et al. (2014) describe energy suppliers as indirectly supportive stakeholders because they are generating electricity. They further argue that larger companies can somewhat be affected negatively through community projects since this can increase competition and result in lower market shares. Another stakeholder, network operators can also be a supportive or a hindering stakeholder, because of that infrastructure and grid sometimes is lacking in rural areas but also sometimes slows down projects when connecting to the grid (Ruggiero et al., 2014).

Commercial developers, focusing on building a plant and further operating it, can also take a supportive or hindering role depending on the collaboration with the local community, or if they just are competing for great sites. This can be overcome by joint ventures to benefit the commercial developer and the local community (Ruggiero et al., 2014). Odabashian et al. (2019) discuss these with a somewhat different approach. They rather argue that project owners and contractors are driven by the motives to generate revenues and gain skills and knowledge, sometimes being the financier of the project. Project owners and contractors can still be seen as supportive of starting the project and often being the financier (Odabashian et al., 2019).

Technology owners/suppliers are motivated by making the technology for renewable energy cost-competitive with conventional energy (Odabashian et al., 2019). This is important for the deployment of technology and will lead to more projects becoming successful.

Stakeholder involvement at intercommunity level

The intercommunity level of influence contains a smaller number of stakeholders, namely communities located nearby and organisations that are intermediaries (Ruggiero et al., 2014). To clarify, the authors argue that communities that have implemented similar projects and can share knowledge are being portrayed as supportive stakeholders. Successful projects are role models and prove that projects are viable and knowledge can be shared within regional networks (Ruggiero et al., 2014). Odabashian et al. (2019) further strengthen this by implying that successful partnerships between different stakeholders creates a positive effect by the possibility to contribute with knowledge in future projects.

Intermediary organisations can be social enterprises or connected to the public sector according to Ruggiero et al. (2014). They argue that these mainly provide guidance and are thus supportive stakeholders, seen as playing a major role for communities that lack the experience of realising a project (Ruggiero et al., 2014).

Stakeholder involvement at intracommunity level

The final level discussed by Ruggiero et al. (2014), the intracommunity, involves the specific local community. According to the authors, the community can contribute with a positive attitude to ease the project process, the resources needed as land, and further community ownership. This is described as a supportive stakeholder which gives fewer planning issues on the way to carrying out a project (Ruggiero et al., 2014). This goes in line with Odabashian et al. (2019), describing the state and local government as more involved in local projects than the national government. They argue that the local government supports these projects, with the driver that an implemented project can lead to increased work opportunities and economic growth. Thus, providing a positive impact on the local community with the creation of jobs and a higher economic standard for the households. However, Ruggiero et al. (2014) argue that the local community sometimes can be a hindering stakeholder by doubting the benefits of the project. Interests can be conflicting and local residents can oppose the projects (Ruggiero et al., 2014). Odabashian et al. (2019) and Enevoldsen and Permien (2018) further strengthen this by implying that individuals sometimes oppose projects because they want to keep the landscape as it is. People that are living somewhere near a project are often seen as hindering stakeholders, being additionally reluctant to wind power projects (Ruggiero et al., 2014). These are affected by occurring noise and further that the surrounding landscape is worsened. However, local communities are often beneficiaries as jobs and income can be generated through projects which increase economic development and yield support from individuals (Ruggiero et al., 2014; Odabashian et al., 2019).

Local businesses can be supportive or hindering (Ruggiero et al., 2014). This is because new projects can be seen as increased competition, but they can likewise create new opportunities. If the latter is the case, these local businesses benefit from the projects, by the generation of new income (Ruggiero et al., 2014). Finally, the last stakeholder group within the intracommunity level presented by Ruggiero et al. (2014) is the local project champions who contribute with intangible resources such as specific skills, competencies and knowledge throughout the whole process of a project. These people are described as supportive stakeholders according to Ruggiero et al. (2014). However, when these people are non-existent, the project might face problems due to lack of competencies (Ruggiero et al., 2014). Ruggiero et al. (2014) emphasise that the latter is more often the case in small communities, hindering these projects from being successfully implemented.

Summary

To sum up, the different stakeholders that Ruggiero et al. (2014) discuss can have either a supportive or a hindering role which is in line with Phillips et al. (2003). Sometimes stakeholders can even take both roles, which can create conflicts of interest (Ruggiero et al., 2014). Stakeholders play a vital role in carrying out a successful project and are strongly influencing the result (Ruggiero et al., 2014; Odabashian et al., 2019). Odabashian et al. (2019) further stress that some projects might not make it through the planning step because of resistance from stakeholders, often local organisations or individuals in a community. Thus, they argue that relationships between stakeholders are important together with goals that are aligned among these. Ruggiero et al. (2014) emphasise that the results of renewable energy projects within the community can further influence the stakeholders, consequently changing their attitude and turning them from a hindering to a supportive stakeholder which could contribute to future projects nearby. This goes in line with Odabashian et al. (2019) who state that completed projects can have an influence on other projects as stakeholders' relationships and capabilities can complete projects in other locations. Further, they argue that the collaboration and contribution among stakeholders decides the outcome of the project. Thus, stakeholders play a pivotal role and have a big impact on the turnout of projects (Ruggiero et al., 2014; Odabashian et al., 2019), strongly indicating the significance of relationships and collaboration among stakeholders.

4.1.2.3 Project success

Odabashian et al. (2019) emphasise that defining project success is as much of a challenge as achieving project success. The authors argue that project success can be specific depending on the context. De Wit (1988) agrees by highlighting that measuring success is complex as it is affected by time and stakeholders. One stakeholder might perceive the project as a success while the other perceives it as a failure (De Wit, 1988). This illustrates the complexity of stakeholder involvement. To address such issues, Pinto and Slevin (1987) have highlighted factors critical to project implementation; clear and aligned goals of a project, support from top management, a detailed plan for every stage, client consultation, selection and training of personnel, mastering technical tasks, client acceptance, monitoring feedback during the whole process, communication, and troubleshooting. Troubleshooting means exploring problems along the way (Pinto & Slevin, 1987). Pinto and Slevin (1987) further argue that the critical factors can be considered separately but naturally influence each other. This means that interdependent factors affect the outcome of projects. These factors aim to reach a successful project and are vital for achievement, where communication has been classified as a necessity

(Pinto & Slevin, 1987). This indicates how important communication and alignment among stakeholders are for project success. This goes hand in hand with clear goals and clarified responsibilities, which also is described as vital factors for project success according to Pinto and Slevin (1987). As De Wit (1988) and Odabashian et al. (2019) argue, project success can be hard to define since it is bound to and varies depending on the context. This implies that the definition of process success will vary for diverse projects. Odabashian et al. (2019) argue that renewable energy projects need sound relationships between stakeholders for a project to even start, indicating that relationships play a great role in achieving project success. However, there is not a fixed definition of project success. For newly invented technologies and facilities, following through with the implementation and completing the project might be the definition of success.

4.2 Technology diffusion

4.2.1 Diffusion of technology and commercialisation barriers

Diffusion of technology happens when technology moves from novel to mature, thus moving from a low to high market penetration. With renewable energy, classic diffusion theories might not be the best option for explaining the adoption that takes place for new technologies. The large impact of policies on renewable energy diffusion, as well as high investment costs creates a different situation for renewable energy technologies compared to consumer products, which are more commonly analysed in diffusion theory (Rao & Kishore, 2010). Alongside technological advancements and the cost reductions that follow, policies affect market penetration. A classic technology "learning curve" will thus be hard to follow (Rao & Kishore, 2010). Policies facilitate renewable energy technology establishment by removing barriers. The incentives for renewable energy policies are the underlying sustainability benefits that they bring.

Today, renewable energy is an important part of the energy mix in several countries, but in the 80s, the commercialisation rate for wind and solar power was low. The renewable energy commercialisation rate increased in the 90s, but by the start of the millennium, the increase was still not recognised by the energy industry to any large extent (Jacobsson & Johnson, 2000). Jacobsson & Johnson (2000) argue that the transformation processes in the energy system are explained by three components: (1) Actors and their competence (technical and other), especially so-called prime movers who are big actors leading change; (2) networks of different organisations and parties; and (3) institutions who are either hard (legislation, capital market or educational system) or soft (culture). Jacobsson and Johnson (2000) address areas of the transformation process where more research is needed: (1) creation of variety in the knowledge base, for instance, uneven distribution in R&D with more government investments in nuclear than in wind power; (2) the process of institutional change, for example, the lack of institutional change in terms of vetoes which makes wind power permits hard to get while easy to hand in complaints about; and (3) the formation of "prime movers". Prime movers are important technology promoters that conduct four key tasks: "raise awareness, undertake investment, provide legitimacy and diffuse the new technology" (Jacobsson & Johnson, 2000, p. 636).

While Jacobsson and Johnson (2000) focused on actors, networks and institutions, Reddy and Painuly (2004) gathered information on the diffusion barriers by interviewing different stakeholders in renewable energy projects to find the greatest hindrances to market penetration. Reddy and Painuly (2006) found government intervention to be an important tool for removing barriers to renewable energy diffusion. Similarly, Jacobsson & Lauber (2006) has looked at concrete examples of the diffusion of renewable energy. In Germany, the diffusion of renewable energy had to conquer substantial barriers to be established as a legitimate energy source (Jacobsson & Lauber, 2006). The authors argue that the largest challenge for both solar and wind power diffusion was winning political support for subsidies. Once renewable energy support was in place, the German renewable energy technology development was rapid; first in wind and later in solar (Jacobsson & Lauber, 2006). This highlights the important role policies play in renewable energy establishment and confirms Reddy and Painuly's (2004) study. Juszczyk, Juszczyk, Juszczyk & Takala (2022) have investigated recent renewable energy technology barriers, and have found that the same diffusion barriers occur in countries with very different contexts. The authors focus on regulatory and socio-economic factors and have found non-optimal regulatory frameworks, shortage of financing options and poor social awareness as major barriers to the diffusion of renewable energy technologies. Other problems are externalities that are not accounted for when comparing renewable energy technologies with conventional, more polluting, technologies (Owen, 2004; Juszczyk et al., 2022; Seetharaman, Moorthy, Krishna, Nitin Patwa, and Yash Gupta, 2019).

Painuly (2001) stresses the importance of finding barriers to renewable energy penetration. He argues that barriers vary between regions and countries, making assessments of great importance for finding major barriers. Painuly (2001) recommends looking into three areas to find barriers to renewable energy technology penetration: literature survey, site visits and interaction with stakeholders. Barriers can be divided into different levels, where the next level builds on the former (Painuly, 2001). For instance, finance is a major area containing many challenges and is labelled a first level barrier, high cost of capital and lack of access to capital are second-level barriers as they impact the first level, and high interest rates are a third level barrier as they affect the second level (in cost of capital). Dividing the barriers into levels makes it easier to follow differences. Common barriers brought up by Painuly (2001) are lack of social acceptance (also referred to as social or local opposition), system constraints, lack of standards, codes and certifications, lack of R&D culture or R&D government support, lack of stakeholder involvement in decision-making, uncertain government policies, environment and lack of infrastructure.

Painuly (2001) argues that stakeholders have to find renewable energy barriers and take actions to overcome them. Such actions can remove government policies on the cost of capital. "The role includes generic actions to remove barriers, building human and institutional capacity, setting up research and development infrastructure, creating an enabling environment for investment, and providing information and mechanisms to promote RETs" (Painuly, 2001, p. 84). Barriers can be removed by policies either by forcing actors to breach barriers or by removing them directly (Painuly, 2001). The EU carbon emission trading system (EU, 2022a), is a current example of when incentives to force barriers to be breached are created rather than having them removed. The carbon trading system means that companies will have to pay more for emissions. Over time, the alternative to keep polluting is likely to be more costly than switching to greener technologies.

Seetharaman et al. (2019) have looked into diffusion barriers and chose four main areas based on previous research: social, economic, technological and regulatory barriers. Their study proved that only social, technological and regulatory barriers have a significant effect on the diffusion of renewable energy technology. These three factors not only significantly affect renewable energy deployment but also influence economic barriers. According to Seetharaman et al. (2019), each type of barrier is affected by several sub-categories, which can be compared to the levels of barriers mentioned by Painuly (2001). The subcategories presented by Seetharaman et al. (2019) broadly confirm what previous research has established: barriers to the diffusion of renewable energy are public awareness, not in my back yard-syndrome (NIMBY), loss of income and lack of experienced professionals as social barriers; lack of infrastructure, lack of standards, lack of R&D capabilities and technology complexities as technological barriers; and lack of national policies, inadequate fiscal incentives, administrative hurdles, impractical government commitments and lack of standards/certifications as regulatory barriers. The authors also present four examples of barrier breakers: user-friendly procedures, stakeholders satisfaction, successful R&D ventures and cost savings.

To sum up, the literature on renewable energy diffusion agrees on common diffusion barriers such as energy policies, lack of regulations, lack of infrastructure, insufficient R&D, immature technology, high investment costs, high cost of capital, grid concerns, insufficient knowledge, and externality disadvantages. This shows that the scientific field of renewable energy technology diffusion is aligned and has agreed on similar barriers. There is very little contradiction. One rare example of a contradiction is that financial barriers have been toned down from being seen as one of the major barriers to diffusion in the early 2000s (Painuly, 2001) to being seen as only indirectly affecting renewable energy penetration (Seetharaman et al., 2019) in recent time. A possible explanation for the difference is that renewable energy investments are now relatively cheap compared with other energy types (Lazard, 2021a), and that renewable energy investments are more attractive to investors today than they were at the turn of the millennium.

4.2.2 Challenges from the perspective of Sweden

In Sweden, there has long been a focus on sustainable solutions. The government stated already in 1990 that Sweden should be leading the transition to a more sustainable society, with an increasing use of renewable energy solutions (Hansson & Nerhagen, 2019). The importance of a global transition to sustainable development is increasing and the Swedish government has set a target whereby electricity consumption in Sweden will come from sources of renewable energy by 2040 (Zhong, Bollen & Rönnberg, 2021). Most renewable electricity in Sweden comes from hydropower, but the capacity of wind power has increased and is contributing to a larger extent by each year (Statistiska Centralbyrån, 2021). Zhong et al. (2021) argue that it is possible to reach the target of 100% electricity that comes from renewable energy sources by 2040, in line with government targets. To achieve the goal set, the authors stress that the wind power capacity of today needs to be tripled. This could be accomplished within 20 years (Zhong et al., 2021). Elavarasan et al. (2020) emphasise that Sweden has been successful in implementing renewable energy solutions, which is in line with the Swedish government's goal. Energy policies have been a noteworthy contribution according to Elavarasan et al. (2020). However, renewable solutions are facing political, social and industrial barriers, which have to be overcome before goals are reached in Sweden (Elavarasan et al., 2020). Achieving social acceptance is vital to establishing new renewable energy technologies in Sweden (Elavarasan et al., 2020). Elavarasan et al. (2020) argue that the required alignment with both policymakers' and investors' need is an industrial barrier. They explain that incorporating the objectives from both stakeholders can be a challenge due to different requirements.

One of the essential technologies in the transformation to renewable energy sources is wind power, and Sweden has been increasing its wind capacity more intensively than other countries on a global scale (Enevoldsen & Permien, 2018). Wind power deployment does not happen without resistance, however, and Khan (2003) stresses that wind power projects are facing challenges of social acceptance. He argues that in Sweden, the local municipalities become key actors since they have a mandate for decisions. This is further strengthened by Fridolfsson and Tangerås (2013) who argue that vetoes and not having to motivate the decisions are one of the primary barriers in Sweden, which is not the case in all countries. For reasons like this, it is important to look into the national and local environment of the country that a project takes place in to find the biggest barriers as challenges differ between countries (Painuly, 2001; Seetharaman et al., 2019). Linked to local challenges, Khan (2003) emphasises that the political attitude and the local populations' attitude towards developing wind power projects can vary. Enevoldsen and Permien (2018) argue that projects can be turned down because of a negative attitude towards wind power among the population, a so-called social opposition, which is usually based on the expected impact wind turbines have on the landscape. Enevoldsen and Permien (2018) emphasise that this is especially true within the northern parts of Sweden, where the landscape is more untouched. Both Khan (2003) and Enevoldsen and Permien (2018) stress the vitality of including citizens in the wind power projects, which can lead to a more positive attitude towards the energy type and a social acceptance.

4.2.3 Challenges of green hydrogen

Turner (2004) argues that an obstacle to sustainable hydrogen production is the large amount of energy that is needed to produce it, making inefficient electrolysers have a substantial impact on the costs of hydrogen. Seh et al. (2017) confirm that the biggest obstacle to hydrogen created by electrocatalysis is its low efficiency and argue that electrocatalyst effectiveness needs to be higher for clean energy technologies to be able to penetrate the market. However, the high costs of hydrogen from water electrolysis have the potential to be offset by the low production costs of wind power (Turner, 2004), which creates incentives for pairing up green hydrogen with wind power.

Vogl et al. (2021) have looked at policy concerns from the viewpoint of green steel in Sweden and have found that there is a lack of inducements for producing green steel today. Green hydrogen production is part of the process of decarbonising steel and the current EU emission trading system does not yet give enough support for energy-intensive industries to make a transition to clean solutions. Not enough support means that the decarbonised industries are still not cost-competitive, neither in Europe nor globally, which makes investments difficult (Vogl et al., 2021). This ultimately affects the attractiveness of green hydrogen, as no companies will turn to green solutions if they end up at a cost disadvantage towards competitors, at least if this disadvantage is forecasted long-term. Policies have helped the establishment of renewable energy through tools like feed-in tariffs, contracts for differences and renewable portfolio standards, but for the production of basic materials, different kinds of policy instruments are required (Vogl et al., 2021).

Contrary to most green hydrogen literature, there is research indicating that green hydrogen could be competitive in Europe already today. Jovan and Dolac (2020) argue that such is the case for green hydrogen as an alternative fuel. The prerequisite for fuel competitiveness is that green hydrogen does not apply to environmental taxes, at least not until the technology is well established. The authors argue that green hydrogen can be profitable today also in terms of secondary control services, which means that a hydrogen storage provider will benefit from reconverting hydrogen back to electricity and sending it to the electrical grid on days of energy shortage. The benefits also apply to days of energy overproduction when green hydrogen producers can take advantage of low (or even negative) electricity prices (Jovan & Dolac, 2020).

4.3 Literature review synthesis

Project management literature, project uncertainty and stakeholder theory, explains problems that have to be managed in a project from uncertainty and stakeholder perspectives. The two theories overlap: stakeholder relationships affect project uncertainty and uncertainties in the project affect relationships with stakeholders. Examples of overlap can be seen in project uncertainty literature where close collaboration with stakeholders is recommended to cope with unplannable uncertainty (De Meyer et al., 2002), and in stakeholder theory where having several stakeholders involved in a project is said to increase complexity and create uncertainty (Böhle et al., 2016). Therefore, looking at both project uncertainty and stakeholder involvement literature will give a better understanding of how stakeholders navigate uncertainties in the project. Although project uncertainty is the main area of research, stakeholder involvement affects project uncertainty, which explains the inclusion of the two research areas in the *"project management"* heading. Looking at project management literature gives a chance to understand how key stakeholders navigate project uncertainty. Thus, project management addresses the first research question and its sub-question.

There is not only overlap between the two research areas included in project management, but also between project management and technology diffusion. Green hydrogen will be part of the energy system, which explains why the literature on the diffusion of other renewable energy technologies is relevant for green hydrogen diffusion. In renewable energy technology diffusion literature, common themes of challenges to renewable energy technology establishment can be found, such as local opposition (Enevoldsen & Permien, 2018; Khan 2003; Seetharaman et al., 2019; Painuly, 2003), lack of standards (Painuly, 2001; Seetharaman et al., 2019), high investment costs[2] (Rao & Kishore, 2010; Painuly, 2001; Seetharaman et al., 2019) and lack of infrastructure (Painuly, 2001; Seetharaman et al., 2019). All barriers add uncertainty and researchers have emphasised the importance of government actions for renewable technology diffusion (Jacobsson & Johnson, 2000; Reddy & Painuly 2004). Therefore, previous renewable energy technology diffusion literature presents several barriers which are relevant for explaining uncertainties in the project. At the same time, green hydrogen project aspects can help confirm or reject previous research on renewable energy technology diffusion. Additionally, Jacobsson & Johnson (2000) argue that the transformation processes in the energy system are explained by actors and their competence, and networks of different organisations and parties. In line with these arguments, one can reason that looking at a specific green technology project and the involved stakeholders can help to create an understanding of the diffusion of technology. The second research question will thus be answered by looking at technology aspects, but as can be seen, there is an interconnection between technology and project aspects in terms of green hydrogen.

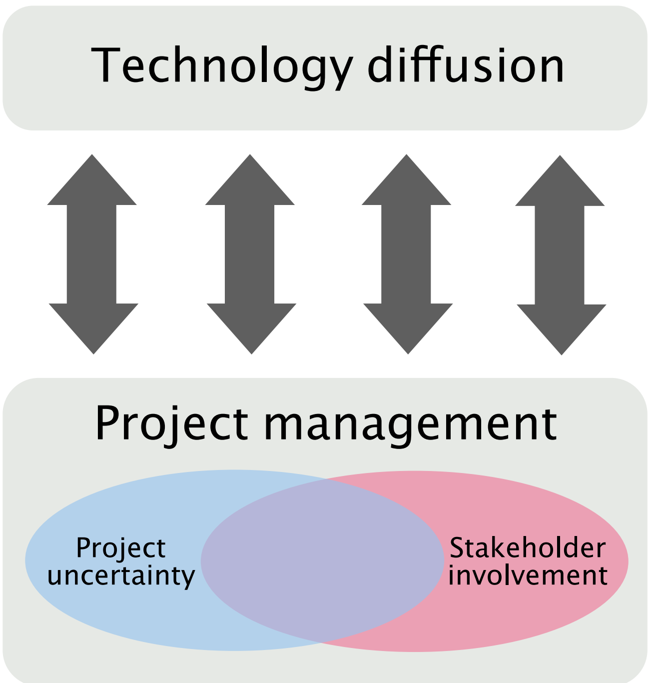

Figure 2 – The relationship between research areas.

[2] Although high, capital costs of onshore wind power and utility-scale solar PV are considerably lower than those of coal and nuclear energy (Lazard, 2021a).

5. Empirical findings

This section presents data gathered from interviews conducted for this thesis. At first, the general roles and the stakeholders involved are described. Then, data collected from the two key stakeholders, RES and Ånge municipality, is presented along with data from technical experts involved in the project. In these parts, the major concepts and themes of the respondents can be seen. First, project management is discussed. Secondly, technology diffusion is described. Lastly, the main findings are summarised.

5.1 General roles

Three groups of actors were interviewed, namely Ånge municipality, RES Nordics and technical experts. Together they work on the green hydrogen facility project in Alby where they have different roles. In this project, however, RES has the role of a developer of the green hydrogen facility. Technical experts provide technical support and assess the costs and impacts of the different alternatives, and are therefore tied to RES and the development of the hydrogen production facility. They have a big impact on project technology. The respondents from Ånge municipality are not local politicians, but officials from the municipality responsible for developing the industrial site and working on a detailed development plan for the area.

Other stakeholders are the local politicians, the local community, regional electricity distribution system operators (regional DSO) and industrial offtakers. The latter are companies that buy what the hydrogen facility produces (hydrogen, oxygen or excess heat). Thereby, many different stakeholders are involved in the project and affect its outcome, which increases complexity.

5.2 RES

5.2.1 Project management

5.2.1.1 Project uncertainty: challenges

Non-existent green hydrogen market

Hydrogen price and the costs to produce are great uncertainties for the project in Alby according to the respondents. The concerns originate from the uncertainties associated with a non-existent green hydrogen market, which respondents argue makes a common price difficult to set. Production costs create the first challenge, as it will be impossible to sell green hydrogen from Alby if production costs are too high, whether there is a commodity market in place or not. Respondent C at RES states that this might potentially be the greatest challenge: *"It is all about how costly it is to make it [hydrogen], to produce it. It might be the biggest uncertainty"*. According to respondents, the absence of known costs adds to the complexity of the project as it makes it hard to sign offtake agreements with industrial partners that are interested in establishing industries on the site.

Local opposition

Local opposition creates additional uncertainties for the project in Alby according to the respondents at RES. Although the local opposition is directed at wind power and not hydrogen, RES respondents argue that the opposition to wind power has potential consequences for the green hydrogen project due to the energy supply needed for the project and the industrial actors that will establish in the area. Respondent C at RES stresses the importance to distinguish hydrogen from wind power, and clarifies that renewable energy is a prerequisite for hydrogen production:

> *"If you are to manufacture hydrogen you will need the energy. I mean, you cannot replace wind power with hydrogen. You need wind power to make hydrogen, or another type of energy. So those [wind power and hydrogen] are not the same thing according to me. The connection is very important to understand, that they are different things."*

According to respondents at RES this connection is not always apparent, which creates a constant threat from local opposition to wind, in turn raising the uncertainty for the green hydrogen project. The respondents do not consider the opponents to be a majority in the municipality, but rather believe that the opposition comes from a small number of individuals with a disproportionately large impact, which might be attributed to the municipality's size. Respondent A explains that a small population means that most individuals have relations with each other, which makes it easier to get support for opposing opinions.

Political uncertainty

Respondents from RES argue that political uncertainty takes place in the local opposition towards wind power. They stress that as politicians find it hard to grant permits for wind power projects, the second part of the project runs a great risk of being delayed unless additional energy is added to the grid. This would bring financial and competitive consequences for RES. The respondents explain that the first part of the project is expected to be finished by year-end 2024/2025 and the last part two years later 2026/2027.

Regional DSO time consuming processes

Hesitance, time consuming processes and an unwillingness of regional DSOs to take risk creates additional project uncertainty. In the Alby project, there are two regional electricity distribution system operators, referred to as regional DSO one and regional DSO two. Respondents state that regional DSO one affects the first phase of the project where 20 MW of current energy production is needed and regional DSO two impacts the second phase where new energy is needed for electrolysers of 100MW. Respondent A state that DSO one is hesitant and respondent B state that DSO two is more accommodating. Since DSOs have an impact on the time-line of the project, RES is willing to take an additional risk for phase two by investing in processes related to the DSOs concession according to respondent B.

Permits

Respondents from RES address the uncertainties associated with permits, which are directly related to time aspects of the project. Respondent C argues that there are many complex permitting processes that have to be in place and the uncertainties that surround them: *"[...] all* *these permitting processes and those uncertainties, what is the actual impact in terms of time, what kind of worries will we bump into?*". Although respondents believe that at least the basic permitting processes in the Alby project will be sorted, they claim that there will always be uncertainty associated with permits.

New business area

An additional subject brought up by respondents is whether an ability to lean back on previous experience exists or not. Green hydrogen is so new that no one (not even the experts) have worked on tangible green hydrogen projects before, which naturally comes with a set of challenges. Respondent C on RES highlights difficulties associated with the lack of an existing market:

> *"[...] it is naturally not as easy to do as in a form of business we already know. Then we have all agreements, we have all structures to lean against. We don't have that in this case."*

However, another respondent at RES argues that RES do have some structures to fall back on although green hydrogen projects are novel. The reason is that green hydrogen requires similar permitting processes, contact with the same authorities and a similar approach to investor value creation as wind power projects. Respondent B explains how RES takes an active approach to push projects forward in both types of projects:

> *"You can say that we are enablers. We currently push the municipality, we push plan processes and everything, we are used to carrying out development projects. In that context this is the same as any other project that we are driving, it is about project management and finding and creating opportunities. [...] It is [about] contact with authorities, keeping track of rules and regulations and all those parts. Understanding and providing value for investors."*

This shows that there are aspects where RES can take advantage of previous knowledge, but that it does not apply to all areas in the project due to the novelty of green hydrogen, which is what respondent C was referring to. Respondent C argues that there are similarities between wind power and green hydrogen projects, but that the hardest tasks are known in the former but not in the latter:

> *"[...] in a wind power project [...] it's more clear exactly what things we need to drill through. In a project like this [green hydrogen] we might have to look more to find where we should drill [...] so it is an extra layer of uncertainty".*

5.2.1.2 Project uncertainty: challenge reducers

Previous experience

The new business area of green hydrogen presents a challenge but also an opportunity for RES to develop knowledge within a new area while still having some advantages from the previous experience from wind projects. As RES has the experience to lean back on when it comes to handling development projects, they can push the Alby project forward even when facing unexpected challenges. This increases RES' ability to manage and reduce uncertainties.

Risk takers

To enable the project to move forward, RES takes risks that they are not obligated to take, such as the financial risk of grid connection. Respondent B points out that the decision to develop a 100MW hydrogen facility is an example of risk-taking which is appreciated by investors. The respondent also point out that RES takes additional financial risk to speed up concession processes of DSO two to ensure access to the electricity grid for later stages of the project. Respondent C argues that project development is about managing uncertainty and that you have to be willing to take risks to move forward: "*if you are afraid to do wrong you will not get anywhere*".

Local connection of wind power

The respondents express how the local abundance of renewable energy and wind power in particular is a prerequisite for the project. They further describe how the locally established substation Tovåsen has the potential to provide up to 1500MW of energy, which allows energy-intensive industries as well as the green hydrogen facility itself to be established in the area. However, respondents explain how only 750MW is built and most of that energy is reserved for other uses. Therefore, new capacity must be installed for the remaining 750MW to support the green hydrogen production plant and surrounding industries. Although renewable energy is abundant in the region, respondents stress that green hydrogen will most likely have to be produced by renewable energy that has been added to the grid during the last 24 months to be classified as green. This enhances the need for further wind power establishment (or other renewables) in the region. Respondents have not mentioned that any other renewable energy source than wind power is to be connected to the Tovåsen substation and respondent C emphasises that wind power is the best option at the latitude of the region. Respondent C also highlights the fact that the renewable energy that will be consumed by green hydrogen production in Alby doesn't necessarily have to be produced next to the site, but that it has a symbolic value. Respondent A suggests that there are implications from the EU that the electricity will have to be produced in the same electricity area as the hydrogen production to be labelled as green. This means that the electricity for the Alby project might have to come from SE2, which further enhances the argument for local energy production.

Respondents at RES see the opportunity to clarify the relationship between wind power and local benefits through the green hydrogen project: *"For us, I see the great opportunity of really clarifying the connection of wind power and local production"*. The greatest benefit of a local connection from RES point of view is that it offers an opportunity to strengthen the link between local energy production and consumption. Since this brings industrial opportunities it could reduce political uncertainty. Respondents express that the project has the potential to become a green hub where several industries are included and can create job opportunities in the municipality and increase the attractiveness of the region. The clarification between wind power and green hydrogen shows the strategic importance of green hydrogen as it offers an opportunity to get new experience in a new line of business while still promoting RES core business activities such as wind power project development and energy storage solutions.

Aligned long-term goals

From a cooperation perspective, the project has the benefit of having aligned long-term goals between key stakeholders, which helps in dealing with uncertainty. Respondents explain that RES and the municipality have a similar long-term vision of the project, where a green hub and in turn job opportunities will be created. This means that the offtaker preferences of the project are aligned as well; respondent B on RES highlights the need for ethical offtakers; *"[...] we have ethical guidelines on who we accept or reject."*. Long-term goals on their own are not sufficient for working on uncertain projects. Respondent C at RES describes how the long-term goals call for flexibility:

> *"Then the goal in itself can be to develop, which role we play and will play in a project like this. It is not necessarily engraved in stone from the start, but is developed [...] then you have to adjust your plans and path based on the goal you're working towards."*

This makes the project constantly move in the right direction, towards the final goal of an operating green hydrogen facility with industrial offtakers of the hydrogen and its by-products, even though the path to the end goal is constantly changing.

5.2.1.3 Stakeholder involvement

Hindrances

The green hydrogen facility project involves several stakeholders which makes the project even more complex. Various stakeholders need to be on board when the project is progressing towards finalisation according to the respondents. Some could hinder the project and cause delays. Respondents at RES explain that time consuming processes from the regional electricity distribution system operators is a hindering aspect from an important stakeholder; first, internal processes are slow and secondly, concession processes are slow. Respondents also highlight that politicians play an important role that could either hinder or support the project. Respondent A argues that politicians get nervous when the debate for wind power gets intense. Respondent B further emphasises that politicians' hesitance has become especially noticeable since it is time for elections this year. Opposition to wind power is thus a problem, as politicians are affected by local opposition. Considering the crucial role wind power plays for the potential hydrogen production in Alby, the project will run late if no more energy supply is added to the region. Luckily, the attitude towards green hydrogen is different than it is toward wind power and respondents underline that the local opinion is positive. Respondents are hoping this will affect the opinion on wind positively and reduce political uncertainty.

Enablers

Since the start of the green hydrogen project and the opportunities that follow, the collaboration with Ånge municipality has been good and respondents at RES say that it is characterised by transparency, aligned long-term goals and clearly defined roles. According to respondents A and B, RES also provides extra support in areas where they can act faster and have more experience.

Overall, RES is experiencing a good collaboration with different stakeholders where transparency is the central word which is crucial for carrying out the project. Respondent C at RES frames it in the following way: *"We are open, transparent towards each other. We are very much working towards the same goal, or similar goals"*. However, the process can be slow when it comes to certain stakeholders according to respondents. Regional DSOs have time consuming processes. According to respondents, DSO one is more hesitant than DSO two. Regarding RES' relationship with offtakers, there are communication challenges related to the novelty of the hydrogen market, where both parties struggle to express their needs. Respondent C at RES highlights the difficulties that come with not being able to communicate clearly:

> *"[In] areas where we cannot be clear, the stakeholders that relate to that information and those areas, of course they cannot be precise with their needs towards us then. You cannot say that our communication is poor; our communication is good but we might not progress as fast [as we wish] since we have not come as far in these areas".*

5.2.2 Technology diffusion

5.2.2.1 Challenges

In the interviews, challenges and opportunities for the overall diffusion of green hydrogen have appeared. One of the biggest concerns expressed by respondents is that additional renewable energy production needs to be added to the electricity grid for hydrogen to be labelled as green. Respondent A emphasises the importance of adding energy: *"If we are going to start the green production of hydrogen, we cannot use the existing energy system. We have to add new energy".* Respondents point out SE2, where the Alby project is located, as an area of significant importance for the establishment of energy-intensive industry and therefore also for the establishment of green hydrogen. Respondents thus express the importance of greater wind power and renewable energy establishment for the diffusion of green hydrogen technology. This presents the challenge of local opposition since wind power is intensively debated. Local opposition is an area of concern according to respondents at RES. Since green hydrogen is dependent on green energy, it faces the same challenge in the form of a strong local opposition towards building for instance additional wind power capacity. Another challenge for the diffusion of green hydrogen that has appeared from interviews with respondents from RES is that the non-existent green hydrogen market creates commercialisation issues since it is hard to sign agreements with offtakers for the price of green hydrogen.

5.2.2.2 Opportunities

Respondents point out that the opportunities for green hydrogen technology are numerous. They argue that many carbon-intensive sectors need to make a sustainable transition and have green hydrogen as the only option for decarbonisation. Respondents find the best use of green hydrogen to be directly in the production processes of manufacturing industries (e.g. ammonia, steel) or as fuel in the transportation sector. Respondent C emphasises the importance of green hydrogen for the future: *"I think it is extremely important, both for industries and* *transportation. [...] I think it is very important for the sustainable transition, that is clear".* Wind power, or some form of renewable energy, is expressed by respondents at RES as a prerequisite for producing green hydrogen. By allowing wind power to get a local connection through hydrogen production, both technologies have the opportunity to develop in symbiosis and become more widespread within society.

5.3 Ånge municipality

5.3.1 Project management

5.3.1.1 Project uncertainty: challenges

External factors

Respondents from the municipality argue that external factors, such as findings of ancient remains or protected species on the site, could impact the project by prolonging or stopping permitting processes for the site. This would affect the detailed development plan for the area and increases the risk of project delay.

Regional DSO time consuming processes

According to respondents from the municipality, the project in Alby is facing challenges in the time-consuming processes of regional DSOs. Respondent A claims that DSO two is accommodating but that their processes are slow. Respondent B argues that the project will be delayed in phase two if no more energy production is added. Since time consuming processes of the DSOs affect the ability for new energy to be added to the grid, there are implications on behalf of the municipality that the regional DSOs processes can have a negative impact on the timeline of the project.

Local energy supply

Respondents consider the local energy supply to be an uncertainty since new renewable energy will be needed for green hydrogen to be labelled green. Therefore, green energy production is indispensable for producing green hydrogen. Respondent B clarifies the need for more renewable energy in the region:

> *...it [energy supply] has to be new for the last 24 months which means that all wind power we have in the municipality now is pretty much unusable. The first module of the production facility is finished at the year-end of 2024/2025 so that doesn't do it. It has to be new".*

Lack of development knowledge

Respondents emphasise that a challenge in the project is that the municipality has a lack of knowledge of project development, as the municipality has focused on scaling down its operations (while trying to maintain as many functions as possible) during the past forty years due to a declining population. This makes the transition to development-based operations noticeable. Respondent B at the municipality argues that there is a drastic difference between maintenance and development. Respondent B further explains that there is good information on how a municipality can scale down, but not on how they can work with development: *”How to scale down the operations of a municipality, there is endless [information]. But there is nothing about how to adjust and to start developing”*.

After project completion, respondents from the municipality expect the provision of competence to become a challenge in the municipality. Respondents emphasise the risk of not being able to provide the appropriate competence to the industries that will establish themselves in the green hub.

Permits

Respondents from the municipality emphasise that permits could affect the time plan for the Alby. Respondent A stresses that several permits are needed for the industrial site in Alby. Respondents B and C agree and argue that numerous environmental permits are necessary to even start building the green hydrogen facility. Respondent C underscores that the detailed development plan needs to be approved. The detailed development plan takes the impact on the local environment into account and also needs to be consulted with affected neighbours. This is a compulsory step towards an approved detailed development plan. Respondent C frames the uncertainty of people appealing against the detailed development plan: *”If we have 200 affected neighbours […] who think that it is great that something is happening, it is still enough that one person is not happy and appeals [the detailed development plan]”*. If this would happen in the Alby project, the project could be delayed since those processes take time. However, respondent C doesn’t expect this to be the case in Alby since the local community is positive about the project.

5.3.1.2 Project uncertainty: challenge reducers

Aligned long-term goals

Respondents of the municipality argue that there is a vision of the future, with a local connection of wind power and where the Alby project becomes a green hub. The green hub will be a green industrial cluster which puts Ånge municipality on the map and brings the municipality into a new industrial era. The preferences of what type of offtakers should establish on the site are aligned between the municipality and RES, where the emphasis is on job creation and circularity in the use of resources. Respondent A at the municipality explains that the municipality’s focus is largely on job creation: *”Our municipality council says jobs, jobs, jobs as the three biggest priorities”*. The respondents from the municipality consider RES to be accommodating to their needs in this aspect, which means that RES look for industrial offtakers that create job opportunities and contribute to the local community. The aligned goals take their basis in a transparent communication between RES and Ånge municipality. Respondent D argues that transparency is important when striving towards the same objectives. Respondents also highlight the importance of flexibility in the project to deal with uncertainty. Long-term goals keep the project on the right track, but flexibility is what makes it move forward in each step.

Local connection of wind

The respondents emphasise that local wind power is a prerequisite for the Alby project. However, they argue that wind power has a bad reputation since wind power produced locally is exported to other regions of the country. Thus, the local population often sees no local benefits. In this aspect, the green hydrogen project in Alby can make a difference since it can show how wind power in the region creates job opportunities for the local population through the hydrogen production it enables. This might mitigate local opposition to wind power. Respondent C describes that wind power is often a sensitive topic:

"It is very sensitive with wind power for many people [...] Not for all but for some. It is a lot of people that have opinions regarding that [wind power]. In addition, many [residents] argue that wind power is great but not here".

All respondents from the municipality argue that a local connection is necessary to attain a positive opinion of wind power. In the Alby project, opportunities are created for the community by the use of locally produced energy which clarifies the benefits of using wind power. Respondents A and B emphasise that the reactions from the local population have been very positive regarding the green hydrogen project and that the project has gotten a lot of attention and created a hope for the future of the local community.

Social enablers

To handle uncertainty in the project, respondents in the municipality describe how they act as social enablers. They contact the right people, are accommodating towards potential industrial actors and try to solve problems in their organisation. Respondent A stresses the importance of being open and not saying no: *"It is once again important to communicate and to not be strict and say no 'that won't work'".*

5.3.1.3 Stakeholder involvement

Hindrances

The respondents at Ånge municipality stress that some of the involved stakeholders are acting and responding slowly. Respondents argue that processes take time which could hinder the project and potentially cause delays. For instance, the municipality isn't used to development which makes it inherently slower than RES. However, the respondents argue that in this collaboration, the municipality works on speeding up its processes to match RES pace. Moreover, the response from the regional DSOs can disrupt the time plan of the project if grid connection demands are not met. Respondent B on the municipality:

> *"Regional DSO two and the Swedish Transport Administration are very large and public authority-like and unfortunately fairly slow in that aspect, it takes time. Dealing with the regional DSO two is very positive, but as I said it takes time."*

Respondent B, therefore, argues that DSO two is accommodating, but that its processes take time. Part of the DSOs slow acting can be attributed to the time consuming processes of concessions.

Enablers

According to respondents at Ånge municipality involved in the green hydrogen project in Alby, the key stakeholders of the project have aligned long-term goals and a good collaboration built on transparency and frequent dialogue. The other key stakeholder, RES, is perceived as acting quick and moving forward at a fast pace. Respondent A from the municipality on his/her perception of RES organisation: *"It is an organisation that is big, but small in its fast-paced way of working".*

Respondents from the municipality argue that the roles in the collaboration are confirmed and that each stakeholder has its responsibility. However, the need for flexibility means that there will be overlap in some areas. Municipality respondents claim that the municipality's work is focused on developing the site where the production facility will be located, while RES primarily work on the business case and the development of the hydrogen production facility. Responses from municipality officials show that the municipality has individuals involved in the project that acts as social enablers which makes the project move forward. This means contacting the right people in the right organisations, being solutions-oriented and pushing the project forward. The respondents also indicate that individuals at RES act in similar ways. Another positive aspect expressed by municipality respondents is the hope that the project brings the local population. The hope manifests itself in that the local population can see that things are changing for the better; that companies are once again interested in the region and job opportunities can be created.

5.3.2 Technology diffusion

5.3.2.1 Challenges

The municipality points out that challenges to the diffusion of green hydrogen lie in external factors, for instance, if taxes on green hydrogen production would appear. Respondent A outlines the challenge for green hydrogen technology to diffuse:

> *"It would be if they came up with something as "now we will impose a huge tax on it", but otherwise I don't know. I don't see it [happening] since it [hydrogen] turns into water vapour.".*

Respondents working at the municipality also present local opposition to wind power as a challenge, since wind (or other renewable energy sources) is a prerequisite for the technology to become widespread. They further emphasise that green hydrogen production can bring a local connection to wind power and in turn has the potential to improve the local opinion.

5.3.2.2 Opportunities

The respondents see that green hydrogen technology has a bright future and consider industrial uses (e.g., ammonia, steel, and batteries), transportation and storage as the primary uses. These industries are seen as hard to decarbonise and green hydrogen offers a green alternative. Respondent D highlights the areas of use for green hydrogen: *"[...] There are many applications for [green] hydrogen. One area is the transportation sector, while many of the* *industries that exist today could replace dirty energy types or things like that because of green hydrogen".*

5.4 Technical experts

5.4.1 Project management

5.4.1.1 Project uncertainty: challenges

The non-existent green hydrogen market is a challenge in the green hydrogen project in Alby. Respondent A argues that it makes price setting and signing contracts with offtakers a tough task:

> *"All the off-takers will be uncertainties until contracts are signed. So the revenues of the project won't be certain until contracts are negotiated and signed so anyone can change their mind and the project falls apart because the investors are interested in how much hydrogen, oxygen or heat they are going to sell to these people."*

If the project falls apart further down the line there will be sunk costs and economic losses for RES and the municipality according to respondent A. Another important project challenge is permitting processes. Respondent B argues that the time for permitting process in the Alby has the potential to make the project lose traction:

> *"These permitting processes take up quite large amounts of time and therefore there have been talks about whether we should overlap them to save time. It is what you need to do and this is a soft spot in many projects like this, that once you have finally reached some kind of decision, then you have to do the permitting process and once the permitting process is completed the project has cooled down."*

Another challenge is local opposition, which is mentioned by all groups of respondents. Both technical expert respondents mention local opposition as a potential barrier to the project, which is related to permitting processes for wind power. According to the experts, another challenge for the Alby project is the explosiveness of hydrogen. From a project perspective, respondent A sees that the explosiveness creates uncertainty since safety distances might affect the location of the industrial site. If safety distances make the site unattractive for industrial use, it will be hard to attract businesses.

5.4.1.2 Project uncertainty: challenge reducers

Although the challenges are many, the technical experts see many opportunities in the Alby project. The biggest one is that the green industrial cluster will create an opportunity to monetise all by-products as mentioned by respondent A:

> *"I am still surprised how good it seems for a green hydrogen project, now we have a potential client for hydrogen through the industrial hub, we have a potential user for the oxygen and low-grade heat, it is fantastic. You can monetise everything that comes off the electrolysis or the waste product, as well as the hydrogen."*

The technical expert respondents see local benefits in the project due to its proximity to wind power production. Respondent B also emphasises flexibility as a key for handling uncertainties in the project and the importance of conducting risk analysis to assess different potential scenarios in the project.

5.4.1.3 Stakeholder involvement

Hindrances and enablers

Several stakeholders are involved where the technical experts emphasise that the municipality plays an important role and that keeping close ties with municipality officials is important. They further argue that the local population also plays a role as local opposition can affect the project, primarily by stopping permitting of wind power projects. Permitting is also an issue from a safety point of view according to the experts. Respondent A suggests handling potential hindrances by working closely with key stakeholders and building relationships.

5.4.2 Technology diffusion

5.4.2.1 Challenges

The technical experts point out that there is not a market for green hydrogen yet, and see it as a challenge for the diffusion of the technology. Respondent A highlights the difficulties from both a producer and offtaker perspective:

> *"We have a little bit of a chicken and egg situation with hydrogen, which is that people don't necessarily want to use hydrogen yet because there is no market, no market available that you just can switch over and people don't necessarily want to generate hydrogen yet because finding that firm, off-taker and getting investor comfortable with risk is difficult".*

Respondents further argue that early adopters will have to face higher hydrogen costs as production costs of green hydrogen are expected to be higher than traditional energy in the beginning due to high electrolyser costs and lower efficiency. As technology progresses, respondents expect capital expenditures to drop and electricity prices (belonging to operational expenses) to play a more prevailing role. Respondent A frames the dynamic:

> *"The CAPEX portion of the hydrogen costs will begin to play a lower part in it and obviously electricity will play a bigger part of it as the CAPEX portion comes down over time. In this early development phase of these technologies, there will be cost reduction through CAPEX, through for example PEM reducing any amount of iridium, platinum and titanium and all these raw metals going to PEM electrolysis".*

The reason why electricity prices play such a big role in green hydrogen costs is that the electrolysers are powered by electricity. This highlights the importance of low electricity prices. Higher production costs are not all that hinder the widespread adoption of green hydrogen. Respondent A argues that many industries are facing switching costs to adapt to green hydrogen-based operations. The respondent contends that there are exceptions such as ammonia manufacturers and refineries that already use hydrogen in their processes.

The energy supply is critical for the diffusion of green hydrogen technology. The technical experts emphasise the importance of renewable energy as it is a requirement for green hydrogen production. According to respondent B, a large energy production up-scale is needed in Sweden for green hydrogen technology to penetrate the market. Both experts have raised some concerns about the carbon neutrality of green hydrogen if electrolysers are connected to the local grid. Although it presents an ambiguity of whether the physical energy that goes into the electrolyser is a hundred per cent carbon neutral, the experts do not consider it a big problem due to the existence of power purchase agreements (PPAs).

Variable renewable energy production is another problem raised by the respondents, as it makes dimensioning of electrolysers hard and raises the question of how much storage is needed to cover up for days of low production. In a practical sense, however, this is more of a problem for an off-grid hydrogen facility. Another price-related problem expressed by the technical experts is the higher green hydrogen price compared to fossil fuels, which is worsened by the lack of subsidies. This makes it hard for green hydrogen to compete with fossil fuels in the short term. Long-term, carbon emissions prices or other policy efforts might even out prices.

5.4.2.2 Opportunities

There are many sectors where green hydrogen technology could decarbonise industries. The technical experts agree that green hydrogen plays an important role, especially in the processing industries where hydrogen can be used as feedstock (e.g. ammonia production) and as fuel for the heavy transportation sector. Respondents address the need for storage in connection to the hydrogen facility to be able to export hydrogen even at times of low renewable energy production, but do not see energy storage for electricity grid balancing as a primary use of hydrogen. Both experts also mention the explosiveness of hydrogen as a potential barrier to diffusion but do not consider it a major one; respondent A regards explosiveness as dangerous in passenger cars and argues that industrial uses are much better due to the safety practices already in place, and respondent B argues that hydrogen storage takes up much space as a result of safety distances. None of the respondents mentioned anything about it hindering the overall diffusion of the technology.

5.5 Summary of empirical findings

5.5.1 Project management

5.5.1.1 Project uncertainty

Respondents have pointed out several themes of uncertainties: energy supply, local opposition to wind power, permitting processes and time consuming processes of regional DSOs all give rise to uncertainties. According to RES and experts, the non-existent green hydrogen market is an issue since it creates a situation where price setting is hard and contracts with offtakers are difficult to sign. Time consuming processes of the electricity distribution system operators can lead to project delay as a lack of grid access and it is seen as a major challenge. Respondents want quicker processing times on behalf of the DSOs in order to reduce concession processing time and the risk of project delay. The novelty of green hydrogen also brings concerns related to lack of experience and structures to fall back on according to respondents from RES and Ånge municipality. When respondents do not know how time-consuming or difficult it is, the only way forward is to keep trying. In terms of experience, RES benefits from previous knowledge of permitting processes of site development and of knowing the importance of having an early dialogue with DSOs.

Although the difficulties are plentiful, respondents describe the opportunities and unique advantages of the Alby project. The possibility to create a green hub where many industries are tied to the hydrogen production facility reduces challenges; revenue streams from by-products of hydrogen production are created and additional job opportunities emerge by creating an industrial cluster or a so-called green hub. More collaborative advantages in the Alby project are that the involved stakeholders have aligned long-term goals and are flexible in their approach to the project to make it move forward in the face of uncertainties. The Alby project creates an opportunity to give a local connection of wind power from the region, which the respondents hope could reduce local opposition to wind. More wind power is needed for phase 2 of the project, which explains the importance of reducing local opposition to wind power to meet project deadlines.

5.5.1.2 Stakeholder involvement
The respondents mention the time consuming processes of the regional electricity distribution system operators as a potential hindrance to the project, making DSOs potentially hindering stakeholders that can delay the project. Local opposition to wind can also hinder the project, making the local community and local politicians potentially hindering stakeholders as no access to renewable energy for stage two will lead to project delay. However, answers from respondents do not indicate that the local politicians are a hindering stakeholder at this stage, although elections can make them a hindering stakeholder if they oppose local wind power. The same can be said about the local community, which is positive about the green hydrogen project today. The key stakeholders act as enablers to the project, RES as risk-takers that drive the project forward and the municipality as social enablers. A wide majority of respondents agree that the two key stakeholders have a close collaboration. The collaboration is based on transparency and aligned long-term goals. The roles of the key stakeholders are confirmed according to the respondents, but there is also flexibility in the collaboration where one party can take more responsibility if needed.

5.5.2 Technology diffusion
The stakeholders involved have various roles and perceive different uncertainties and opportunities. However, there are some experiences which permeate the different areas. Technical experts and respondents from RES point out that the non-existent green hydrogen market is a major challenge for green hydrogen technology to penetrate the market. This is to a large extent outside of the scope of the municipality's responsibility in the project, which explains why respondents from the municipality haven't mentioned it as a challenge for technology diffusion. All stakeholders agree that wind, or any other renewable energy source,

is a prerequisite for producing green hydrogen. Respondents argue that the green hydrogen project gives a local connection to wind power, as it allows the energy to be consumed close to where it is produced. Respondents hope that this will reduce the local opposition to wind. Reducing local opposition is important for the project as more renewable energy has to be added for the project to be completed in its second phase. Additionally, the consensus of the respondents is that industrial uses (e.g. steel and ammonia) where hydrogen is used as feedstock in the industrial process is the best use for hydrogen. The second best use is as fuel for the transportation sector. Energy storage is a third possible use of green hydrogen, but energy losses make many respondents doubtful of its viability although some are positive.

6. Analysis

In this section, an analysis is carried out by using the literature presented in the literature review for analysing the empirical findings. The section discusses project management and technology diffusion. It is important to keep in mind that there might be overlap between theories and areas due to interrelations.

6.1 Project management

6.1.1 Project uncertainty

6.1.1.1 Opportunities and challenges

In the end, working with uncertainties will open up both opportunities and challenges. Ward and Chapman (2003b) have emphasised how uncertainties handled in the right way can bring opportunities. In the Alby project, the root causes of uncertainty have been addressed by many respondents, which goes to show why uncertainty management literature is a good fit for analysing the Alby project and the collaboration between RES and Ånge municipality. In the case of RES, the opportunities differ based on the approach that RES takes to the business model of the hydrogen facility. For the municipality, opportunities are related to the possibility of creating a green cluster that will bring new industries and job opportunities to the region.

Ward and Chapman (2003b) argue that there are several areas which lay the foundation for uncertainty in projects. These areas have been covered by respondents in the interviews for this thesis although no such questions have been asked. Ward & Chapman (2003b) talk about a lack of specifications, which has been addressed by respondents concerning the non-existent green hydrogen market. The authors also address that a lack of experience in a certain field can create uncertainty, which is true in the Alby project where RES has no previous knowledge in developing green hydrogen projects, and the municipality has little development experience at all. Ward & Chapman (2003b) talk about events with an unknown effect on the project, and in the case of the Alby project, permitting processes, market conditions (non-existent market, costs) and elections (political uncertainty) are examples of events that have an unknown impact.

Other causes of uncertainty have not been seen as demanding by respondents. Ward and Chapman (2003) discuss the importance of defining roles and establishing which projects cost each actor bear, and each actor's responsibilities. These uncertainties have not been pointed out specifically by any respondents, which might be attributed to the roles being clearly defined between RES and Ånge municipality. Respondents have described a frequent dialogue, close partnership and aligned long-term goals as characteristics of the collaboration, which might further explain why roles and responsibilities are not considered much of a problem since the stakeholders continuously update each other and work towards similar goals. Removing uncertainty by deciding project conditions in the early phases of the project is something that RES and the municipality have done in the Alby project. The municipality has focused on the development of the site and RES on the hydrogen production facility, although there has been some overlap in responsibility as RES has been involved in the site development.

Ward and Chapman (2003) address the issue of uncertainty regarding objectives and priorities. These uncertainties can be seen in each key stakeholder's responsibilities in the project. According to respondents, such uncertainties are often related to external factors in the Alby project. One can assume that it is hard to make priorities when the efforts needed to complete the tasks are unknown. A respondent from RES highlighted the difficulty of not knowing time frames and argued that trial and error was the only way forward as RES needed to "drill" in different tasks to find which ones are the most urgent or time-consuming. Some objectives are familiar and more straightforward, such as certain permitting processes for RES and aspects of the detailed development plan for the municipality. Ward & Chapman (2003b) also claim that uncertainty in the roles is a common source of uncertainty, but in the Alby project, very little role-specific uncertainty in the roles has been expressed during the interviews as a result of previous efforts to clarify each stakeholders role.

Ward & Chapman (2003a) argue their 'six Ws' framework consists of six questions that should be asked to handle uncertainty. In the Alby project, interviews have shown that the partners in the project have touched upon these questions and answered most of them: Respondents are well aware of the parties that are involved and the motives of the different actors. They are also aware of overall time perspectives as the deadlines for the major phases of the project have been set. Respondents are conscious of how each part of the project should be carried out and what resources are required since these aspects to a large extent are unknown.

6.1.1.2 Drawing on previous learnings

Perminova et al. (2008) promote the idea of 'reflective learning', where standardised and modularised processes facilitate decision-making in projects. By using reflective learning, teachings from earlier stages of a project, or previous projects contributes to knowledge. This knowledge can be accessed and used to get an understanding of where efforts should be directed and where less attention is needed (Perminiova et al., 2008). Flexibility is at the core and procedures are a way of speeding up decision-making. Böhle et al. (2016) have a similar view of uncertainty and encourage using 'experience-based action' to handle uncertainty, which means learning to respond routinely to critical uncertain situations by utilising previous learnings.

Looking at the Alby project from this perspective becomes interesting as no actors have much previous experience to lean back on; green hydrogen is so novel that not even the experts have worked in green hydrogen projects before. Respondents on RES highlighted the lack of experience to lean back on but explained how previous wind power projects gave them some advantages. For instance, respondents knew the time aspects of different permitting processes and which authorities needed to be contacted. An example where RES have previous knowledge of permitting processes is that of concessions, where previous projects have given knowledge of the long processing time of the regional DSOs. In this aspect, RES takes an extra financial risk on a part of the project where it is not obligated to put effort into speeding up the concession processes. RES also have knowledge on which permitting processes are possible to carry out in parallel. This proves that accumulated knowledge acquired in previous projects can help to deal with uncertainty, just as the literature has suggested (Perminova et al., 2008; Böhle et al., 2016).

However, there are still many unknowns in the Alby project where RES do not have any knowledge to fall back on. To go through the unknown parts of the project, one respondent argued that the only way forward was to keep trying. After a few tries, they will know what processes are the most time consuming and where efforts should be directed. Perminova et al. (2008, p. 78) claim that: *"If you do not have uncertainty, you do not have evolution"*. Respondents at RES expressed similar thoughts and argued that project development is about managing uncertainty.

The municipality has even fewer structures to lean back on than RES and the experts do in this project. Where RES and the experts can go back to former renewable energy projects, whether it is wind, solar or storage projects, the municipality has none. Instead, the municipality has focused their efforts on maintaining functions for a decreasing population during the last forty years or so. This has been pointed out as a problem by most respondents as it means that some processes are moving forward slowly. In this case, respondents from RES echo what has been said by respondents at the municipality, which is a signal that the transparency and frequent communication between the two key stakeholders creates alignment. The municipality needs to learn how to act at a faster pace for the project to succeed. The municipality is currently switching to a development-based approach and thus has a good opportunity to create standards and gain intuition on how following development projects should be handled, in accordance with advice from Perminova et al. (2008) on reflective learning.

Although neither organisation can fall back completely on previous knowledge in terms of the hydrogen project, it does not mean that they cannot learn from decisions made in the project leading up to where they are. Perminova et al. (2008) stress the importance of standardising and modularising processes to keep the acquired knowledge as a guide for future decision-making. On this background, it might be a good idea for both RES and the municipality to try to standardise processes as they go, and work as reflectively as possible in the Alby project. Working reflectively helps in finding risks and opportunities based on previous knowledge (Perminova et al., 2008). RES has the option of using reflective learning as a tool for upcoming green hydrogen projects, first on a national level for the RES Nordics, but also on a global level for projects in other regions of the world. For Ånge municipality, the acquired knowledge can be used to get processes in place for supporting other development projects. Although this might be good advice with reference to Perminova et al. (2008) and Böhle et al. (2016), there are no indications that RES or the municipality do not already work in a reflective learning manner or use experienced-based action for decision-making. On the contrary, RES has emphasised the benefit of having previous knowledge to lean on.

Another topic that a wide majority of respondents have brought up is that of aligned long-term goals. Because of the novelty of green hydrogen projects, it is very hard to set clear goals for every stage of the project. However, it is still possible to have long-term goals and having these aligned between key stakeholders is an important strength (Odabashian et al., 2019). The aligned long-term goals also mean that offtaker preferences are similar between the two key stakeholders in the project, RES and the municipality. This is partially connected to values as neither RES nor the municipality wants to cooperate with a company with unethical values. The aligned offtaker preferences also mean that RES supports the municipality in its work towards finding industries that create local job opportunities.

6.1.1.3 Responses to uncertainty types

De Meyer et al. (2002) argue that there are four different types of uncertainty which are to be handled differently. The authors call the smallest type of uncertainty “variation”. This type of uncertainty has been described by several respondents in the Alby project. It has to do with the detailed development plan of the site and various types of permitting processes such as safety distances for the explosive hydrogen and permits from the county administrative board to establish industry on the site. For variation uncertainty in the Alby project, most respondents are only worried about external factors that are uncontrollable, for instance seeing that there are protected species on the site so that the project gets called off. This creates conditions for the second type of uncertainty called “foreseen uncertainty”. When facing unforeseen uncertainty De Meyer et al. (2002) recommend creating contingency plans for different potential scenarios. However, no respondents have mentioned any contingency plans, making “variation” a better label for the uncertainties related to handling safety distances and site permits in the project.

The third type of uncertainty is called unforeseen uncertainty and as the name indicates, a project team will not be able to predict exactly where uncertainties will arise or their magnitude, but the team will know areas where they are more likely to occur (De Meyer et al., 2002). From this perspective, it is likely that most of the uncertainties that respondents find troublesome belong to this type of uncertainty. Examples of areas where unpredictable uncertainties can have a big impact on a project are grid connection, the non-existent green hydrogen market (which comes with pricing and offtaker concerns), local opposition and political uncertainty. De Meyer et al. (2002) stress the importance of building relationships and keeping close contact with stakeholders when dealing with unforeseen uncertainty. A majority of respondents have mentioned a tight relationship between RES and the municipality, and consider the frequent dialogue to be a core characteristic of the project. De Meyer et al. (2002) stress the significance of flexibility when facing unforeseen uncertainty. A wide majority of respondents have mentioned flexibility in some form as a tool for handling uncertainty. Flexibility becomes even more important when facing the last type of uncertainty, “chaos” (De Meyer et al., 2002). As team members cannot see chaos coming (De Meyer et al., 2002), it is only possible to decide when this uncertainty type has been faced in retrospect. In the Alby project, the novelty of green hydrogen creates conditions for chaos but respondents describe a willingness to move forward. Moving forward and trying to look long-term have been mentioned as coping mechanisms for facing uncertainty by respondents.

All respondents in the Alby project describe types of uncertainty which are hard to plan for. The types of uncertainty that De Meyer et al. (2008) call unforeseen uncertainty and chaos are therefore the most demanding uncertainties in the project. Both unforeseen uncertainty and chaos require flexibility and close relationships (De Meyer et al., 2002).

A majority of respondents involved in the Alby project have emphasised the importance of flexibility and describe how they take a flexible approach to the project, which increases the likelihood of project success according to the presented literature. RES' ability to work flexible might have to do with previous projects and the ability to handle uncertainty. One respondent at RES even stated that working with uncertainty is what project development is about. Respondents from the municipality describe how they are trying to keep up with RES and seem to be in the process of developing flexibility capabilities on their own, even though they are tied down by previous practices aimed at avoiding stagnation. The flexibility in the project is made possible through the aligned long-term goals; many respondents describe the project as one filled with uncertainties but one that keeps moving forward because they know where they want to end up. Apart from flexibility, maintaining a close relationship and a frequent dialogue is the other major uncertainty management effort that is prevalent in the green hydrogen project. This goes to show that the uncertainty categories mentioned by De Meyer et al. (2002) and their management are relevant for the green hydrogen project in Alby.

6.1.2 Stakeholder theory

The Alby project involves several stakeholders which makes the project complex and strengthens the stakeholders' impact on how the project is carried out. Stakeholders play a pivotal role in project success (Ruggiero et al., 2014; Philipps et al., 2003; Hillman & Keim, 2011). In the Alby project, the respondents emphasise the importance of collaboration and involvement of each stakeholder.

6.1.2.1 The importance of stakeholders

A project involves many actors and the relationships between these can be complex, which leads to uncertainty (Ward & Chapman, 2003). This is illustrated in the Alby project where several stakeholders can affect the outcome of the project and where the relationships play a crucial role in successfully carrying out the project. A large number of stakeholders creates uncertainties in the project since several needs have to be cared for. To mitigate additional uncertainties arising, the needs and roles of the stakeholders in projects should be addressed and clarified (Ward & Chapman, 2003) which is described by all respondents from the two stakeholders; Ånge municipality and RES. The stakeholders’ roles have been made clear and responsibilities outlined, even though they might sometimes overlap, e.g. when RES is providing additional support in site development. However, it is communicated that RES has the responsibility for developing the green hydrogen facility while Ånge municipality focuses efforts on the industrial site. A frequent dialogue seems to create a foundation for good collaboration among stakeholders and in turn make the project move forward.

The needs of each stakeholder should be addressed since all stakeholders can impact the project (Enevoldsen & Permien., 2018; Hartono et al., 2014; Böhle et al., 2016). RES and Ånge municipality are the main stakeholders in the green hydrogen project, but several additional stakeholders affect the outcome of the project. Because of this, it is essential to successfully manage the stakeholders involved accompanying their needs. Ignoring stakeholders’ needs could potentially result in dissatisfied stakeholders that hinder the project and in a worst-case scenario result in an uncompleted project, which clarifies the need to handle each stakeholder involved in a project.

The cooperation in the Alby project is characterised by transparency and frequent dialogue, especially between RES and Ånge municipality. They have aligned long-term goals for the project which contributes to greater collaboration. This goes in line with Odabashian et al. (2019) who stress that close relationships and aligned goals are keys to reaching a good outcome of a project. In this aspect, the Alby project's chances for success are strengthened by close collaboration.

6.1.2.2 Relationships between stakeholders

The relationships between stakeholders are of high importance for successful projects (Ruggiero et al., 2014; Odabashian et al., 2019). The relationship between local communities and larger commercial companies is both a challenge and prerequisite for renewable energy projects (Aitken, 2010). This can be exemplified in the Alby project, where it is vital that Ånge municipality and RES have a high level of transparency and a close collaboration to carry out the project successfully. The relationship between stakeholders, especially RES and Ånge municipality, becomes additionally important since the project are affected by many uncertainties that might delay the project, such as local opposition to wind power from the local community. A good relationship is needed for mitigating these uncertainties. Especially since the lack of social acceptance is more common within wind power projects (Khan, 2003; Cass & Walker, 2009; Aitken, 2010). This demonstrates the importance of involving local stakeholders, so they gain benefits in terms of job opportunities and economic wealth which is in accordance with Ruggiero et al. (2014). The green hydrogen project in Alby provides the opportunity to benefit the local community and the local population, creating job opportunities through industry establishments. This does in turn yield economic growth. Down the road, the local population might see a positive link between local wind power, the green hydrogen facility and job opportunities. One can therefore argue that stakeholders will be more supportive of the Alby project if they can reap its benefits.

6.1.2.3 Hindering or supportive stakeholders

Stakeholders can either hinder or support a project, having a negative impact by hindering the project or a positive by supporting it (Philipps et al., 2003; Ruggiero et al., 2014). According to Ruggiero et al. (2014), stakeholders' attitude toward a project depends on whether they will benefit from the project or be harmed by its outcome. This is important to consider since stakeholders both affect and are affected by the project at the same time. Involving stakeholders is in other words critical (Odabashian et al., 2019). The Alby project includes several stakeholders; RES as a commercial developer, Ånge municipality as the local community, the local population in Ånge municipality, local politicians, regional electricity distribution system operators and offtakers.

Commercial developer

RES is the commercial developer of the Alby project and is working closely with Ånge municipality. Commercial developers are important stakeholders in renewable energy projects (Ruggiero et al., 2014; Odabashian et al., 2019). The focus of RES is to build the green hydrogen facility but they also support the municipality in the development of the industrial site. This makes RES a supportive stakeholder that also cares about the development of the local community. RES focus is therefore in line with the description of a supportive commercial developer given by Ruggiero et al. (2014), which means that not all focus is on personal gains. RES concentrates on developing a broader portfolio by gaining skills and knowledge of green hydrogen project development. According to Odabashian et al. (2019), focusing on acquiring skills and knowledge are motives of project owners, which can help explain why RES has an incentive to take on an extended role in responsibilities to support the local community.

Local municipality

The local government is, according to Odabashian et al. (2019), more involved than the national government when it comes to local projects like the one in Alby. As such, the local municipality is a very important stakeholder (Ruggiero et al., 2014; Odabashian et al., 2019)[3]. Local communities are often beneficiaries of successful projects in form of job opportunities and economic growth; as a result local municipalities are supportive stakeholders (Odabashian et al., 2019). This can be seen in the Alby project where Ånge municipality acts as a supportive stakeholder that wants the project to be implemented for job opportunities to be created. Ånge municipality is working intensively with the detailed development plan and is contributing with the area of land where the site will be built. In line with Ruggiero et al. (2014), the municipality takes the role of a supportive stakeholder. The municipality contributes to the project by conducting the detailed development plan. A challenge is that the municipality has not worked on developing projects for a long time, rather the opposite. They have primarily been working on maintaining society functions with a receding population during the last forty years. Because of this, the municipality is not as fast-paced as RES, which is continuously working with development. This is something that they are aware of. As a result of this, Ånge municipality is working hard to keep the same pace as RES and is making an effort to be a supportive stakeholder for the project.

Electricity distribution system operators (regional DSOs)

In renewable energy projects, one important stakeholder group are the network operators who can be supportive or hindering stakeholders (Ruggiero et al., 2014). A network operator is considered to be hindering in a situation when its time consuming processes of connecting to the grid result in a delayed project (Ruggiero et al., 2014). In the Alby project, there are two network operators. These are referred to as regional electricity distribution system operators, regional DSO one and two. Respondents highlighted that these impact the Alby project by making the energy needed available, where DSO one provides the energy for the first phase and DSO two provides the energy for the second phase. Regional DSO two has a positive attitude but their processes are slow and it takes time to get an answer from them while DSO one is more less communicative. To not delay the Alby project in phase two, infrastructure investments have to be decided on urgently. The regional electricity DSOs can thus take either a hindering or a supportive role; a hindering role by slowing down the project and causing delays if processes are moving too slow, or a supportive role by finishing the needed processes

[3] Odabashian et al. (2019) definition of the local government can be seen as equal to the local municipality. Ruggiero et al. (2014) instead include the local municipality in the label local community.

in time to supply the required grid capacity needed for the Alby project. Therefore, they are critical stakeholders that need to take a supportive role to carry out a successful project.

Local population and local politicians in the municipality

Individuals in the local population might oppose projects when living close to a renewable energy project or when they want to keep the rural landscape untouched (Odabashian et al., 2019; Enevoldsen & Permien, 2018; Ruggiero et al., 2014). Social acceptance of wind power is generally lower than for other renewable energy sources (Khan, 2003; Cass & Walker, 2009; Aitken, 2010). According to respondents and indications from the EU (2022), more renewable energy will be needed for hydrogen to be classified as green. Industrial establishments that will use hydrogen or by-products are expected to be energy-intensive, which increases the need for more energy supply. The local population can thus take the role of a hindering stakeholder by loudly opposing wind power in the region, which will likely spill over to the green hydrogen project. In this case, the project can get delayed as a result of opposition to wind power. In addition, the local politicians may begin to falter if the wind power debate gets too intense and the local municipality politicians could take the roles of a hindering stakeholder instead of being supportive, which would affect the outcome of the project. So far, respondents claim that the local opinion is supportive of the green hydrogen project due to the possibilities it brings the local community. This shows how local politicians and the local community are acting as supporting stakeholders towards the green hydrogen project, but potential resistance to wind from the same stakeholders is still a concern that could affect the green hydrogen project in later stages.

Local project champions

Local project champions are presented as an invaluable resource since these people can contribute with rare competencies and knowledge (Ruggiero et al., 2014). Ruggiero et al. (2014) emphasise that local project champions can so push the project forward and are considered to be supportive stakeholders. A lack of local project champions is common in small communities (Ruggiero et al, 2014). However, even though Alby municipality is sparsely populated, the green hydrogen project seems to have local project champions that drive the project forward. The local champions work within Ånge municipality as officials and describe themselves as social enablers. They contribute with large contact networks and connect the right individuals to successfully carry out the project. They make contact and try to avoid saying no to interested industrial actors. The local champions in Ånge are therefore supportive stakeholders which can play an important role in the success of the Alby project.

Offtakers

Another important stakeholder group are the offtakers. Offtakers need to be involved in the project; as consumers of green hydrogen (or by-products), they are one of the most important stakeholders. Although offtakers are not discussed by Ruggiero et al. (2014) or Odabashian et al. (2019) as a stakeholder, they are arguably important in the Alby project. No revenues are certain until contracts are signed. So far, the non-existent green hydrogen market and the difficulties associated with price setting have made it hard to sign contracts with offtakers. Offtakers' role can be seen as supportive once contracts are signed - a vital step for the development of the project. Conversely, they take a hindering role if the process to sign contracts takes a long time as this impacts the project development.

6.1.2.4 Mainly supportive stakeholders

To sum up, many different stakeholders affect the outcome of projects by taking a supportive or hindering role as argued by Ruggiero et al. (2014) and Phillips et al. (2003). Most of the stakeholders in the Alby project are supportive and push the project forward. Still, some stakeholders could hinder the completion of the project. This shows how important the involved stakeholders are and that one individual actor can delay the project and in turn affect its outcome, in accordance with Ruggiero et al. (2014) and Odabashian et al. (2019). Examples of stakeholders that can delay the project are regional DSOs whose processes are time-consuming and the local population of Ånge municipality where opposition to wind power impacts the hydrogen projects timeline. On a positive note, the green hydrogen facility project can create job opportunities, making the local community beneficiaries. This yields a positive attitude towards the green hydrogen project. Ruggiero et al. (2014) argue that stakeholders will take a supportive role when they are beneficiaries of a project. In line with this, the green hydrogen project in Alby can change the attitude towards wind power for the better, since it shows that the local community is the beneficiary. Respondents have described how local opposition to wind has emerged as a result of wind power being exported to other regions of the country. Since the green hydrogen project in Alby demands renewable energy and is located close to wind power production, the link between wind power, green hydrogen and the local community as beneficiaries can be established.

6.1.2.5 Communication and alignment

Stakeholder involvement is complex since project success can be perceived differently by stakeholders (De Wit, 1988). As such, communication and alignment are vital to address the complexity of having several stakeholders involved in a project (Pinto & Slevin, 1987). This can be seen in the Alby project, where transparency and frequent dialogue have been vital factors for achieving the good collaboration amongst stakeholders that there is. Cooperation between stakeholders and the contribution of each one is essential and decides the result of the project according to Odabashian et al. (2019). In the Alby case, the stakeholders are dependent on each other for carrying out the project, for instance on regional DSOs for electricity grid access and energy supply; Ånge municipality for the land, detailed development plan and wind power permits; and RES for building and developing the green hydrogen facility. Thus, all pieces are crucial and close communication and collaboration is needed. This emphasises the importance of communication which Pinto and Slevin (1987) point out is a necessity to reach a successful project. Communication is also needed to achieve alignment in defined goals and responsibilities (Pinto & Slevin, 1987). The benefit of alignment is seen in the Alby project where everyone agrees on what to strive for, making it easier to work in a direction that takes the project closer to completion. The alignment is a result of clear communication and close collaboration in the project, creating a strong belief in the project.

6.2 Technology diffusion

6.2.1 Policies

There are many commercialisation barriers to the diffusion of renewable energy technology. For instance, government intervention and policies are often needed to mitigate the barriers of high investment costs (Reddy & Painuly, 2004; Jacobsson & Lauber, 2006). Vogl et al. (2021) argue that so is also the case for green hydrogen. Examples of successful support for renewable energy technologies have been seen in wind and solar power, which enabled a rapid establishment of the technologies (Jacobsson & Lauber, 2006). Although literature often addresses policy aspects, respondents talked sparsely about policy aspects of the Alby project. The technical experts mentioned that subsidies might be necessary for green hydrogen technology to break through, but did not elaborate much on why. The reason why there has been little focus on policy aspects might be explained by the novelty of the project and the fact that green hydrogen is in a very early diffusion stage. Nonetheless, green hydrogen will likely need subsidies to compete with fossil alternatives according to technical experts. If the industries that switch to green operations cannot produce cost-competitive products, green technologies will not be attractive (Vogl et al., 2021). This does in turn affect the diffusion of the technology. Therefore, the need of additional policy support for green hydrogen depends on its ability to compete with fossil alternatives without subsidies. Since its competitiveness is hard to determine at this stage, it makes sense that respondents have not focused on policy aspects.

6.2.2 Conventional technology versus new technology

A barrier to renewable energy technology diffusion is the comparison between renewable energy technology and conventional technology since externalities are not taken into account (Owen, 2004; Juszczyk et al., 2022; Seetharaman et al., 2019). Against this background, the researchers argue that it is harder for renewable technologies to compete with the traditional prices. According to respondents, prices cannot yet be set and there are many uncertainties associated with a non-existent market that affect the competitiveness of green hydrogen. Since grey hydrogen is produced from natural gas (Lazard, 2021b), high natural gas prices will affect the attractiveness of green hydrogen versus grey. At the same time electricity prices have a large impact on green hydrogen (Turner, 2004), either positively or negatively. Additionally, attractiveness is affected by future carbon prices (Lazard, 2021b). As a result, many different factors have an impact on green hydrogen competitiveness, making price setting difficult.

In some markets, it has been argued that green hydrogen could be competitive with conventional energy already today since it is not eligible for environmental taxes (Jovan & Dolac, 2020). In the Alby project though, expert respondents have pointed out that it is likely that early green hydrogen offtakers will have to deal with higher prices compared to using fossil fuels. Externalities of fossil fuels are hard to set a price on (Owen, 2004; Juszczyk et al., 2022; Seetharaman et al., 2019), meaning that green hydrogen has to compete on somewhat uneven terms. Solutions like carbon prices could help even out the plane field, but as it seems like right now, there are challenges for the diffusion of green hydrogen in its race against fossil fuels.

6.2.3 Social opposition

The primary barrier to the Alby project that can affect the project outcome and in turn the diffusion of the technology is social opposition which is emphasised by all respondents. This goes in line with how the lack of social acceptance is a big barrier to renewable energy projects (Painuly, 2001; Seetharaman et al., 2019; Elavarasan et al., 2020). Social opposition to wind power projects is more common (Khan, 2003; Cass & Walker, 2009; Aitken, 2010). This takes form in the lack of public awareness and the so-called "not in my backyard" phenomena according to Seetharaman et al. (2019). They explain that the NIMBY phenomenon means that the opinion towards something is positive as long as it is not located close to the individuals in question, and that wind power suffers from this phenomenon. Local opposition can lead to projects being turned down (Enevoldsen & Permien, 2018) which emphasises the importance of achieving social acceptance for projects to facilitate the diffusion of technology. The negative response to renewable energy projects from the local population often takes its basis in a strong willingness to keep the rural landscape untouched in the northern parts of Sweden (Enevoldsen & Permien, 2018). This can be seen in the Alby project where the not in my backyard syndrome is present in the local population, even if only by a few individuals. Respondents argue the opposition to a large degree is based on the belief that energy produced in the municipality is exported to other parts of Sweden and that individuals cannot see what their benefit from wind power establishments that affects their local environment. According to respondents, more renewable energy production has to be established to support later phases of the green hydrogen project. Since more energy production is needed, the Alby project is negatively affected by local opposition to wind. Respondents have pointed out that the local substation Tovåsen provides an opportunity to deliver the demanded electricity if more wind power is connected to it. This shows how the diffusion of green hydrogen technology can be hindered by local conditions; in this case, opposition to wind power. Assumingly, the local conditions would have been different if this project was carried out in another country. Khan (2003) argues that wind power faces the strongest social opposition of renewable energies. The impact of local opposition to wind can be seen in the Alby project where wind power is needed for producing the green hydrogen. Therefore, it is important to relieve opposition by showing a link between wind power in the region and local benefits.

To show that the local community are the beneficiaries of a project is vital and facilitates carrying out a project (Odabashian et al., 2019). Successful projects could positively affect the diffusion of green hydrogen technology. Since the Alby project shows a local connection that makes the local community beneficiaries, the local opposition towards wind power can decrease if the local population sees the connection between wind power and green hydrogen. Social opposition is seen as a barrier to the research of renewable energy projects (Painuly, 2001; Seetharaman et al., 2019; Elavarasan et al., 2020). Indications from Alby show that this barrier can be removed if the local connection is clear and the local community becomes beneficiaries of green hydrogen projects. This goes in line with involving the stakeholders and considering their needs as emphasised by Elavarasan et al. (2020) to successfully carry out wind power projects, which is the basis for the green hydrogen facility.

6.2.4 Political uncertainty

Political uncertainty is a result of Sweden's decision-making process in terms of infrastructure investments. Since there is a municipal veto on wind power (Jacobsson & Johnson, 2000; Khan, 2003; Fridolfsson & Tangerås, 2013), there is pressure on politicians to act in the interest of the local population, even though it might be in the municipalities best interest to follow through with wind projects as it facilitates industrial establishments. In Alby, respondents have expressed that the second phase of the green hydrogen project might be delayed if the energy production in SE2 is insufficient. More wind power can be connected to the local substation Tovåsen and solve this issue but opposition to wind power and political uncertainty can rule out or delay its establishment. More energy production is needed, but can be stopped by local opposition and political uncertainty. This shows how political uncertainty on a local level can have a big impact on the establishment of green hydrogen. Rejecting wind power permits becomes easier since politicians' decisions do not have to be motivated (Fridolfsson & Tangerås, 2013). Without the obligation to motivate choices, local politicians have few incentives to make decisions that can harm their reputation. Therefore, vetoes have a negative impact not only on the diffusion of renewable energy technology but also on green hydrogen technology. In short, the municipal veto creates difficulties for the establishment of wind power and in turn hydrogen.

6.2.5 Summary of barriers

To sum up, the non-existent green hydrogen market and the local opposition are the project barriers in Alby that have the greatest implications for the diffusion of green hydrogen technology. Local opposition barriers have been well mentioned in previous research on renewable energy technology diffusion (Seetharaman et al., 2019; Elavarasan et al., 2020; Jacobsson & Johnson (2000). However, green hydrogen in itself is not highly debated in terms of social opposition but the renewable energy needed to produce it, in this case wind power, often is. The Alby project shows that this may be mitigated by a strong local connection where the local community becomes the beneficiaries. It gives an example of how stakeholders being included in a project leads to a more positive attitude which is emphasised by Enevoldsen and Permien (2018) and Khan (2003). A non-existent market has not been mentioned as a problem itself in renewable energy technology diffusion literature and the reason is likely that the electricity market is well established. What has been mentioned, however, are the problems related to the lack of standards. In the Alby project, the lack of standards for green hydrogen affects price setting and in turn prices for green hydrogen.

7. Conclusion

The final section presents answers to the stated research questions and discusses the purpose of the research. Thereafter, contributions and suggestions for future research are revealed.

7.1 Research questions answers and discussion

This thesis has looked into two main areas; first aspects related to project management and secondly aspects of technology diffusion in relation to green hydrogen. The two areas of project management, project uncertainty and stakeholder theory go hand in hand and often overlap, as stakeholders affect uncertainties and uncertainties themselves affect stakeholder relationships. Before the main research question, a sub-question will be answered to highlight stakeholders' impact on uncertainties. The first research question can then be answered more thoroughly as collaboration related aspects will be included in it. This lays the foundation for answering the first research question of how key stakeholders navigate project uncertainty. In addition, the Alby project shows challenges and opportunities for green hydrogen technology, with implementations for its diffusion. Therefore, this thesis has a second focus connected to the technology diffusion, of which aspects are covered in a second research question.

Sub-question:
How do different stakeholders affect project uncertainty?

There are several stakeholders involved in the Alby project, which makes it complex. All stakeholders involved affect uncertainties. Additional uncertainties arise as more stakeholders become involved in the project. However, trying to reduce uncertainties by not including stakeholders is not an option. An example is the regional DSOs whose processes bring uncertainty but are needed for grid access. Not including this stakeholder would put the project to a halt. It is therefore vital to identify these areas and to balance the interests and needs of the stakeholders to establish a good collaboration which impacts the outcome of the project positively.

The two main stakeholders in the Alby project, RES and Ånge municipality, both mitigate potential uncertainties by taking a supportive role in the project. Respondents describe RES as fast-paced and the municipality as eager to progress although a lack of development experience can decelerate project development. Local politicians affect the project by taking either a supportive or a hindering role depending on their decisions on wind power permits. This creates an uncertainty that can lead to project delay. On the positive side, the two key stakeholders in the project are supportive. Their collaboration is characterised by transparent communication, frequent dialogue and aligned long-term goals. These characteristics keep the project on track when facing uncertainties.

Some stakeholders can take a hindering role, which could lead to additional uncertainties. If opposition to the Alby project becomes widespread, the local population could be seen as a hindering stakeholder. Indirectly, local opposition to wind will also make the local population a hindering stakeholder, since it can delay the green hydrogen project. Another potentially hindering stakeholder are the regional DSOs, where slow internal processes and slow concession processes can delay the Alby project in its first and second phase. However, answers from respondents indicate that DSOs two is accommodating and slow actions can be attributed mainly to slow concession processes. This DSO can be labelled as supporting. The other DSO is less accommodating and has slower internal processes, making it more hindering. Offtakers are an additional stakeholder group that impacts the project. Unsigned contracts with offtakers create uncertainty and an unwillingness to sign contracts would make them a hindering stakeholder.

First research question:
How do key stakeholders navigate project uncertainty in the development of a green hydrogen facility in Sweden?

The sources of uncertainty take shape in different forms in the Alby project. The green hydrogen market is non-existent, which makes it hard to set prices and sign offtaker agreements. Local opposition to wind power affects local politicians in their decision-making process for wind power. The political uncertainty in turn creates a source of potential project delay. Permitting processes for the site, for getting access to the grid and for wind power to get energy supply for the 100MW phase two of the project are additional uncertainties. In the project, several factors can help manage uncertainty. Aligned long-term goals, frequent dialogue and transparency keep the project on track. Getting a symbolic local connection of wind power can help reduce local opposition and facilitate the establishment of the power supply needed for the second phase of the project. This would reduce the risk of project delay. Lastly, the individuals at the municipality act as social enablers and individuals at RES act as risk-takers, which helps overcome barriers.

In literature, different sources and types of uncertainty have been researched. Looking at sources of uncertainty in projects, most aspects of the literature on uncertainty management have been brought up by respondents when talking about the Alby project even without having been asked directly. First and foremost, this shows awareness of uncertainty sources in the project. It also proves that project uncertainty and stakeholder literature is relevant for describing challenges in green hydrogen projects. Project uncertainty affects the project in different ways, either positively or negatively. The key stakeholders, Ånge municipality and RES, have worked towards removing uncertainties when possible by setting timelines and defining roles. The key stakeholders in the project have taken a solution-oriented approach and try not to get stuck in the uncertainties.

Different types of uncertainty have been covered in literature and have helped explain which kind of uncertainty is faced in the Alby project, according to descriptions from respondents at RES and Ånge municipality. It appears that the uncertainty in the project is either small and possible to manage by planning, or great enough that flexibility will serve as the best capability for managing it. Respondents in the Alby project have described flexibility as a way of managing major levels of uncertainty. Previous research has shown that significant uncertainty requires more flexibility which is shown in practice in the Alby project.

Due to a varying degree of previous knowledge of dealing with the uncertainties, the conditions for dealing with uncertainty are different for the key stakeholders in the Alby project. RES' experience in other renewable energy projects has created knowledge and structures to lean back on in some cases. However, due to the novelty of green hydrogen, not all uncertainties can be solved by previous knowledge. The municipality, on the other hand, has little development experience to take comfort in. Regardless of the differences between the key stakeholders, reflective learning and experience-based action could help both parties access information learned in previous projects, or at earlier stages in the green hydrogen project. Since respondents have discussed the importance of previous knowledge or challenges of having a lack thereof, it seems like the key stakeholders have already taken a reflective learning or experience-based action approach to the project.

Second research question:
What project factors affect the diffusion of technology?

If successful, the Alby project can inspire other communities in Sweden or abroad. Having a role model for future projects can help the diffusion of green hydrogen technology. In this thesis, two major barriers to the diffusion of green hydrogen can be seen: a local opposition to wind power and a non-existent green hydrogen market. A completed green hydrogen project has the potential to show that a concrete local connection of wind power can reduce local opposition to wind power and in turn the risk of delay in projects. From this point of view, green hydrogen can facilitate the establishment of other renewable energy technologies. In Alby, respondents argue that more wind power is needed for the energy supply of the project's second phase. As is indicated in both the Alby project and renewable energy technology diffusion literature, local politicians can be hesitant to provide permits for wind power projects due to local opposition. However, seeing that there is a local demand for renewable electricity might change the opinion to wind for the better. Green hydrogen attracts job intensive industries but is reliant on renewable energy to be labelled as green. The local connection of wind power through green hydrogen shows how local opposition, which is a major barrier in renewable energy diffusion literature, can be mitigated by green hydrogen.

In the Alby project, the other large barrier to green hydrogen is related to a non-existent commodity market for green hydrogen. This makes price and cost estimations hard, which in turn makes offtaker agreements on green hydrogen hard to sign. The Alby project shows that production costs and the price of green hydrogen compared to fossil alternatives affect the ability to follow through with the project. Just like literature has shown for other renewable energy technologies, the relative costs of renewable energy versus fossil fuels impact the diffusion of green hydrogen technology. Literature on renewable energy diffusion often emphasises policy aspects, but in the Alby project, such remarks have been very modest. The reason might be that the project is in such early phases that policy aspects are overlooked due to more pressing issues, in this case, local opposition and the non-existent green hydrogen market.

On top of the obvious diffusion barriers listed above, this thesis contributes to the knowledge about the diffusion of green hydrogen by highlighting project-specific challenges that other projects are likely to face due to the novelty of green hydrogen. The first and greatest challenge will be to deal with uncertainty, which stems from numerous sources such as local opposition, political uncertainty and a non-existent green hydrogen market where no prices are set. A second challenge will be to successfully manage relations with an extensive number of stakeholders. Even though these two categories of challenges have been discovered in the Alby project, other green hydrogen projects on a national level or even on a global scale are likely to face similar challenges until the market has settled.

7.2.1 Contribution to theory and suggestions for future research

The thesis has investigated a green hydrogen facility project in Alby with an exploratory approach. Although the research has come across interesting findings, some areas could be further explored. Suggestions are given below.

First, the findings of the thesis regarding stakeholder theory in the Alby project have confirmed the foregoing literature, emphasising the importance of stakeholders and their impact on projects. Stakeholders affect uncertainties and project outcome, which can be seen by how a few potentially hindering stakeholders might delay the Alby project. The Alby project would not have made it as far as today if the cooperation among stakeholders had been poor. The project is an ongoing process where the collaboration between key stakeholders up until today has been good, a close collaboration which needs to be maintained throughout the project. Recommendations for future research is therefore to investigate the Alby project once completed. Conducting a multiple case study on completed green hydrogen projects from a stakeholder theory perspective would give an even greater understanding of stakeholder aspects of green hydrogen projects. This thesis has also shown that project uncertainty literature is relevant for explaining uncertainty management of the green hydrogen project in Alby, Sweden. Respondents have described how different sources have created uncertainty in the Alby project. Further, respondents have expressed different uncertainty types which are either plannable or demand flexibility. Respondents also emphasised the value of taking advantage of previous learnings similarly to advice in reflective learning and experience-based action literature. Therefore, this thesis contributes to project uncertainty theories, and in particular those that address uncertainty sources, uncertainty types or knowledge from previous experience. For future research, the authors of this thesis advise researchers to look at project uncertainty by conducting single or multiple case studies on other green hydrogen projects in Sweden to confirm the results of this study. In a second step, looking at project uncertainty in green hydrogen projects in other European countries is recommended to help understand project uncertainty in green hydrogen on a wider scale. Hopefully, such an understanding can help promote the diffusion of green hydrogen and help European countries reach climate goals such as those set by the EU.

Secondly, looking from a perspective of technology diffusion, the findings in this thesis are in line with former literature on the diffusion of renewable energy technology. Previous literature on renewable energy technology diffusion has highlighted the issue of local opposition to renewable energy projects. In the Alby project, direct opposition to the green hydrogen project cannot be seen, but towards the wind power which is a prerequisite for the second part of the project to be completed. The relationship between local opposition to renewable energy and green hydrogen should be further investigated in upcoming research as the Alby project shows that they are interdependent. Implications show that renewable energy can benefit from green hydrogen establishments in Sweden to reduce local opposition, and conversely that green hydrogen benefits from wider access to renewable energy. Another area which should be further investigated is the non-existent green hydrogen market. This area has created large uncertainties in the Alby project, and due to its potential impact, further research is welcome. As the market is still evolving, performing qualitative studies of representatives of both project developers and industry offtakers in Sweden would increase the understanding of the magnitude of the problem. On a larger scale, a qualitative analysis on a European or global level would contribute to the understanding of the problem.

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9. Appendix

Appendix 1: Interview guide 1 – Municipality

Part 1:

1. Berätta om dig själv, din bakgrund och din roll kopplad till projektet i Alby
2. Hur länge har du jobbat i kommunen? Vilka roller har du haft?
3. Har du jobbat med förnybara energiprojekt innan? I så fall, hur?

Part 2:

1. Om du har jobbat med förnybara energiprojekt innan, vilka utmaningar har dessa mött?
2. Berätta lite om hur dialogen påbörjades gällande projektet i Alby. Hur reagerade du när det först kom på tal?
3. Vad bidrar du med när det gäller vätgasprojektet i Alby?
4. Vad bidrar kommunen med?
5. Vilken roll har ni i projektet i Alby?
6. Är rollerna i samarbetet officiellt uttalade?
7. Hur insatt är du i tekniska aspekter av projektet?
8. Vad vill kommunen få ut av projektet?
9. Har kommunen möjlighet att påverka projektets utformning? Till exempel, val av teknik?
10. Vilka möjligheter ser du med projektet i Alby?
11. Hur ska dessa tas tillvara på?
12. Vilka osäkerheter ser du med projektet i Alby?
13. Varför uppstår dessa osäkerheter?
14. Hur hanterar ni dessa/ hur kan dessa bemötas?
15. Hur har du upplevt samarbetet med RES? (Utmaningar/funkat bra)
16. Vilka andra intressenter påverkar projektet?
17. Hur har samarbetet fungerat med dessa?
18. Vad för osäkerheter anser du finns i samarbetet med dessa intressenter?
19. Vad tycker du krävs för ett lyckat samarbete i projektet?
20. Har ni i kommunen kommunicerat med allmänheten gällande projektet i Alby?
21. Hur har detta skett?
22. Hur har projektet bemötts av allmänheten?
23. Har kommunen någon preferens gällande vilken sorts företag som etablerar sig i området (Alby)?
24. Hur ser ni på vindkraftens förhållande till vätgas?
25. Vad tror du om framtiden för grön vätgas?
26. Vilka möjligheter ser du?
27. Vilka osäkerheter ser du gällande den gröna vätgasens roll i framtiden?
28. Är det något du vill tillägga som vi borde ha tagit upp eller något svar du vill utveckla?

Appendix 2: Interview guide 2 – RES

Part 1:

1. Berätta om dig själv, din bakgrund och din roll kopplad till projektet
2. Hur länge har du jobbat på RES? Vilka roller har du haft?
3. Vilken sorts förnybara energiprojekt har du jobbat med innan? Vilken roll har du haft i dem?

Part 2:

1. Hur kom du i kontakt med grön vätgas?
2. Berätta lite om Albyprojektet och hur dialogen med andra intressenter startade
3. Berätta om din roll i projekt Alby?
4. Berätta om RES roll i projekt Alby?
5. Är rollerna i samarbetet officiellt uttalade?
6. Varför initierade ni projektet?
7. Vad bidrar RES med när det gäller vätgasanläggningen i Alby?
8. Vad vill ni få ut av projektet?
9. I vilken utsträckning kan ni påverka projektets utformning? Till exempel, val av teknik?
10. Vilka möjligheter ser du med projektet i Alby?
11. Hur ska dessa tas tillvara på?
12. Vilka osäkerheter ser du med projektet i Alby?
13. Varför uppstår dessa osäkerheter?
14. Hur hanterar ni dessa/hur kan dessa bemötas?
15. Hur har du upplevt samarbetet med kommunen? (Utmaningar/funkat bra)
16. Vilka intressenter påverkar projektet?
17. Hur har samarbetet fungerat med dessa?
18. Vad för osäkerheter anser du finns i samarbetet med dessa intressenter?
19. Vad tycker du krävs för ett lyckat samarbete i projektet?
20. Har ni någon preferens gällande vilken sorts företag som etablerar sig i området i Alby?
21. Hur ser ni på vindkraftens förhållande till vätgas?
22. Vad tror du om framtiden för grön vätgas?
23. Vilka möjligheter ser du att grön vätgas medför för vår framtid?
24. Vilka osäkerheter ser du gällande den gröna vätgasens roll i framtiden?
25. Vilka användningsområden ser du som mest framstående för den gröna vätgasen?
26. Ser du några likheter mellan utveckling av förnybar energi och grön vätgas? Gällande kommersialisering och etablering av tekniken.
27. Ser du några skillnader?
28. Är det något du vill tillägga som vi borde ha tagit upp eller något svar du vill utveckla?

Appendix 3: Interview guide 3 - Technical experts

Swedish interview guide:

Part 1:

1. Berätta om dig själv, din bakgrund och din roll

2. Har du jobbat med förnybar energi innan? (Vind, sol, vattenkraft etc)
3. Vilken roll har du haft i dessa projekt?

Part 2:

1. Om du har jobbat med förnybara energiprojekt innan, vilka utmaningar har dessa mött?
2. Har du jobbat med projekt inom grön vätgas tidigare?
3. Vilken/vilka roller har du haft?
4. Hur brukar utformningen av gröna vätgas projekt se ut? Vilka är dom olika stegen i utvecklingen av projekten?
5. Berätta lite om projektet och hur dialogen med andra intressenter startade
6. Berätta om din roll i projekt Alby
7. Vad bidrar du med när det gäller projekt kring gröna vätgasanläggningar?
8. Vad vill ni få ut av gröna vätgasprojekt?
9. I vilken utsträckning kan du påverka utformningen av projektet i Alby? Till exempel, val av teknik?
10. Vilka möjligheter ser du med gröna vätgasprojekt?
11. Vilka möjligheter ser du med projektet i Alby?
12. Hur ska dessa tas tillvara på?
13. Vilka osäkerheter ser du med gröna vätgasprojekt?
14. Vilka osäkerheter ser du för projektet i Alby?
15. Hur kan ni bemöta osäkerheterna?
16. Vilka intressenter påverkar det gröna vätgasprojekt i Alby?
17. Vad för osäkerheter anser du finns i samarbetet med dessa intressenter?
18. Vad tycker du krävs för ett lyckat samarbete i projektet?
19. Hur ser ni på vindkraftens förhållande till vätgas?
20. Vilka användningsområden ser du som mest framstående inför framtiden?
21. Ser du några likheter mellan utveckling av förnybar energi och grön vätgas? Gällande kommersialisering och etablering av tekniken.
22. Ser du några skillnader?
23. Är det något du vill tillägga som vi borde ha tagit upp eller något svar du vill utveckla?

English interview guide:

Part 1:

1. Tell us about yourself, what is your background, education and your current role?
2. Have you worked with renewable energy before? (Wind, solar, hydro etc)
3. Which roles have you worked in earlier?

Part 2:

1. What have been the main challenges of the renewable energy projects that you were involved with previously?
2. Have you worked with projects within green hydrogen before?
3. What roles have you had?
4. What are the most important steps of development in green hydrogen projects?
5. Can you tell us about your role in the Alby project?

6. Can you tell us about the collaboration between different parties in the Alby project from your point of view?
7. What are your main contributions to green hydrogen projects?
8. To what extent are you able to affect the shape of the Alby project? For instance, choice of technology.
9. What opportunities do you see with green hydrogen?
10. What opportunities do you see in the Alby project?
11. How do these opportunities arise?
12. How should you best take advantage of the opportunities of the Alby project?
13. Which uncertainties do you see with green hydrogen in general?
14. Which uncertainties do you see in the Alby project?
15. How do these uncertainties arise?
16. How do you manage the uncertainties?
17. Which stakeholders affect the green hydrogen project in Alby?
18. What kind of uncertainty can you see occurring in relation to these stakeholders?
19. What would you say is key for successful cooperation in the Alby project?
20. What is your view on the relationship between wind power and hydrogen?
21. How do you look at the future of green hydrogen?
22. Which areas of application do you consider to be the most important for green hydrogen?
23. Do you see any similarities between the development of renewable energy and green hydrogen in terms of commercialization?
24. Do you see any differences?
25. Is there something that you would like to add or anything that you would like to discuss?

Appendix 4: Example of thematic analysis

Municipality

Concepts	Themes	Theoretical framework
Local opposition	**Diffusion of technology challenges**	**Technology diffusion**
External factors (e.g. taxes)		
Wind prerequsite for green hydrogen	**Diffusion of technology opportunities**	
Local connection of wind power		
Transporting sector		
Industrial uses		
Storage		
Project delay	**Project uncertainity challenges**	**Project management**
Local energy supply (SE2)		
External factors (project specific)		
Permits		
Lack of provision of competence		
Lack of development knowledge		
Regional DSO time-consuming processes		
Transparency	**Project uncertainity challenge reducers**	
Social enablers		
Aligned long-term goals		
Local connection of wind power		
Aligned offtaker preferences		
Slow response/acting (municipality)	**Stakeholder involvement hinderances**	**Project management**
Regional DSO time-consuming processes		
Social enablers	**Stakeholder involvement enablers**	
Swifteness from other partners		
Transparency		
Frequent dialogue		
Aligned long-term goals		
Close collaboration		
Roles confirmed (specific responsibility)		

RES

Concepts	Themes	Theoretical framework
Energy supply	**Diffusion of technology challenges**	**Technology diffusion**
Local opposition		
Non-existing green hydrogen market		
Wind prerequsite for green hydrogen	**Diffusion of technology opportunitites**	
Important for a sustainable transition		
Transporting sector		
Industrial uses		
Politcal uncertainty	**Project uncertainity challenges**	**Project management**
Project delay		
Permits		
Offtaker contracts (nothing signed)		
Local opposition		
DSOs hesitant to taking risk		
New business area (extra uncertainty)		
Regional DSO time-consuming processes		
Non-existing green hydrogen market		
Local connection of wind power	**Project uncertainity challenge reducers**	
Risk takers		
Flexibility		
New business area - previous experience		
Aligned long-term goals		
Political uncertainty	**Stakeholder involvement hindrances**	**Project management**
Regional DSO time-consuming processes		
Project delay		
Local opposition		
Roles confirmed (specific responsibility)	**Stakeholder involvement enablers**	
RES provides extra support		
Aligned long-term goals		
Close collaboration		
Transparency		

Technical experts

Concepts	Themes	Theoretical framework
Non-existing green hydrogen market	**Diffusion of technology challenges**	**Technology diffusion**
Costs of green hydrogen versus traditional fuels		
Explosive		
Energy supply		
Industrial uses	**Diffusion of technology opportunitites**	
Renewable energy prerequisite		
Transporting sector		
Non-existing green hydrogen market	**Project uncertainity challenges**	**Project management**
Explosive		
Offtaker contracts (nothing signed)		
Permits		
Local opposition		
Local connection to wind	**Project uncertainity challenge reducers**	
Monetise all by-products		
Risk analysis		
Flexibility		
Local opposition	**Stakeholder involvement hindrances**	**Project management**
Permits (safety)		
Municipality		
Relationship building (offtakers/municipality)	**Stakeholder involvement enablers**	